Communications on Applied Nonlinear Analysis
ISSN: 1074-133X
Vol 32 No. 2s (2025)

Blockchain-Based Drug Supply Chain Recommendation System (B-DSCRS) with Machine Learning for Supply Chain Management

Dr.F. Rahman[1], Vasani Vaibhav Prakash[2]

[1]Assistant Professor, Department of CS & IT, Kalinga University,Raipur, India.

[2]Research Scholar,Department of CS & IT, Kalinga University,Raipur, India.

Article History:

Received: *01-09-2024*

Revised: *12-10-2024*

Accepted: *28-10-2024*

Abstract:

The pharmaceutical industry has been struggling to keep tabs on its goods across the supply chain for the last decade, which has opened the door for counterfeiters to sell their phoney medications. Integrated product supply chain management mostly focuses on distribution. The pharmaceutical business places a premium on the drug distribution process because of the importance of ensuring the safe handling, storage, and distribution of medical items. The global pharmaceutical sector is facing a significant threat in the form of counterfeit pharmaceuticals. Blockchain technology can manage and monitor the supply chain process with remarkable efficiency when used to its maximum capacity.This paper proposed and implemented a Blockchain-based Drug Supply Chain Recommendation System (B-DSCRS). A pharmaceutical supply chain management system built on the blockchain and a consumer medication recommendation system powered by machine learning comprises our proposed system's two primary components. As a first step in the smart pharmaceutical industry's medication delivery process tracking and monitoring.Conversely, the machine learning module suggests the finest medications for pharmaceutical sector clients. Lastly, our suggested system goes through the testing process to ensure it is efficient and user-friendly.

Keywords: Pharmacy, Blockchain, Machine Learning.

1. INTRODUCTION

Suppliers and consumers are linked via supply chain management. One of the most important parts of distribution is getting products from producers to consumers [1]. Logistics costs impact distribution, which in turn increases firm profits. When it comes to product-integrated supply chain management, distribution takes precedence [21]. Medication distribution is the blood of the company because of the storage, processing, and distribution of pharmaceutical substances. Someone or some organization must be involved and responsible for the correct execution of the distribution process for it to work as planned [3]. The safe and timely delivery of high-quality pharmaceutical drugs to patients is the responsibility of a complex network called the pharmaceutical supply chain (PSC) [22]. Among the many challenges faced by the PSC include maintaining product integrity, combating the sale of counterfeit pharmaceuticals, and eliminating shortages in output. Disorders in PSCs have an impact on healthcare system efficiency and medicine shortages [5] [16].

Therefore, improving the PSC and keeping up-to-date with innovative methods and technology are necessary to ensure safe and effective medication delivery [8] [23]. The healthcare business has large inventory expenditures, making optimization of inventory management particularly crucial [7].

Distributed or decentralized ledger technology is the core of blockchain. Two of the distinguishing characteristics of blockchain are its immutability and append-only nature [24]. It is a distributed ledger since all nodes in the network have a replica of the data [6] [9] [14]. A smart contract is a piece of logic that is incrementally incorporated into company processes that allows two parties to engage in blockchain-based commercial transactions by mutual consent [25]. Distributed ledger technology (blockchain) allows several independent nodes to independently confirm transactions without relying on or knowing one other [11]. Two hash codes—the previous hash code and the current hash code—are stored in each network block. You may see the most recent block hash code and the one from the prior block here [26]. The use of transaction and crypto codes ensures that all blocks inside the network are securely linked to one another [13]. Secondly, using strong mathematical approaches is essential. The blocks may be uploaded to the blockchain network once miner nodes use these strategies to validate them without compromising their contents [27]. An ever-expanding succession of blocks that comply to specified rules hold data in the blockchain, a distributed ledger system [10] [15].

The main contribution of this paper

1. This paper BL-DSCRS has been proposed to track the supply chain and improve the supply chain management.

2. The proposed BL-DSCRS uses a machine-learning method to recommend medicine to customers.

3. Module one involves the smart pharmaceutical industry's medication supply chain management system's deployment utilizing Hyperledger fabrics, which can continually monitor and trace the medicine distribution process.

Section 2 includes the literature study, Section 3 explores the suggested approach, Section 4 discusses the numerical findings and discussion, and Section 5 concludes the overall paperwork.

2. LITERATURE STUDY

Research [28] shows a favourable and statistically significant correlation between PSC performance and inventory level control when using structural equation modelling (SEM).The practical implications of this research include helping hospital pharmacies determine the optimal methods for managing pharmaceutical inventory and comprehending how demand forecasting and inventory control affect PSC performance, allowing for the prevention of stockouts and the ability to weather variations in supply and demand. Information about suppliers' performance and the criteria employed may be gleaned from the findings obtained utilizing the best-worst method (BWM) in conjunction with geometrical analysis for interactive assistance (GAIA) [17]. Five pharmaceutical vendors' performance was compared using this mixed-methods technique. The first priority was the prompt shipment of the items. They are able to comprehend and convey the results more effectively because to GAIA's visualisation. A method for evaluating SCRMA-based supply chain risks in the pharmaceutical industry [18]. Digital platforms such as blockchain and big data analytics may improve supply chain cooperation, according to the study's findings [2] [4] [12]. To implement a circular economy, the pharmaceutical industry uses a closed-loop supply chain inventory model (C-

LSCIM) [19]. A generalized reduced gradient non-linear programming model is used for both pharmaceutical inventory and government decision-making. Researchers were able to examine these complex systems and the effects of different policy factors on the operational performance of these companies under varying degrees of uncertainty by applying a simulation-based logistics assessment framework (SLAF) to pharmaceutical supply chain networks worldwide [20]. Various approaches of pulling the logistical levers were considered in the study. The essay builds the simulation framework using the regular logistical processes of a well-known biopharmaceutical company.

3. PROPOSED METHODOLOGY

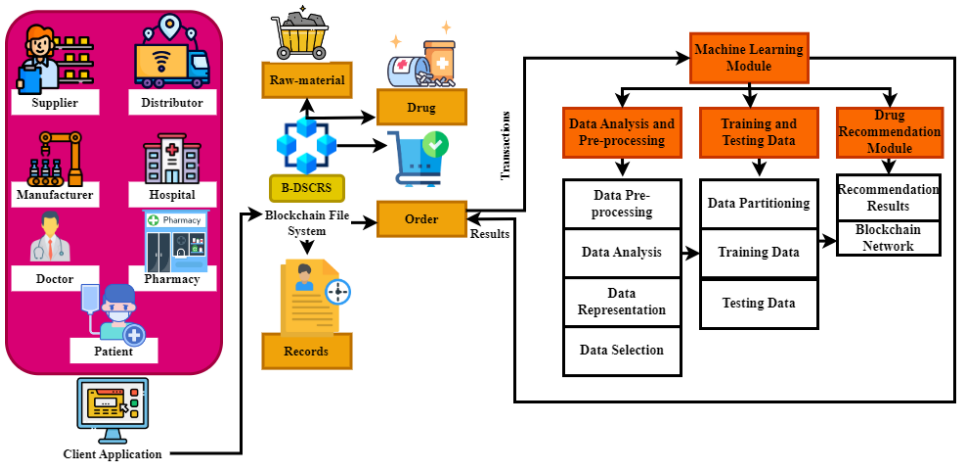

Figure 1: Proposed B-DSCRS

The primary design of the suggested system is seen in Figure 1. A supply chain that is transparent, secure, automated, and resilient has been established with blockchain technology. It ensures dependability by preventing counterfeit drugs from entering into the supply chain. With the use of blockchain technology and machine learning, our proposed system would build a pharmaceutical supply chain and medication recommendation system. Algorithms for machine learning and blockchain have contributed to the effectiveness of the healthcare system. Latency, transaction response time, and throughput were used in several studies to assess our system's performance. Our system's simulation results are promising. The pharmaceutical sector benefits from this technique by increasing income and eliminating counterfeit drugs. To develop and apply the network to real-time pharmaceutical enterprises to test our system's performance. Machine learning model suggestions will be more accurate and valuable.A few peer nodes run the consensus process to keep the distributed ledger consistent. According to our process, the pharmaceutical industry gets raw materials from the initial source. Everyone may log in and complete transactions utilizing the system's web application interface. Any node in the network may validate and submit a raw material order from a manufacturer to the supplier. When raw materials are ready, the supplier verifies the order. On blockchain, permission rules, such as a client seeing a company's pharmaceutical data, can only be executed by the customer. The propose a blockchain system that uses the same mechanisms as the previous example to allow doctors to purchase medications from manufacturers. Authenticate the doctor first. Manufacturers must verify transactions. The doctor must finalize the deal. An event notification confirms successful transactions.

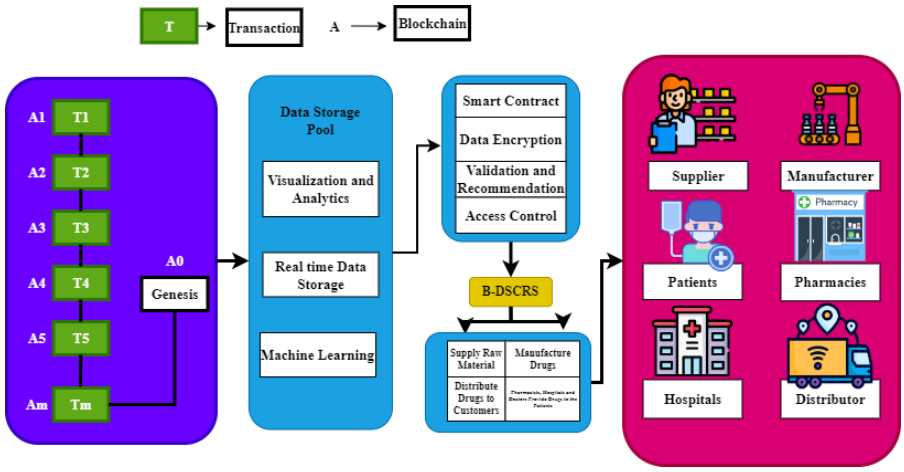

Figure 2: Supply Chain Management System

The design and architecture of the supply chain management system is shown in Figure 2. Distributing data in blocks containing many transactions is the primary objective of the blockchain network. These transactions undergo security measures such as encryption and hashing before being stored. Distributed ledger and smart contract services are offered by the user-oriented system. Two main components make up the suggested system: the recommendation component and the medication supply chain management component. Users are able to perform a lot using the system's front-end web interface, including buy drugs, edit records, transmit data, track pharmaceuticals in transit, manage clients, and more. This encompasses all parties involved, including manufacturers, retailers, doctors, and patients. Preventing the sale of counterfeit drugs and ensuring the security of SCM for end users are the primary objectives of this system. Blockchain security and integrity management make our solution secure. Every user may track their drug delivery using this B-DSCRS system. The network partitioned into private subnets using channels to guarantee nodes' connections were secure. Nodes with the same channels may discreetly exchange data. This channel's architecture lets users create secure private networks. Our technology doesn't allow patients to do much directly, but they can scan the bar code on the container to validate the drug they purchase at the pharmacy. Patients learn about the medication company, manufacturer, expiry date, and price. Confine suppliers to talk to manufacturers about raw materials. As a private network, these members have separate channels.

Machine learning-based medicine recommendation is another aspect of our proposed system that helps pharmaceutical firms serve customers. These algorithms were trained on favourable and negative medical website comments from users. Due to this training, pharmacy, clinic, hospital, and patient customers have profited from our model's top medicine recommendations.Our medicine supply chain management solution includes customer pharmaceutical proposals, unlike others. This permission-blockchain approach makes our B-DSCRS solution unique. This limits system access to approved users. The user administrator checks and adds users to this network using secret login credentials and enrollment certificates. Consumers may use this secure blockchain. Consensus links registered users to the private network for transaction completion and order management. A distributed ledger and smart contracts store and execute transactions in virtual environments at each blockchain network node. The smart contract lets these nodes verify the transaction and add the

block to the ledger. Most crucially, consensus protects a single transaction history and prevents invalid transactions. Consensus mechanism gives each transaction a unique digital signature and hash code. An open public ledger records transactions, events, and user behaviours in the proposed system.

4. RESULTS AND DISCUSSION

The B-DSCRS solution integrates a blockchain-based pharmaceutical supply chain management system with a machine learning-driven consumer drug recommendation system. The paper describes its development and implementation in depth. Tracking and monitoring medication distribution is the first stage of the smart pharmaceutical sector. In contrast, the pharmaceutical industry relies on machine learning to provide customers with the best medicine recommendations.

i) SupplyChain Management Ratio (%)

The Blockchain-based drug supply chain recommendation system B-DSCRS enhances supply chain management. First, blockchain technology is completely transparent and traceable. Tracking and verifying pharmaceuticals from production to distribution lowers counterfeit drug entry for authenticity and safety, making medications transparent.

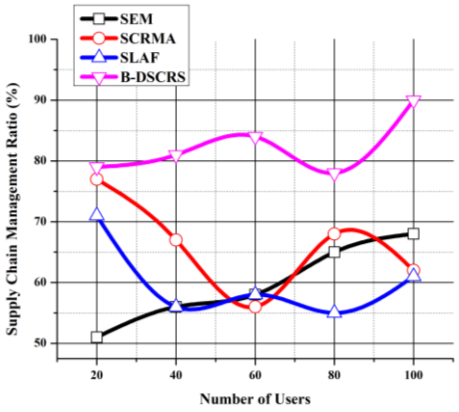

Figure 3: Supply Chain Management Ratio (%)

Figure 3 examines the supply chain management ratio (%). Blockchain is immutable and decentralized, making it safer. Hackers cannot access blockchain data due to its immutability. Keeping the supply chain and critical data safe fosters stakeholder trust. Automating verifications and transactions using smart contracts streamlines supply chains. It increases efficiency, decreases human error, and makes pharmaceutical delivery safer. Machine learning helps B-DSCRS recommend the best pharmaceuticals to consumers, boosting pharmaceutical supply chain efficiency and safety.

ii) Drug Delivery Ratio (%)

B-DSCRS makes medication delivery safer, more transparent, and more efficient. The blockchain system verifies drugs across the supply chain to ensure authenticity and proper handling. Transparency reduces counterfeit drugs and enhances medication delivery trust.

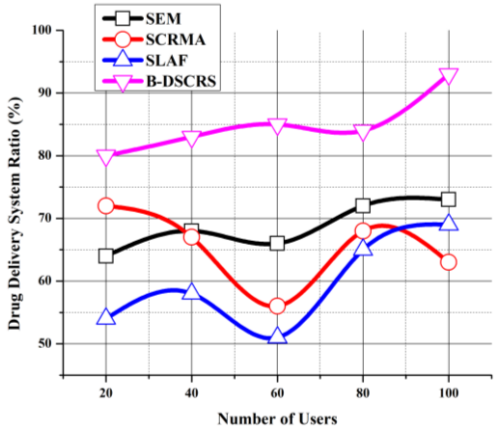

Figure 4: Drug Delivery System Ratio (%)

Figure 4 expresses the drug delivery ratio (%). Drug storage and transportation verification are automated using smart contracts. It simplifies delivery and protects drug quality. Machine learning enhances customer satisfaction and service customization by analyzing client preferences and offering the best medicines. The B-DSCRS improves drug delivery system safety, reliability, and efficiency for pharmaceutical companies and consumers.

5. CONCLUSION

Blockchain technology has replaced the previous method of supply chain management with one that is more open, audible, secure, automated, and robust. The fundamental goals of our proposed scheme, which consists of two parts—a medication supply chain system and a medicine recommendation system—are the installation of a system that is enabled by blockchain technology and machine learning. Using algorithms for machine learning and blockchain technology, the system has accomplished outstanding results in the healthcare sector. Multiple tests were carried out to assess the efficiency of our system by measuring its latency, transaction response time, and throughput, among other performance indicators. Our system's simulation results should be rather promising, it appears. The pharmaceutical business stands to gain significantly from this strategy, which will help reduce the prevalence of counterfeit medications while also increasing sales. To increase the scale of the network and use it with real-time pharmaceutical companies to test and confirm the system's functionality in upcoming projects. With a supply chain management ratio of 93.8% overall and 92.4% for the medication distribution system, the suggested strategy is very effective.

REFERENCES

[1] Sugihartanto, M. F., Mahendra, M. R., Baihaqi, I., & Rizaldy, H. (2024). Supply Chain Risk Management Assessment and Strategy: Case Study in a Hospital Pharmacy. Jurnal Teknologi dan Manajemen, 22(1), 35-44.

[2] Mehak, S., Himanshi., & Sanju, S. (2024). Privacy-enhancing Blockchain Solutions for the Healthcare Sector: Efficient Message Sharing and Robust Big Data Protection. Journal of Internet Services and Information Security, 14(2), 85-97.

[3] Shen, J., Bu, F., Ye, Z., Zhang, M., Ma, Q., Yan, J., & Huang, T. (2024). Management of drug supply chain information based on “artificial intelligence+ vendor managed inventory” in China: perspective based on a case study. Frontiers in Pharmacology, 15, 1373642.

[4] Cina, M., & Asha, P. (2024). FedProx: FedSplit Algorithm based Federated Learning for Statistical and System Heterogeneity in Medical Data Communication. Journal of Internet Services and Information Security, 14(3), 353-370.
[5] Schneikart, G., Mayrhofer, W., Frysak, J., & Löffler, C. (2023). A Returnable Transport Item to Integrate Logistics 4.0 and Circular Economy in Pharma Supply Chains. Tehnički glasnik, 17(3), 375-382.
[6] Malathi, K., Shruthi, S.N., Madhumitha, N., Sreelakshmi, S., Sathya, U., & Sangeetha, P.M. (2024). Medical Data Integration and Interoperability through Remote Monitoring of Healthcare Devices. Journal of Wireless Mobile Networks, Ubiquitous Computing, and Dependable Applications (JoWUA), 15(2), 60-72. https://doi.org/10.58346/JOWUA.2024.I2.005
[7] Bhatt, J. (2023). Use of blockchain in medical supply and pharmacy. Journal of Online Engineering Education, 14(1s), 6-9.
[8] Abugabah, A. (2023). Smart Medical Systems Based IoT: Exploring the Relationship Between Essential Algorithms and Service Orientation. Journal of Wireless Mobile Networks, Ubiquitous Computing, and Dependable Applications, 14(4), 115-127.
[9] Jha, R. K., Alam, P., Priyadarshi, N., Ghazi, M. A., & Bhargavi, M. S. (2023). Counterfeit drug prevention in Pharma supply chain using blockchain technology. In IEEE 3rd International Conference on Intelligent Communication and Computational Techniques (ICCT), 1-6.
[10] Neelima, S., Manoj, G., Subramani, K., Ahmed, A., & Chippy, M. (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.
[11] Akram, W., Joshi, R., Haider, T., Sharma, P., Jain, V., Garud, N., & Narwaria, N. S. (2024). Blockchain technology: A potential tool for the management of pharma supply chain. Research in Social and Administrative Pharmacy, 20(6), 156-164.
[12] Mohandas, R., Veena, S., Kirubasri, G., Thusnavis Bella Mary, I., & Udayakumar, R. (2024). Federated Learning with Homomorphic Encryption for Ensuring Privacy in Medical Data. Indian Journal of Information Sources and Services, 14(2), 17–23.
[13] Mariappan, M. B., Devi, K., Venkataraman, Y., Lim, M. K., & Theivendren, P. (2023). Using AI and ML to predict shipment times of therapeutics, diagnostics and vaccines in e-pharmacy supply chains during COVID-19 pandemic. The International Journal of Logistics Management, 34(2), 390-416.
[14] Veera Boopathy, E., Peer Mohamed Appa, M.A.Y., Pragadeswaran, S., Karthick Raja, D., Gowtham, M., Kishore, R., Vimalraj, P., & Vissnuvardhan, K. (2024). A Data Driven Approach through IOMT based Patient Healthcare Monitoring System. Archives for Technical Sciences, 2(31), 9-15.
[15] Bridgelall, R. (2023). Unlocking Drone Potential in the Pharma Supply Chain: A Hybrid Machine Learning and GIS Approach.Standards, 3(3), 283-296.
[16] 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.
[17] Dzung, Nguyen Vu, Nguyen Huu Nhan, and Nguyen Thanh Long. "Existence, uniqueness, and convergence of solutions of strongly damped wave equations with arithmetic-mean terms." Results in Nonlinear Analysis 5.2 (2022): 191-212.
[18] Ishizaka, A., Khan, S. A., Kheybari, S., & Zaman, S. I. (2023). Supplier selection in closed loop pharma supply chain: a novel BWM–GAIA framework. Annals of Operations Research, 324(1), 13-36.
[19] Wong, W. P., Saw, P. S., Jomthanachai, S., Wang, L. S., Ong, H. F., & Lim, C. P. (2023). Digitalization enhancement in the pharmaceutical supply network using a supply chain risk management approach. Scientific Reports, 13(1), 22287.
[20] Suhandi, V., & Chen, P. S. (2023). Closed-loop supply chain inventory model in the pharmaceutical industry toward a circular economy. Journal of Cleaner Production, 383, 135474.
[21] Diaz, R., Kolachana, S., & Falcão Gomes, R. (2023). A simulation-based logistics assessment framework in global pharmaceutical supply chain networks. Journal of the Operational Research Society, 74(5), 1242-1260.
[22] Azizian, M., Sepehri, M. M., & Mirzapour Al-e-Hashem, S. M. J. (2023). Simulation-Based Models of Multi-Tier Financial Supply Chain Management Problem: Application in the Pharmacy Sector. Mathematics, 11(19), 4188.

[23] Aguero, D., & Nelson, S. D. (2024). The potential application of large language models in pharmaceutical supply chain management. The Journal of Pediatric Pharmacology and Therapeutics, 29(2), 200-205.
[24] Vann Yaroson, E., Breen, L., Hou, J., & Sowter, J. (2023). The role of power-based behaviours on pharmaceutical supply chain resilience. Supply Chain Management: An International Journal, 28(4), 738-759.
[25] Weledesenbet, T. A. (2023). Assessment on Vaccine Supply Chain and Logistics Systems in the Case of Ethiopian Pharmaceuticals Supply Agency Jimma Branch, Jimma South West Ethiopia. Systematic Reviews in Pharmacy, 14(2), 71.
[26] Angelov, Vasil. "Spin 3-Body Problem with Radiation Terms (II)-Existence of Periodic Solutions of Spin Equations." Results in Nonlinear Analysis 5.2 (2022): 96-111.
[27] Gomasta, S. S., Dhali, A., Tahlil, T., Anwar, M. M., & Ali, A. M. S. (2023). PharmaChain: Blockchain-based drug supply chain provenance verification system. Heliyon, 9(7), e17957.
[28] George, S., & Elrashid, S. (2023). Inventory management and pharmaceutical supply chain performance of hospital pharmacies in Bahrain: A structural equation modeling approach. SAGE Open, 13(1).