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BLOCKCHAIN SUPPLY CHAIN MANAGEMENT FOR HEALTH CARE APPLICATIONS: A SURVEY

Mr. Nitin Mohan Shivale*
Dr. Pratap Singh Patwal**
Dr. Parikshit Mahalle***

ABSTRACT

The utilization of blockchain in supply chain management is very effective in recent years. By using blockchain in SCM transactions has efficiently traceable and auditable. This survey aims at providing an overview of various existing research papers that discuss the role, applications, and probable of blockchain in revolutionizing the medical supply chain. The studies surveyed collectively underscore the dire need for enhanced transparency within the ecosystem of healthcare. Blockchain provides real time tracking of medicine goods in secure manner in SCM. One of the themes that keeps cropping up in the research is how blockchain will be able to help block counterfeit drugs and improve traceability of pharmaceuticals from production to delivery to the very end-user. Some studies also look more closely at smart contracts in automatic processes like the making of a payment, procurement, and even compliance management. Thus, with blockchain, business operations are also being improved. Also, blockchain studies have looked more intently at data integrity and safe ways in which information among stakeholders-manufacturers, distributors, healthcare workers, and even regulators-can share or be shared to them. However, this surveyed research also recognizes the scalability issues, regulatory hurdles, and high cost of initial investment in implementing blockchain. This body of work has thus demonstrated that though blockchain holds great potential for transforming the medical supply chain, more research and stakeholder collaboration is required to achieve broad-based adoption and realization of benefits.

Keywords: *Blockchain, Supply Chain Management, Hash Generation, Traceability, Mining, Smart Contract.*

Introduction

Blockchain technology has emerged as perhaps an innovative contraction to these current challenges of the medical supply chain through its decentralized and indestructible nature. It promised a revolution in manufacturing, tracking, and delivering medical merchandise with increased traceability, transparency, and security. Further, it enables information sharing among parties involved securely, and automated processes through smart contracts ensure added efficiency in supply chain operations. This research article is purposed to study the applications, benefits, and limitations that blockchain technology has on the medical supply chain, drawing insights from various studies conducted between last five years. This paper describes how customized blockchain can be leveraged in combating counterfeit drugs, improving operational efficiency, and ensuring data integrity through a survey of existing literature. It also outlines the challenges of blockchain adoption, such as scalability, regulatory compliance, and cost implications, while discussing potential solutions and future directions for research and implementation. This article aims to serve as a foundational resource for policymakers, healthcare professionals, and industry stakeholders, highlighting the transformative role of blockchain technology in establishing a more secure, transparent, and efficient medical supply chain

* Research Scholar, Computer Science & Engineering, School of Computer Science & Engineering, Nirwan University Jaipur, Rajasthan, India.
** School of Engineering & Technology Nirwan University, Jaipur Rajasthan, India.
*** Dean & Director of Research, VIT Autonomous Institute, Pune Maharashtra, India.

Literature Review

According to [1] supply change management in multi-party involvement and evaluation in medical SCM. It integrates separate blockchains for manufacturers, distributors, and regulators, ensuring data integrity and security across stakeholders. The system enables real-time tracking of medical products, leveraging blockchain for decentralized, tamper-proof data management. Smart contracts automate compliance processes, reducing manual oversight. Multi-MedChain also enhances transparency by securely sharing supply chain data while maintaining privacy. The proposed architecture is scalable and incorporates mechanisms to address counterfeit drug detection and prevention effectively. Furthermore, the study discusses the potential to streamline communication between stakeholders, improving decision-making and operational efficiency.

- **Drawback of this Paper:** The system's reliance on multiple blockchains increases complexity, potentially impacting performance and requiring significant computational resources for inter-chain communication and coordination, posing challenges for smaller stakeholders to adopt.

The multi-layer blockchain architecture for electronic health records and drugs SCM has proposed in [2]. This architecture comprises distinct layers for data storage, transaction validation, and user access control, ensuring scalability and security. By integrating a consortium blockchain for data sharing and a public blockchain for transaction integrity, the system enhances trust among stakeholders. The access control mechanism and secure cryptographic technique has used for secure data transmission in entire supply chain. For drug supply chains, the framework improves traceability, aiding in counterfeit prevention and regulatory compliance. The study highlights the architecture's performance efficiency, particularly in reducing transaction delays and enhancing throughput, making it suitable for large-scale healthcare systems.

- **Drawback of this Paper:** The model's dependency on dual-blockchain systems increases infrastructure complexity, raising operational costs and posing potential challenges in real-time implementation for smaller healthcare providers or resource-constrained regions.

The [3] explores the probable of blockchain smart contracts to increase security and efficiency healthcare systems. Their study focuses on leveraging smart contracts for automating healthcare processes, including insurance claims, patient data management, and procurement in the supply chain. By eliminating intermediaries, the system reduces operational delays and errors while enhancing transparency and trust. The researchers demonstrate the feasibility of blockchain-based smart contracts in securing sensitive medical data and ensuring its accessibility to authorized parties only. The paper also highlights the advantages of real-time updates in medical records and the seamless integration of various healthcare services through decentralized ledger technology.

- **Drawback of this Paper:** The reliance on smart contracts necessitates high-level programming accuracy, as errors in coding could lead to contract failures or exploitation, limiting its applicability without robust quality assurance mechanisms.

According to [4] the incorporation of blockchain technology with digital twin systems in supply chain management, focusing on healthcare applications. By combining blockchain's immutable ledger with digital twin technology, the study suggests improvements in traceability, operational efficiency, and fraud prevention. The paper highlights applications such as vaccine distribution, inventory management, and real-time tracking of medical supplies. Furthermore, the authors discuss the benefits of blockchain-based digital twins in mitigating risks associated with counterfeit products and supply chain disruptions. The review concludes with potential research avenues, including enhancing scalability and interoperability for wider adoption.

- **Drawback of this Paper:** The mixing of blockchain through digital twins requires substantial computational resources and advanced IoT infrastructure, presenting challenges for implementation in regions lacking robust technological frameworks.

The [5] analyse the adoption of blockchain technology in creating sustainable healthcare supply chains. This work emphasizes role of blockchain in cultivating transparency and efficiency as well as environmental sustainability in SCM. Key applications include waste reduction, optimized resource utilization, and real-time monitoring of medical goods. By incorporating blockchain, the authors highlight improvements in traceability and stakeholder collaboration, which are crucial for addressing challenges like counterfeit products and delayed deliveries. The research also discusses critical factors influencing blockchain adoption, including organizational readiness, technological maturity, and regulatory support. The study concludes that it has significant potential to transform the healthcare supply chain, ensuring better performance and sustainability.

- **Drawback of this Paper:** The study identifies a lack of regulatory clarity and the high cost of initial blockchain implementation as significant barriers to adoption, especially for smaller healthcare providers and supply chain participants.

The automatic procurement smart contracts in the medical supply chain management. Their solution focuses on reducing procurement delays, eliminating intermediaries, and improving contract compliance. By automating key processes, such as payment releases upon delivery confirmation, the system ensures operational efficiency and minimizes disputes among stakeholders. The researchers demonstrate how blockchain enhances transparency, providing a tamper-proof record of transactions while safeguarding sensitive procurement data. Use cases include drug supply tracking and streamlining supplier-buyer relationships. The paper concludes with an evaluation of the system's performance, emphasizing reduced processing time and enhanced accuracy.

- **Drawback of this Paper:** The system's reliance on blockchain smart contracts necessitates a robust legal framework for resolving disputes and addressing unforeseen contingencies, limiting its adoption in regions with regulatory ambiguity.

According to [7] drug traceability in blockchain based supply chain using immutable ledger. The system leverages blockchain's immutable ledger to record and verify the movement of pharmaceutical products from manufacturers to end-users. By employing QR codes and IoT devices, the system captures real-time data on drug production, storage, and distribution, ensuring transparency and security. The researchers highlight blockchain's role in mitigating counterfeit drugs, improving inventory management, and enhancing compliance with regulatory standards. Additionally, the study presents a performance evaluation, demonstrating the system's scalability and efficiency in handling large transaction volumes. The framework supports improved stakeholder trust and better patient safety through verifiable traceability mechanisms.

- **Drawback of this Paper:** The reliance on advanced IoT devices and real-time data inputs poses challenges for implementation in regions with limited technological infrastructure or inadequate supply chain digitization.

According to [8] the study identifies key benefits, including enhanced transparency, traceability, and fraud prevention. Specific applications discussed include pharmaceutical tracking, vaccine distribution, and supplier verification. The authors explore blockchain's potential to improve operational efficiency through automated processes and tamper-proof data sharing. They also highlight ongoing challenges, such as scalability, interoperability, and high implementation costs, which limit blockchain's widespread adoption. The paper emphasizes the need for further research into hybrid models that combine blockchain with other technologies. The study concludes with recommendations for future research, particularly in enhancing blockchain’s scalability and integrating regulatory frameworks.

- **Drawback of this Paper:** Scalability remains a significant hurdle, as the technology struggles to handle large transaction volumes efficiently, making it less viable for high-demand healthcare supply chain operations.

In [9] present a blockchain-enabled model for managing multi-party maintainable supply chains, emphasizing healthcare applications. The model integrates blockchain for secure, transparent data sharing across supply chain tiers, including suppliers, manufacturers, and distributors. By leveraging smart contracts, the system automates procurement, payment, and compliance processes, reducing delays and operational inefficiencies. The study also discusses blockchain's role in enhancing sustainability through waste reduction and optimized resource utilization. A case study on pharmaceutical supply chains highlights the model's effectiveness in improving traceability and minimizing counterfeit products. The proposed solution addresses key challenges, such as inventory management and supplier coordination, ensuring a more resilient and efficient supply chain.

- **Drawback of this Paper:** The system's reliance on multi-echelon coordination increases complexity, requiring extensive collaboration among stakeholders, which can be challenging in fragmented or poorly integrated healthcare supply chains.

The vaccine SCM has described in [10], which focusing on addressing challenges like counterfeit vaccines, cold chain monitoring, and delivery inefficiencies. The framework integrates blockchain for transparent and secure record-keeping, combined with IoT devices for real-time monitoring of vaccine storage conditions. By ensuring tamper-proof data and automating compliance checks, the system enhances the reliability and safety of vaccine distribution. The study also highlights blockchain's potential in facilitating stakeholder coordination, improving inventory management, and ensuring timely delivery of vaccines. The authors evaluate the framework's effectiveness through simulations, demonstrating its ability to enhance traceability and reduce wastage.

- **Drawback of this Paper:** The framework requires advanced IoT infrastructure and high initial costs, limiting its feasibility for regions with inadequate resources or underdeveloped supply chain technology.

This paper provide an in-depth review of blockchain applications has describes in [11], in terms of trackability, transference of goods. The study emphasizes blockchain's potential to combat counterfeit drugs, streamline inventory management, and enhance regulatory compliance. By employing smart contracts and distributed ledger technology, the reviewed solutions address inefficiencies in traditional supply chain processes, such as delays and data discrepancies. The paper also explores the usage of blockchain with numerous techniques, to further enhance supply chain operations. Future directions highlighted include developing more scalable blockchain frameworks and addressing interoperability challenges to facilitate widespread adoption.

- **Drawback of this Paper:** The study identifies scalability and interoperability issues as significant barriers, alongside the need for standardized protocols and regulations to ensure smooth integration across diverse pharmaceutical supply chain ecosystems.

According to [12], describes details review of blockchain involvement and impact in medical SCM which emphasizing secure data management, SCM logistics and patient-centric care. The study outlines blockchain's potential to secure medical records, enhance drug traceability, and improve healthcare delivery efficiency. It also examines real-world case studies and pilot implementations, highlighting blockchain's role in reducing fraud and ensuring data integrity. Challenges discussed include regulatory hurdles, technical scalability, and the need for stakeholder collaboration. The review concludes with recommendations for further research in hybrid models combining blockchain with AI and IoT to address existing limitations.

- **Drawback of this Paper:** The review notes that blockchain adoption is hindered by a lack of clear regulatory frameworks and high implementation costs, especially in resource-constrained healthcare systems.

FHIR Chain: Applying Blockchain to Securely and Scalably Share Clinical Data

The secure data sharing approach using blockchain called FHIR Chain has describes in [13]. It built on the FHIR (Fast Healthcare Interoperability Resources) standard, the system ensures interoperability among diverse healthcare platforms. FHIR Chain employs blockchain for tamper-proof data storage, enabling secure data sharing without breaching patient privacy and maintain the anonymity. This approaches integrates secure cryptographic approach and role based access control to multiple parties sin secure manner. The study demonstrates the its scalability and performance effectiveness through simulations, showcasing its potential for wide-scale adoption in healthcare environments.

- **Drawback of this Paper:** FHIR Chain's dependence on advanced encryption and interoperability standards could limit its application in regions where healthcare systems lack digital infrastructure or standardized data-sharing protocols.

The [14] identifies key use cases, including EHR management, drug traceability, and clinical trial transparency. The dynamic decentralized feature of blockchain can reviewed solutions enhance trust among stakeholders and reduce risks accompanying with data breaches and fraud. The authors also highlight blockchain's role in supporting regulatory compliance and enabling seamless data sharing across healthcare systems. Limitations such as high energy consumption, scalability issues, and regulatory uncertainties are discussed, with suggestions for addressing these challenges through hybrid architectures and consensus mechanism optimization.

- **Drawback of this Paper:** High energy consumption and scalability challenges associated with blockchain consensus mechanisms are highlighted as significant barriers to adoption in large-scale biomedical and healthcare applications.

The [15] provides a blockchain offers a decentralized approach to manage and store patient records, providing immutable and transparent access to medical data while maintaining strict privacy controls. The author highlights use cases EHR data management, health information exchange, and fraud detection. By eliminating intermediaries and enhancing data traceability, blockchain can streamline operations and reduce costs in healthcare systems. Furthermore, the study discusses the role of smart contracts in automating administrative processes and ensuring compliance with regulations. The paper positions blockchain as a revolutionary technology that could redefine trust and efficiency in healthcare delivery systems.

- **Drawback of this Paper:** The paper lacks empirical evidence, relying heavily on theoretical assumptions. It also does not address scalability challenges.

The [16] presents a comprehensive systematic review of blockchain applications in healthcare. The paper categorizes and examines healthcare solutions, focusing on their capabilities and limitations. Key applications include secure storage of patient data, decentralized health information exchange, drug traceability, and clinical trial management. The study highlights blockchain's ability to enhance data security, improve transparency, and foster interoperability between healthcare systems. Moreover, the review identifies several blockchain platforms utilized in healthcare implementations. Despite the promising benefits, the paper emphasizes significant challenges, such as scalability issues, energy consumption, lack of technical expertise, and regulatory barriers. The authors also stress the need for collaboration between healthcare stakeholders, policymakers, and technology providers to enable widespread blockchain adoption. The systematic review concludes by outlining open research questions and future directions, calling for more experimental studies to validate blockchain's practical effectiveness in healthcare contexts.

- **Drawback of this Paper:** The review lacks an in-depth evaluation of real-world implementations, focusing predominantly on theoretical and conceptual studies, leaving a gap in understanding the tangible impact of blockchain in healthcare.

The study [17] investigates patients' attitudes, concerns, and acceptance of blockchain-based HIE systems. Using an experimental approach, the authors examine factors such as perceived ease of use, trust, and privacy concerns. Results indicate that patients view blockchain as a promising solution for secure and transparent health information management. Participants express strong support for the technology's ability to protect sensitive data while granting authorized access to healthcare providers. However, the study also reveals skepticism regarding technical complexities and a lack of understanding of blockchain concepts among patients. The authors emphasize the need for patient education and user-friendly blockchain interfaces to enhance adoption. Overall, the paper demonstrates the feasibility of blockchain-enabled HIE but stresses the importance of addressing patient concerns and improving system design to achieve widespread acceptance.

- **Drawback of this Paper:** The study focuses solely on patients' perspectives, neglecting insights from healthcare providers, policymakers, and technical stakeholders, which are crucial for a holistic evaluation of blockchain-based health information exchange.

The review [18] highlights blockchain's ability to ensure data immutability, enhance interoperability between healthcare systems, and improve patient data access and sharing. It emphasizes how blockchain can address pressing concerns in healthcare, such as fraud reduction, efficient data management, and privacy preservation. The paper also identifies the use of blockchain platforms like Ethereum, Hyperledger, and Bitcoin for healthcare-specific implementations. Challenges such as scalability, legal and ethical issues, and high computational costs are critically discussed. The authors stress the importance of interdisciplinary collaboration to overcome these barriers. Additionally, the review outlines gaps in research, including the lack of large-scale empirical studies and the need for standardized frameworks for blockchain implementation in healthcare.

- **Drawback of this Paper:** The paper primarily focuses on theoretical findings and fails to analyze real-world use cases or assess blockchain's operational feasibility in live healthcare settings.

The [19] propose a taxonomy for blockchain-based applications, categorizing them by sectors, architectures, and challenges. In healthcare, the study highlights blockchain's potential to streamline data exchange and enhance patient trust by ensuring data integrity and privacy. However, the paper identifies significant barriers to adoption, such as regulatory constraints, lack of standardization, and scalability concerns. The authors also explore open research questions, including the development of privacy-preserving mechanisms, energy-efficient consensus protocols, and regulatory frameworks for blockchain use. The review concludes by emphasizing the need for interdisciplinary efforts to address technical, legal, and ethical challenges hindering blockchain adoption.

- **Drawback of this Paper:** The paper's scope is broad, diluting its focus on healthcare-specific challenges and solutions, thereby limiting actionable insights for blockchain implementation in the healthcare sector.

The paper [20] identifies key areas where blockchain is being implemented, including patient data management, supply chain tracking, and clinical trials. It also examines blockchain's role in enabling

patients to maintain control over their data through decentralized platforms. The review notes challenges such as technical scalability, lack of healthcare-specific blockchain standards, and legal compliance issues, particularly concerning data privacy laws like GDPR and HIPAA. The authors emphasize the need for more empirical studies to validate blockchain's effectiveness in healthcare applications. Additionally, the review identifies a lack of healthcare-specific blockchain platforms tailored to address industry-specific requirements.

- **Drawback of this Paper:** The review provides limited insights into patient and provider perspectives, which are critical for understanding blockchain's practical usability and adoption in healthcare environments.

The [21] proposed an medical data access control approach called MedRec leverages Ethereum smart contracts to manage access permissions and create an immutable audit trail of data access. The paper highlights the benefits of MedRec, including enhanced patient control, improved data interoperability, and reduced administrative burdens. The authors also emphasize the system's potential to reduce fraud and errors in medical data handling. However, the paper acknowledges challenges such as scalability, energy consumption, and the need for healthcare providers to adopt blockchain-friendly infrastructure. The study demonstrates the feasibility of blockchain in healthcare through a prototype implementation and experimental evaluation.

- **Drawback of this Paper:** MedRec's confidence on Ethereum raises concerns about scalability and energy efficiency, and the study does not address the challenges of mixing blockchain with inheritance healthcare applications.

The [22] propose a blockchain-based framework called Healthcare Data Gateways for managing healthcare data with enhanced privacy risk control. The framework enables secure and efficient data sharing among patients, healthcare providers, and researchers while maintaining data privacy. The authors introduce novel privacy-preserving techniques, such as data anonymization and access control mechanisms, to ensure that sensitive patient information remains secure during transactions. The framework also supports the analysis of large-scale healthcare data for research and decision-making while mitigating privacy risks. It also highlights the advantages of the system, such as improving healthcare data interoperability, reducing operational inefficiencies, and enabling patient-centered care. However, the authors identify challenges such as system scalability, the need for high computational resources, and compliance with regulatory standards.

- **Drawback of this Paper:** The proposed framework remains conceptual, with no real-world implementation or experimental validation provided, leaving its practical feasibility and performance in a live healthcare environment untested.

According to [23] detail literature review of data privacy and security in blockchain and private data management. Key security features such as immutability, decentralization, and cryptographic mechanisms are highlighted as essential components for protecting sensitive data in healthcare systems. However, the study identifies vulnerabilities, such as susceptibility to 51% attacks, double-spending, and privacy leaks due to transparent blockchain transactions. To address these issues, the authors discuss advanced privacy-preserving techniques. The paper emphasizes that while blockchain gives assurance of data security and privacy, its adoption in healthcare is hindered by scalability challenges, high energy consumption, and the lack of clear regulatory guidelines. The authors recommend further research to develop tailored blockchain protocols that address the unique requirements of healthcare and other industries.

- **Drawback of this Paper:** The study lacks healthcare-specific use cases and experimental validations, offering a broad analysis of security and privacy challenges that may not directly apply to the healthcare sector.

The authors emphasize the benefits of blockchain for data immutability and auditability [24], which are critical for maintaining trust in medical data. The proposed system also integrates cryptographic techniques for access control, allowing only authorized entities to retrieve sensitive information. The paper discusses potential applications, such as protecting patient records, supporting legal compliance, and improving the reliability of clinical research data. Despite its promising features, the authors acknowledge challenges, including high storage and computational costs, limited scalability, and the difficulty of integrating blockchain with existing healthcare infrastructures. The study provides a theoretical evaluation of the system's benefits and challenges but lacks experimental validation or real-world deployment insights.

- **Drawback of this Paper:** The paper is heavily theoretical and does not provide experimental results or practical implementation details, making it difficult to evaluate the system's real-world applicability.

According to [25] highlight the advantages of MedBlock, such as improved interoperability, enhanced patient control over data, and reduced operational costs for healthcare providers. The paper also includes a performance evaluation, demonstrating the system's efficiency in terms of transaction speed and resource usage. However, challenges such as scalability and regulatory compliance are noted as barriers to widespread adoption.

- **Drawback of this Paper:** While promising, MedBlock's reliance on a consortium blockchain raises concerns about trust among participating entities, and its off-chain storage solution poses potential risks for data availability and security.

Conclusion

The integration of blockchain technology into the medical supply chain presents transformative potential, addressing long-standing challenges like transparency, traceability, and security. This survey highlights the extensive research conducted in last few years, underscoring blockchain's ability to revolutionize healthcare logistics. By enabling decentralized, tamper-proof records and real-time monitoring, blockchain is poised to enhance the fight against counterfeit drugs while improving pharmaceutical traceability from production to end-user delivery. Furthermore, smart contracts offer automated solutions for payments, procurement, and compliance, streamlining business operations. Equally important is blockchain's role in ensuring data integrity and fostering secure, efficient information sharing among manufacturers, distributors, healthcare professionals, and regulators. Despite its promise, significant obstacles remain, including scalability issues, regulatory challenges, and high initial investment costs. These barriers necessitate ongoing research and collaboration among stakeholders to unlock blockchain's full potential in the medical supply chain. This body of research establishes a foundation for further exploration, paving the way for practical implementations that can address current limitations. As blockchain technology continues to evolve, its adoption in healthcare logistics could redefine industry standards, ensuring a more efficient, transparent, and secure ecosystem. The insights from this survey provide a roadmap for future innovation and practical advancements in the field.

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