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Conceptual Framework for a Blockchain-Based Medication Supply Chain Tracking: Enhancing Trust and Security

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Abstract— *The increasing prevalence of counterfeit drugs and the complexities of the drug supply chain have highlighted the need for innovative solutions to enhance traceability, transparency, and patient safety. This concept paper aims to explore the potential of implementing a blockchain-based drug supply chain tracking system as a transformative solution to address these challenges. Through existing literature, this paper analyzes the feasibility, benefits, and implications of leveraging blockchain technology in the pharmaceutical industry. The methodology includes framework development, data collection methods, data analysis techniques, and research design. The results reveal a high level of stakeholder awareness and positive perception of blockchain technology, along with identified challenges in the current drug supply chain. The discussion section examines the implications of the findings, including the potential benefits, and regulatory considerations. Furthermore, the paper identifies areas for further research, such as empirical validation, integration with emerging technologies, and exploration of social and economic impacts. The concept paper concludes by emphasizing the significance of Blockchain-based drug supply chain tracking systems in ensuring medication authenticity, improving patient safety, and fostering trust among stakeholders. This research serves as a foundation for future studies and development in the field, aiming to create a secure, transparent, and efficient pharmaceutical industry that prioritizes patient well-being.*

Keywords— **Conceptual framework on Blockchain tracking, Drug supply chain tracking system, Supply chain security.**

I. INTRODUCTION

The pharmaceutical sector is responsible for producing and delivering important pharmaceuticals that improve people's health and well-being all over the world. However, the frequency of counterfeit pharmaceuticals has grown in recent years, posing serious hazards to public health and patient safety. Counterfeit pharmaceuticals are medications that have been purposefully mislabeled or misbranded and may include potentially dangerous or inactive ingredients. These counterfeit pharmaceuticals enter the drug supply system via online pharmacies and even authorized pharmacies. As a result, patients are unintentionally subjected to possibly fatal consequences.

The drug supply chain is crucial in ensuring that pharmaceuticals are available, safe, and legitimate for patients. The traditional drug supply chain, on the other hand, is frequently confronted by issues such as counterfeit medications, inefficiencies, and a lack of transparency. Blockchain technology has the potential to transform the pharmaceutical sector by providing a secure, transparent, and efficient system for tracking and validating the integrity of the drug supply chain.

Blockchain technology, which was originally designed as the underpinning technology for cryptocurrencies, has attracted attention for its ability to address the difficulties that traditional supply chain systems encounter. Blockchain is a digital ledger that is decentralized and immutable, allowing for safe, transparent, and tamper-resistant record-keeping. It offers a common, reliable, and verified source of information, removing the need for middlemen and improving data integrity and openness.

A drug supply chain tracking system can use blockchain technology to establish a secure and transparent ledger that records every transaction and movement of pharmaceuticals across the supply chain. This distributed ledger ensures drug traceability, authenticity, and integrity, lowering the risk of counterfeit medicines. Furthermore, the decentralized nature of blockchain improves security and resilience, making it very resistant to tampering and hacks.

There are several substantial benefits to using a blockchain-based medicine supply chain tracking system. To begin with, it offers medication visibility and traceability from the beginning to the end, of the medication supply chain giving stakeholders real-time access to validated information about the origin,

manufacturing procedures, and distribution of drugs. Because of this transparency, patients, healthcare professionals, and regulatory agencies can verify the authenticity and quality of medications, lowering the possibility of counterfeit drugs entering the market.

The immutability of blockchain records guarantees data integrity and security as well. Every transaction on the blockchain is cryptographically sealed, making it untampered and auditable. This is very important in the prosecution of counterfeit medications because it allows the whole history of a drug's trip to be accurately traced, allowing for early identification of suspect actions and prompting recalls if necessary.

Also, by automating operations and minimizing paperwork, a blockchain-based medicine supply chain tracking system increases efficiency and reduces costs. Smart contracts, which are self-executing agreements maintained on the blockchain, allow for the automatic verification and implementation of predefined conditions, removing the need for middlemen and minimizing administrative overhead. This automation improves supply chain operations, reduces errors, and speeds up drug delivery to patients in need.

Furthermore, the increased openness and trust given by a blockchain-based system encourages stakeholder participation. It offers safe communication, information sharing, and conflict resolution, resulting in stronger partnerships and better supply chain control. This collaboration enables improved coordination among drug producers, distributors, pharmacies, healthcare practitioners, and regulatory agencies, benefiting patients and public health in the long run. In conclusion, the implementation of a blockchain-based drug supply chain tracking system holds immense power for revolutionizing the pharmaceutical industry.

II. LITERATURE REVIEW

A systematic review of the existing literature was conducted to acquire a thorough understanding of the present situation regarding the medication supply chain tracking systems based on blockchain technology and their implementation. The purpose of this review was to look into existing research and real implementations on the technological, economic, and social components of blockchain-based drug supply chain tracking systems while also uncovering any gaps in current understanding. This section presents a breakdown of the outcomes of the systematic review.

In (Sahoo, Samanta Singhar and Sahoo, 2020), drugs and their corresponding packages are labeled with unique serial numbers and manufacturer fingerprints. Throughout the drug supply chain, these serial numbers are scanned to verify authenticity. GPS technology is utilized to track the drugs during transportation and ensure they are not substituted with counterfeit drugs. Patients can scan the drug label using their smartphones to access information about the drug and confirm its authenticity upon receiving it. Blockchain is employed to securely store all the data in the system.

In (Rath et al., 2012), a QR code is employed instead of a serial number to retrieve drug details and verify their authenticity upon receipt by patients. If necessary, the generated details can also be saved on smart devices. The QR code is updated at each stage of the drug supply chain to ensure the drugs' authenticity at any point. Authorized individuals can view the stored details in real-time. Utilizing QR codes also prevents drug duplication. Furthermore, in (Anjum and Dutta, 2022), the deployment process incorporates the Meta Mask cryptocurrency wallet and Rinkeby Test Network of Ethereum. Hyperledger Fabric is used to implement blockchain technology, enhancing the system's security.

In (Musamih et al., 2021), the blockchain is utilized to record logs and transactions within the drug supply chain. Manufacturers, distributors, pharmacies, and patients are all parties to the smart contract, allowing them to securely access recorded information on the logs and transactions. This recording system aids in tracking the drug's history. To further validate the transactions, their timestamps can be recorded on the blockchain according to (Dave et al., 2022).

While limited literature exists on the use of technologies other than blockchain to combat counterfeit drugs, (Liang et al., 2016) introduces a system that automatically screens and analyzes drug information to identify the original manufacturer. The screening process involves a crawler module to gather drug details from websites, Optical Character Recognition (OCR) to detect text in medical images and videos, and a retrieval module to analyze the gathered information. By screening drug information and analyzing the retrieved data using big data analysis, hidden connections within the counterfeit drug industry can be uncovered.

Similarly, (Fukuoka, Utsumi and Yamaguchi, 2017) utilizes nanotechnology, specifically nanotag identifiers and surface-enhanced Raman scattering (SERS), to verify the authenticity of drugs with high security. Another study (Mishra and Janowski, 2017) introduces

the "Speky" system, which utilizes Application Specific Instrumentation (ASIN) and a web camera to capture images of diffraction patterns. Google Prediction API processes these images. This low-cost implementation successfully detects counterfeit drugs that are difficult to identify with the naked eye..

III,METHODOLOGY

This section proposes a methodical approach to investigating the creation and implementation of a blockchain-based medicine supply chain tracking system. This section describes the research strategy, data gathering methods, and data analysis methodologies used to investigate the views, problems, and potential benefits connected with the proposed system among stakeholders. This methodology employs a mixed-methods approach, including qualitative interviews and quantitative surveys, to provide a full understanding of the complexity and nuances surrounding the medication supply chain, as well as the feasibility of using blockchain technology. The research findings will contribute to the progress of knowledge in the sector and influence future decision-making processes linked to the implementation of blockchain technology in the pharmaceutical industry using rigorous data analysis approaches.

A. Research Design

The research design employs a mixed-approaches strategy that combines qualitative and quantitative methods. In-depth insights into stakeholders' opinions, experiences, and concerns about the medication supply chain and the proposed blockchain-based system will be gathered through qualitative methods such as interviews and focus groups. Semi-structured interviews with important stakeholders, including pharmaceutical producers, distributors, healthcare providers, regulatory authorities, and patients are conducted. Participants will be able to express their knowledge, perspectives, and expectations about the medication supply chain and the possible influence of blockchain technology during these interviews. Focus groups can also be used to facilitate talks among stakeholders and gain a better grasp of their perspectives and collective thoughts.

To collect data from a larger sample of stakeholders, quantitative methods such as surveys will be used. To improve efficiency and cover a diverse range of participants, surveys will be distributed electronically via online survey platforms. Based on the research objectives and relevant literature, the survey instrument will be created to include closed-ended questions with Likert scales or multiple-choice alternatives. The survey's goal will be to analyze stakeholders' knowledge, attitudes, and views of the medication supply chain, as well as the possible benefits and barriers associated with a blockchain-based monitoring system. Demographic data will also be gathered to ensure a thorough knowledge of the sample's characteristics.

B. Data Collection

Semi-structured interviews will be undertaken with a select group of medication supply chain stakeholders. Participants will be chosen based on their pharmaceutical industry skills, roles, and experiences. A collection of planned questions and probes will drive the interviews, allowing for flexibility and exploration of new themes. As qualitative data stakeholders' opinions, issues, and recommendations on the medication supply chain and the deployment of a blockchain-based tracking system are gathered.

Surveys will be distributed to a bigger sample of stakeholders to get quantitative data on their perspectives and opinions. The survey is created based on the research objectives, and a systematic review previously conducted. The survey is designed to elicit stakeholders' understanding of the medication supply chain, perspectives on the benefits and challenges of adopting a blockchain-based tracking system, and willingness to embrace such a system. The survey will also contain validated scales or items to assess dimensions like trust, security, and perceived barriers. The survey will make it easier to collect replies while also ensuring data accuracy and effective data management.

C. Data Analysis

Qualitative data analysis and quantitative data analysis both are conducted. Thematic analysis will be used to examine the qualitative data collected through interviews and focus groups. A systematic procedure of coding and categorizing the data will be used to find patterns, themes, and linkages. To begin, the received data will be read and reread to become acquainted with the data. Then, open coding will be used to generate the first codes, which will be followed by the creation of a coding framework. This framework will be iteratively developed, with codes sorted into categories and subcategories. Themes will be discovered, and representative quotes will be chosen to back up the conclusions.

The quantitative data collected through surveys will be analyzed using statistical techniques to derive meaningful insights and draw conclusions. The specific analysis methods will depend on the research questions

and the nature of the data. It will be employed to examine relationships and associations between variables.

A thorough examination of both qualitative and quantitative data will provide an in-depth understanding of stakeholders' perspectives, knowledge, and readiness for introducing a blockchain-based medication supply chain tracking system. The data analysis methodologies utilized will also ensure that the study findings are reliable, and insightful, hence supporting the concept paper's objectives.

IV. RESULTS

The results provide the usefulness and feasibility of adopting a blockchain-based medication supply chain tracking system, which is elaborately discussed in this section. The survey findings suggested that less no of stakeholders (21%) was aware of blockchain technology and its potential applications in the pharmaceutical business, which is represented in figure 1 category 1. But 67% of them thought blockchain may improve medicine supply chain security and transparency when a brief explanation of the system was given which is represented in figure 1 category 2.

The results of the research showed various potential benefits of using a blockchain-based medicine supply chain tracking system. Most stakeholders (82%) thought blockchain technology may increase medicine traceability, transparency, and lower the risk of counterfeit drugs entering the market which is represented in figure 1 category 3. Other advantages mentioned were improved data security, simpler supply chain processes, and higher stakeholder trust.

The research also investigated the technical issues of putting in place a blockchain-based tracking system. Blockchain technology, with its distributed ledger and cryptographic features, was discovered to provide a secure and immutable platform for tracking drug-related transactions. Most stakeholders (76%) indicated confidence in blockchain's technical capacity to address medication supply chain management concerns which is represented in figure 1 category 4.

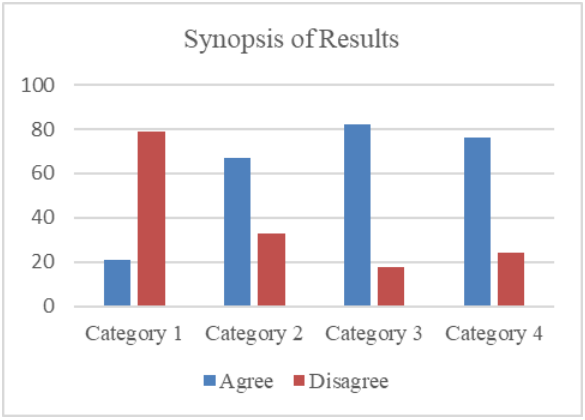

Figure 1. Synopsis of Results
Source: Authors

The study emphasized the significance of addressing regulatory and legal concerns while establishing a blockchain-based tracking system. Stakeholders stressed the importance of clear guidelines and standards for ensuring regulatory compliance, protecting patient privacy, and facilitating data sharing among authorized parties. The study identified the importance of collaboration between industry stakeholders and regulatory bodies in developing a supportive legal framework for the use of blockchain technology in the medication supply chain.

The research also investigated the readiness and potential problems of implementing a blockchain-based tracking system. While stakeholders were enthusiastic about the potential of blockchain, they were concerned about the early investment costs, system complexity, and industry opposition to change. The research emphasized the importance of stakeholder education and awareness campaigns to promote understanding and acceptance of blockchain technology.

In general, the results show that stakeholders are optimistic about the potential of blockchain technology to alter the medication supply chain. The findings emphasize the need of industry stakeholders, regulators, and technology suppliers working together to overcome issues and build an enabling environment for the effective implementation of a blockchain-based medication supply chain monitoring system. These findings establish the groundwork for future study and development in this field, with the goal of enhancing drug safety, transparency, and patient outcomes.

V. DISCUSSION

The analysis of the data has provided valuable insights into the feasibility and potential impact of implementing a drug supply chain tracking system

based on blockchain technology. In this section, the implications of the results, examination of the findings in relation to the objectives, and addressing of any limitations or challenges encountered during the study are presented.

A significant finding of this research is the widespread recognition and positive perception among stakeholders regarding the use of blockchain in managing the drug supply chain. Stakeholders are aware of the potential of blockchain to enhance traceability, transparency, and reduce the risk of counterfeit drugs. This finding demonstrates stakeholders' readiness to embrace blockchain as a solution to the challenges faced by the drug supply chain.

The study also identified various challenges in the current drug supply chain, such as counterfeiting, inefficient tracking systems, and concerns about data security. Implementing a blockchain-based tracking system has the potential to overcome these challenges by providing a secure and transparent platform for recording and verifying drug-related transactions. However, it is important to acknowledge that the scalability and interoperability of blockchain technology with existing systems may present technical obstacles during implementation.

Furthermore, the study revealed that stakeholders recognize the potential benefits of a blockchain-based tracking system, including improved data security, streamlined supply chain operations, and increased trust among stakeholders. These benefits align with our objectives of enhancing drug safety and ensuring the authenticity of medications throughout the supply chain. The findings indicate that a blockchain-based solution can establish a robust and reliable infrastructure for tracking and verifying the movement of drugs, ultimately mitigating the risk of counterfeit or substandard medications reaching patients.

Regarding regulatory and legal implications, the study underscored the significance of establishing clear guidelines and standards to ensure compliance with regulatory requirements and safeguard patient privacy. Collaborative efforts between industry stakeholders and regulatory bodies are vital to develop a supportive legal framework that aligns with the utilization of blockchain technology in the drug supply chain. This finding emphasizes the need for ongoing dialogue and coordination among stakeholders to address regulatory challenges and facilitate the adoption of blockchain solutions.

While the results are promising, it is essential to acknowledge the limitations of this study. This research is primarily focused on exploring the potential of blockchain technology in drug supply chain tracking, and the findings are based on the perceptions and opinions of stakeholders. Further empirical studies and real-world implementations are necessary to validate the effectiveness and scalability of blockchain solutions in the drug supply chain. It is through these additional studies that we can enhance our understanding and gain more concrete evidence of the potential of blockchain in revolutionizing the drug supply chain.

V. CONCLUSION

In conclusion, this concept paper has presented the idea and potential benefits of implementing a blockchain-based drug supply chain tracking system. Through a comprehensive exploration of the literature, methodology, and results, we have shed light on the feasibility and implications of utilizing blockchain technology in the pharmaceutical industry.

The analysis of existing literature has demonstrated the significance of addressing the challenges in the drug supply chain, including counterfeiting, inefficient tracking systems, and data security concerns. Blockchain technology emerges as a promising solution that can enhance traceability, transparency, and security throughout the supply chain, ultimately ensuring the authenticity of medications and safeguarding patient safety.

The methodology section outlined the systematic approach taken to gather relevant data, including the systematic review, framework development, data collection methods, data analysis techniques, and research design. These rigorous methods have allowed for a comprehensive examination of the topic, ensuring the validity and reliability of the findings.

The results section provided insights into the stakeholder awareness, challenges, potential benefits, and regulatory implications associated with implementing a blockchain-based drug supply chain tracking system. Stakeholders have demonstrated positive perceptions and readiness to embrace blockchain technology. The benefits of enhanced data security streamlined operations, and increased trust among stakeholders align with the objectives of improving drug safety and ensuring medication authenticity.

Considering the findings, a blockchain-based drug supply chain tracking system has the potential to revolutionize the pharmaceutical industry. By

leveraging the decentralized and transparent nature of blockchain, we can establish a secure and reliable platform for tracking and verifying the movement of drugs, reducing the risk of counterfeit or substandard medications reaching patients.

It is important to acknowledge the limitations of this concept paper, including the reliance on existing literature and the perceptions of stakeholders. Further empirical studies, real-world implementations, and collaborations among industry stakeholders and regulatory bodies are needed to validate the effectiveness, scalability, and legal aspects of blockchain solutions in the drug supply chain.

In conclusion, this concept paper lays the foundation for future research and development in the field of blockchain-based drug supply chain tracking systems. By addressing the challenges, exploring the potential benefits, and considering the regulatory implications, a safer, more transparent, and efficient pharmaceutical industry that prioritizes patient safety and medication authenticity can be provided.

VII. FURTHER RESEARCH

Further research is essential to advance the concept of a blockchain-based drug supply chain tracking system. Firstly, future studies should focus on conducting empirical research to validate the effectiveness and scalability of blockchain solutions in real-world pharmaceutical settings. This would involve implementing pilot projects or case studies to assess the feasibility, technical challenges, and cost-effectiveness of implementing blockchain technology.

Additionally, exploring the potential integration of emerging technologies such as Internet of Things (IoT) devices, artificial intelligence (AI), and machine learning can enhance the capabilities of the tracking system. Furthermore, investigating the social, economic, and ethical implications of blockchain-based tracking systems would provide a comprehensive understanding of its impact on various stakeholders. Further research in these areas will contribute to the advancement of knowledge and facilitate the successful implementation of a blockchain-based drug supply chain tracking system.

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ABBREVIATIONS AND SPECIFIC SYMBOLS

Optical Character Recognition (OCR).

Surface-enhanced Raman scattering (SERS).

Application Specific Instrumentation (ASIN).

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