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Innovative Role of Blockchain Pharmaceutical Supply Chain Digital Transformation: Enterprise Architecture Perspective

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Abstract: The advent of the Fourth Industrial Revolution has compelled numerous industries to undergo digital changes or transformations. One example is the pharmaceutical industry, which is responsible for providing medicinal products. The pharmaceutical supply chain assumes a crucial position within the pharmaceutical industry as it enables the secure, streamlined, and dependable transportation of medications from producers to individuals in need. The issue of prioritizing digital transformation within the pharmaceutical supply chain has emerged as a significant problem for hospitals and pharmaceutical businesses. Integrating different components inside the system is effectively supported by the substantial function fulfilled by Enterprise Architecture in this specific context. The objective is to minimize errors, enhance inventory management, optimize product distribution, and guarantee the safety and quality of pharmaceuticals. However, the process of adequately monitoring and verifying data has its challenges. However, these challenges can be efficiently addressed through implementing blockchain technology. In addition to this, Blockchain technology has the potential to enhance industrial efficiency. Utilizing blockchain technology enables the facilitation of transparency, immutability, and data integrity across the entirety of the supply chain. Integrating Enterprise Architecture electronic automation with Blockchain technology enables pharmaceutical enterprises to establish robust systems facilitated by Smart Contracts. The use of this system is expected to significantly enhance automation and regulatory adherence within supply chain processes, leading to notable advancements in operational efficiency, security, and data accuracy. Integrating blockchain technology and smart contracts enables pharmaceutical enterprises to enhance their product offers to hospitals and patients at reduced expenses, facilitating notable advancements in Enterprise Architecture.

Keywords: Blockchain Technology; Digital Transformation; Enterprise Architecture; Pharmaceutical Industry; Smart Contract;

INTRODUCTION

In the contemporary period characterized by perpetual transformation and progress, the pharmaceutical industry and hospitals are undergoing substantial shifts in managing and administering medications to patients. The pharmaceutical supply chain plays a crucial role in facilitating the delivery of products from manufacturers to patients, hence ensuring efficient, safe, and dependable healthcare

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services. Hospitals and pharmaceutical businesses worldwide have significantly emphasized digital transformation to accomplish this objective. Enterprise Architecture (EA) (Hindarto, 2023b) assumes a pivotal role in this context as it facilitates the integration of diverse system components, enhancing efficiency, safety, and quality within the pharmaceutical supply chain. The pharmaceutical sector has seen significant transformations in recent decades. The evaluation and enhancement of pharmaceutical businesses' manufacturing, administration, and delivery processes have been driven by technological advancements, more severe laws, and a growing customer demand for improved medications. However, hospitals are also confronted with the imperative to deliver care of superior quality amidst the formidable obstacles of exorbitant care expenses and intricate regulatory frameworks. Pharmaceutical firms and hospitals are progressively turning to information technology to enhance operational efficiency in response to the growing array of requirements they face.

The pharmaceutical supply chain plays a significant role in the pharmaceutical and hospital sectors. The supply chain encompasses a sequence of operations surrounding the acquisition, manufacturing, packing, distribution, and final transportation of pharmaceuticals to those needing medical treatment. The presence of inefficiencies within the supply chain can lead to significant ramifications, such as escalated expenses, diminished quality of care, and potential hazards to patient well-being. Hence, stakeholders in the pharmaceutical business have recognized the need to prioritize digital transformation within the supply chain. Enterprise Architecture refers to organizations' methodical and structured methodology to strategically plan, create, and effectively manage their information and technology systems. Enterprise Architecture (Wedha & Hindarto, 2023) facilitates businesses' seamless integration of diverse information technology components. These components encompass hardware, software, data, and processes harmoniously consolidated and aligned within a unified and strategic framework. The objective is to enhance operational efficiency service quality, and provide more informed decision-making. Within the pharmaceutical supply chain realm, Enterprise Architecture assumes a critical function in harmonizing and synchronizing all constituent components included in the transportation of pharmaceuticals to individuals in need of medical treatment.

Aligned with advancements in technology, a conjecture has arisen positing that the integration of Enterprise Architecture with blockchain technology (J et al., 2023), (Wu et al., 2023) holds the potential to bring about a favorable metamorphosis inside the pharmaceutical supply chain (Drakatos et al., 2022). The transformative potential of blockchain technology has been demonstrated across various industries, initially emerging as the foundational infrastructure for digital currencies like Bitcoin. Blockchain technology is characterized by its decentralized nature, ensuring the security and immutability of a digital ledger that transparently records transactions. This implies that any alterations made to the pharmaceutical supply chain and documented in the blockchain will possess an unchangeable record, guaranteeing the data's integrity and security. Furthermore, utilizing blockchain technology facilitates the implementation of automation via smart contracts. These intelligent contracts can automate specific procedures inside the supply chain, diminishing the likelihood of human fallibility. Despite the potential advantages of digital transformation and the integration of blockchain technology within the pharmaceutical supply chain, some obstacles that necessitate resolution still need to be addressed. One area of interest pertains to integrating blockchain technology with pre-existing Enterprise Architectures within the healthcare (Thantilage et al., 2023) and pharmaceutical sectors. This entails the modification of pre-existing information technology infrastructures to integrate with blockchain technology, enabling seamless and effective coexistence. Furthermore, it is vital to contemplate the potential required changes in the existing data and processes within the supply chain to incorporate blockchain technology and smart contracts while ensuring negligible disruption to current operations. Furthermore, comprehending the security ramifications linked to utilizing Blockchain Technology (Wu et al., 2023) within the pharmaceutical supply chain is of utmost significance, particularly in light of the delicate nature of medical information and the imperative to adhere to stringent regulatory protocols.

This article aims to dig deeper into the issue of how effective it is to increase the efficiency and security of pharmaceutical supply chains by leveraging blockchain and innovative contract technologies. It addresses the issues associated with these efforts and comprehensively explains the subject matter. In this analysis, we will examine the practical application of this idea and ascertain the real benefits that hospitals and pharmaceutical businesses can gain from its implementation. In addition, the social,

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economic, and regulatory consequences arising from these modifications will be assessed regarding the pharmaceutical supply chain. By increasing our understanding of the interaction of Enterprise Architecture, Blockchain Technology, and the Pharmaceutical Supply Chain, we aim to offer a significant scientific perspective in driving the sector toward a future characterized by increased efficiency and security. The author has formulated three research inquiries warrant investigation to integrate Enterprise Architecture with blockchain technology to revolutionize the pharmaceutical supply chain. What are the primary obstacles that must be addressed when deploying Blockchain technology inside the Pharmaceutical Supply Chain? (Research Question 1). What advantages might be derived from utilizing Blockchain and Smart Contracts inside the Medicines Supply Chain? (Research Question 2).

LITERATURE REVIEW

It is necessary to streamline the pharmaceutical production process using Lean Production Systems to guarantee a sustainable supply of affordable medicines for the population. This study examines the success factors and barriers to LPS in the pharmaceutical industry, particularly for small and medium-sized enterprises (Sieckmann et al., 2018). The research proposes a model of an automated decision-making system with blockchain and smart contracts for pharmaceutical manufacturing companies' value assessment. It consists of four dimensions: integration, optimization, control, and value-added satisfaction, allowing for a thorough evaluation of enterprise value (Liu & Cai, 2018). Due to globalization, diverse entities collaborate across geographies, reaping the benefits of efficient Supply Chains. The Pharmaceutical Supply Chain (PSC) encounters difficulties in tracking due to multiple participants and counterfeit drugs. This paper evaluates the security and efficacy of a secure QR code system using Blockchain, IPFS, and QR code technologies to improve PSC monitoring and tracking (Bapatla et al., 2022). Supply Chains' efficiency has increased due to globalization-encouraged collaboration across multiple locations. Due to the number of participants and counterfeit drugs, the Pharmaceutical Supply Chain needs help in tracking. This paper evaluates the security and efficiency of a secure QR code system using Blockchain technology, IPFS, and QR codes to enhance search in PSCs (Schapranow et al., 2011). The healthcare industry confronts growing regulatory, privacy, and cost difficulties. Leaders and professionals in the health industry are searching for new technologies to enhance health care. The pharmacy's role has shifted to be more patient-centric due to technological advancements, particularly the connected cyber-infrastructure. Nonetheless, privacy, trust, and security issues persist. This article examines cyber-physical system architecture issues in pharmaceutical healthcare services (Devliyal et al., 2022).

The existing literature has yet to extensively examine the convergence of Blockchain Technology with Enterprise Architecture, presenting a potential avenue for identifying a research lacuna. The purpose of this study is not to critique or identify shortcomings in prior research but rather to supplement and enhance current understandings. This research endeavors to strengthen the sense of Blockchain Technology's utilization within the Enterprise Architecture domain by integrating these constituent aspects. It seeks to address potential gaps in knowledge that may have arisen from prior research, thereby offering a more comprehensive contribution.

METHOD

Enterprise Architecture based on TOGAF

Enterprise Architecture (Hindarto, 2023a) is a comprehensive methodology encompassing the strategic planning, design, and management of an organization's information technology infrastructure and resources in a cohesive and interconnected manner. Enterprise architecture is crucial in maintaining the alignment between an organization's information technology and its objectives within a dynamic and evolving business environment. The Open Group Architecture Framework (TOGAF) (Amanda et al., 2023) is widely recognized and extensively utilized as a prominent framework for implementing Enterprise Architecture. The TOGAF framework offers extensive help to enterprises in developing and managing their enterprise architecture. The primary areas of concentration encompassed by this framework are Business Architecture, Application Architecture, Data Architecture, and Technology Architecture (Titi et al., 2023). Corporate Architecture is a discipline that involves the identification of corporate objectives, operational procedures, and the overall organizational framework. Furthermore,

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Application Architecture encompasses the strategic planning and implementation of applications and their alignment with and facilitation of business processes. Thirdly, Data Architecture manages data and information within organizational contexts. In conclusion, the discipline of Technology Architecture encompasses creating designs for the technological infrastructure required to sustain applications and data effectively.

The TOGAF framework presents a stratified methodology that enables firms to comprehensively comprehend their operations and pinpoint areas that might be enhanced. The process encompasses various stages: planning, design, implementation, and maintenance. The planning phase represents the primary stage during which organizations establish their objectives and delineate the challenges they aim to address by implementing enterprise architecture. The design phase encompasses the creation of an architectural framework that outlines how the various components of the system will interact and collaborate. The implementation phase is centered on the execution of the designed architecture within an actual operational setting. In contrast, the maintenance phase is an ongoing process that spans the whole life cycle and aims to ensure the architecture's continued relevance and efficiency.

One of the primary advantages associated with implementing TOGAF is the enhancement of visibility and comprehension of an organization's business operations and information technology. This facilitates the reduction of redundancy, enhancement of efficiency, and improved management of hazards for enterprises. The TOGAF framework also offers consistent guidance to multiple organizational stakeholders, encompassing executive management, technology developers, and enterprise architects. Furthermore, TOGAF competes strongly with many software development approaches, like ITIL (Information Technology Infrastructure Library) and Agile. This enables enterprises to achieve a harmonious equilibrium between robust enterprise architecture and adaptability in managing dynamic circumstances. In general, the TOGAF framework is well recognized and has a proven track record in facilitating the implementation of Enterprise Architecture within various organizational contexts. The utilization of information technology aids firms in optimizing their operational efficiency and effectively attaining their corporate objectives. TOGAF offers a robust framework for effectively strategizing and overseeing enterprise architecture, characterized by a methodical methodology and distinct stages.

Pharmaceutical Company

Pharmaceutical corporations are significant in researching, developing, producing, and distributing medications and other health products. Pharmaceutical companies aim to provide effective and safe medical solutions for various health conditions, from prevalent to rare diseases. In addition to clinical trials, drug approvals, and product patents, they are subject to rigorous regulations. In addition, pharmaceutical companies invest significantly in research and development to discover new treatments and therapies that can benefit millions of people around the globe. To meet stringent quality and safety requirements, pharmaceutical companies employ highly regulated production processes and prioritize supply chain management. They must also keep abreast of technological and regulatory advancements in the pharmaceutical industry. Sustainability and social responsibility are also significant concerns for pharmaceutical companies, particularly regarding chemical waste management and other environmental impacts. In addition, pharmaceutical companies play a crucial role in meeting the requirements of patients and the entire healthcare system. Work with healthcare providers and governments to ensure patients can access affordable, essential medications. Pharmaceutical companies are also responsible for marketing and educating medical professionals and the general public regarding their products.

It is essential to recognize that pharmaceutical companies face unique ethical and moral challenges. They must choose between maximizing profits and meeting the health requirements of the public. Even though certain pharmaceutical products generate enormous profits, there is a moral obligation to ensure everyone has access to vital medications, especially in countries with limited financial resources. In the context of digital transformation, pharmaceutical companies are progressively using information technology to increase the efficiency of their product marketing services. Big Data, artificial intelligence, and data analytics are at the heart of innovation in the pharmaceutical industry, allowing companies to optimize processes and provide patients with improved care. Overall, pharmaceutical companies play a significant role in the global health industry by maintaining and enhancing human health through innovation, research, and developing essential health products.

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Blockchain

The technology known as blockchain has had a transformative impact on various sectors, particularly banking, by offering effective resolutions to issues about security and transparency. The digital ledger in question operates as a decentralized system that records all transactions within the network. In the context of Blockchain Technology, it is essential to note that every block inside a blockchain comprises a set of transactions. Furthermore, cryptographic mechanisms intricately link these blocks, establishing a cohesive chain structure. The manipulation of this chain is highly challenging because each block must possess a valid proof of work, and the consensus of over 50% of the network's computational capacity is necessary for adding a new partnership.

Smart contracts are software applications that operate on a blockchain platform that automates validates, or autonomously executes contractual agreements upon fulfilling predetermined circumstances. They are a significant component of the Ethereum blockchain (Alhijawi et al., 2023), (Urquhart, 2022). Smart contracts have many applications, encompassing money processing, digital asset exchange, electronic voting, and various other functions. Autonomous operations are conducted without human intervention and are solely responsible for strictly adhering to the contractual terms. Intelligent contracts utilize the inherent security and immutability of blockchain technology to guarantee the accurate execution of contractual agreements while also ensuring equal accessibility to pertinent information for all parties participating in these contracts.

Ethereum, a widely recognized blockchain platform, was created by Vitalik Buterin in 2015. Ethereum (Saxena et al., 2023)is renowned for its pioneering role in integrating intelligent contracts within the blockchain framework. This platform enables developers to construct decentralized apps (Dapps) atop it, ensuring that these applications are not subject to the control of a single central organization and are more resilient against potential hacking vulnerabilities. Ether (ETH) functions as a digital currency within the Ethereum network, primarily utilized to remunerate transaction fees and facilitate the execution of smart contracts. Ethereum has undergone a sequence of upgrades, one of which is Ethereum 2.0. This upgrade is designed to enhance network speed and efficiency by implementing the Proof of Stake consensus mechanism.

One of the primary strengths of Ethereum is its robust and quickly expanding ecosystem. Numerous projects and applications have been developed on this platform, encompassing DeFi (Decentralized Finance), which facilitates users in engaging in activities such as borrowing, lending, and trading digital assets without the involvement of conventional intermediaries. Ethereum has emerged as a platform for hosting Initial Coin Offerings (ICOs), enabling blockchain-based initiatives to secure financial resources for their advancement by selling proprietary tokens to interested investors.

In brief, blockchain is a decentralized technological innovation that facilitates the secure and traceable recording of transactions in a ledger. Smart contracts refer to computer programs that can autonomously execute contractual agreements, eliminating human intermediaries' requirements. Ethereum is a prominent blockchain platform that has played a pivotal role in advancing blockchain technology and developing decentralized applications. It is renowned for introducing the concept of smart contracts and fostering a robust ecosystem that encourages innovation within the blockchain space.

Research Methodology

Introduction to Research Methodology is an essential initial step in any research endeavor. In this phase, the researcher describes the data collection, analysis, and evaluation procedures. Using appropriate research methods will ensure the precision and reliability of research findings.

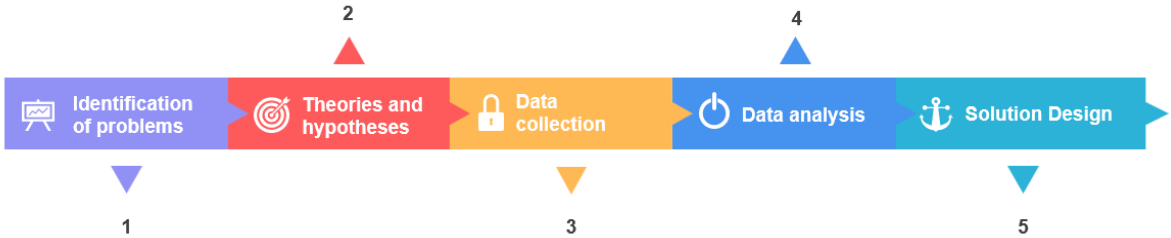

Fig. 1 Research Methodology
Source: Researcher Property

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The following is a description of Research Methodology from Figure 1:

1. Identifying problems in the context of blockchain, smart contracts, and Ethereum presents several significant obstacles. Primarily, blockchain scalability issues result in speed and energy consumption limitations. The security of smart contracts is a concern because they are exploitable. In addition to creating legal ambiguity, the absence of a standardized legal framework for smart contracts contributes to legal uncertainty. In addition, Ethereum confronts scalability issues when the network is congested due to high gas fees. Implementing Proof of Stake in Ethereum 2.0 is a complex process that attempts to resolve this issue.
2. In science, theories, and hypotheses are frequently used to explain natural or social phenomena. They provide the framework for formulating queries, gathering evidence, and testing hypotheses. A theory in science is an explanation that has been repeatedly tested and deemed accurate. A view, meanwhile, is an initial estimate that must be tested. These two ideas are essential to expanding our knowledge and comprehension of the world.
3. Data acquisition is an essential step in research and data analysis. This process involves collecting pertinent and accurate information from various sources, such as surveys, interviews, observations, or secondary data. Once collected, data must be processed, analyzed, and interpreted to obtain valuable insights or knowledge. Data quality is crucial because research outcomes and data-driven decisions are highly dependent on the accuracy and sufficiency of the information collected.
4. Data analysis is a crucial step in the research process that identifies patterns, trends, and essential information from collected data. This entails employing statistical tools or other analytic techniques to transform data into easily digestible insights. In disciplines such as science, business, and social sciences, the results of this data analysis are used to draw conclusions, support decisions, or uncover new information. Careful and precise data analysis can provide profound and valuable insights for addressing obstacles and determining the best course of action.
5. Solution design is a crucial phase of project development in which exhaustive solutions or strategies for overcoming problems or achieving specific objectives are designed. This involves identifying requirements, selecting the most effective approach, and planning implementation. Its design must consider technical factors, budget, resources, and timeframe to ensure an effective and successful solution.

RESULT

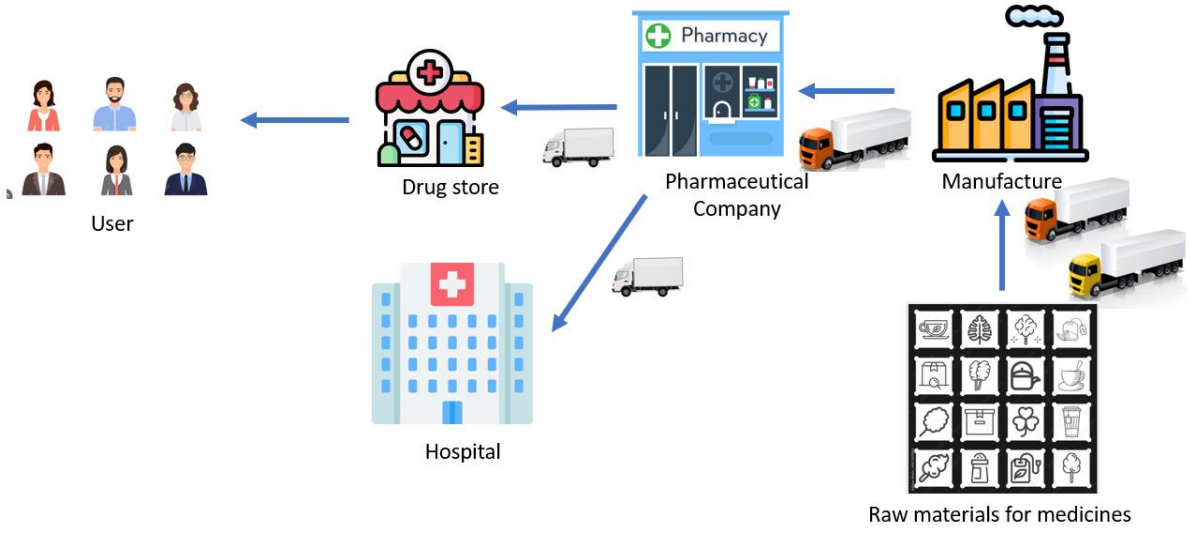

Fig. 2 Traditional Supply Chain for Medicines (existing)
Source: Researcher Property

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Fig. 2, The traditional supply channel for medicines is a complex process that begins with the supply of raw materials through the production stages in drug factories, distribution to pharmacies and hospitals, until finally obtained by buyers or users. The process begins with the supply of raw materials, which may include a variety of chemical substances, active components, or other constituents necessary for the production of the drug. Raw materials suppliers are responsible for providing high-quality materials that adhere to stringent regulatory requirements. After receiving the raw materials, the drug factory commences the production process. They mix, refine, and formulate raw materials into a final drug product. Here, various testing and quality control phases are implemented to ensure that the drugs produced are safe, effective, and comply with applicable regulatory standards.

In addition, pharmaceuticals are distributed to various locations, including pharmacies and hospitals. These drug distribution companies store and transport drug products to these locations. The distribution of these drugs is also strictly regulated, as the medicines must be kept in suitable conditions, and their ultimate destination must be guaranteed. In pharmacies and hospitals, these medications are accessible to purchasers and patients. Pharmacists are responsible for providing patients with accurate information regarding dosage, adverse effects, and how to use medications. Before dispensing the medicine to the patient, they verify that the doctor's prescription is valid. Buyers and consumers can now obtain drugs from pharmacies with a valid prescription. Users may take the medication and adhere to the instructions provided by the pharmacist or physician. This method of traditional medicine distribution has been a cornerstone of public medicine distribution for many years. However, with the advancement of technology and innovation in the drug supply chain, many companies and governments are exploring new methods to improve the drug supply's efficiency, transparency, and accessibility. This includes using blockchain technology to monitor medications and Internet-based systems to directly connect drug manufacturers to hospitals and pharmacies. Despite this, traditional supply channels remain essential in maintaining the quality and safety of available medicines and remain the primary method for distributing medication to the public.

Process 1: Provision of Raw Materials

The drug supply chain begins with the procurement of basic materials. Drug suppliers must identify and acquire the necessary basic materials for drug production. These components may be compounds, active substances, or other essential additives. Suppliers are required to ensure the quality, safety, and regulatory compliance of all raw materials.

Process 2: Drug Manufacturing

After receiving the raw materials, the drug factory commences the production process. This includes combining, processing, and formulating raw materials into finished pharmaceuticals. Various testing and quality control stages are conducted to ensure that the resulting drug satisfies all safety and efficacy requirements.

Process 3: Distribution and Storage

The completed pharmaceuticals are then distributed to pharmacies and hospitals, among other locations. Drug distribution companies are responsible for ensuring appropriate storage and delivery to these locations. This entails monitoring temperature, humidity, and other storage conditions to ensure the drug remains stable and suitable until it reaches its final destination.

Process 4: Prescription and Consultation

In pharmacies and hospitals, these medications are accessible to purchasers and patients. Pharmacists are responsible for providing patients with accurate information regarding dosage, adverse effects, and how to use drugs. Before dispensing the medicine to the patient, they verify that the doctor's prescription is valid. Patients can consult a pharmacist or physician for more information on the drug's administration.

Process 5: Receiving medicines by purchasers or end-users is the fifth step in the distribution process. Buyers and consumers can now obtain drugs from pharmacies with a valid prescription. Users may take the medication and adhere to the instructions provided by the pharmacist or physician. At this point, the drug is in the hands of the purchaser or user and is available for use for medical needs or prescribed treatment.

By dividing this process into five phases, we can examine in greater detail how medications reach the patient or end user via this intricate supply chain.

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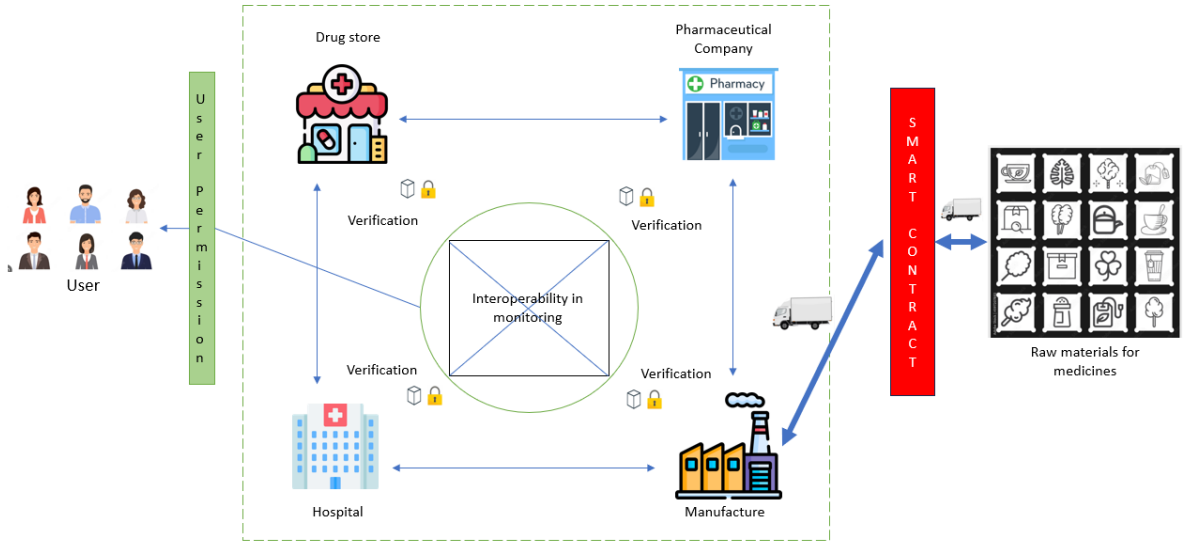

Fig. 3 Proposed Blockchain Technology - Supply Chain for Medicines (improvement)
Source: Researcher Property

Fig. 3, Utilizing blockchain technology holds significant promise in transforming the conventional pharmaceutical supply chain by consolidating five distinct operations into three streamlined and more effective ones. One of the primary advancements in applying blockchain technology within the pharmaceutical supply chain involves incorporating these procedures into a decentralized and inclusive environment. This integration facilitates enhanced transparency, security, and interoperability levels across all pharmaceutical supply chain participants.

Process 1: Procurement of Raw Materials and Manufacture of Pharmaceuticals

This novel strategy entails the integration of raw material supply and medication synthesis into a unified process. The registration of ingredients by raw material suppliers on the blockchain facilitates the expeditious identification, tracking, and verification of the origin of raw materials for medicine producers. Moreover, implementing this approach will provide enhanced transparency and documentation within the drug production process, mitigating the potential hazards associated with using dubious or counterfeit raw materials. Implementing this procedure will enhance efficiency and enable continuous monitoring throughout the medication manufacturing process.

The second process involves the distribution and storage of goods.

In this procedure, the blockchain technology will function as a decentralized database, enabling drug distribution enterprises, hospitals, and pharmacies to document and monitor each phase of a medicine's trajectory. Real-time access would be provided to all stakeholders for the recorded data about temperature, humidity, and other storage conditions. This will guarantee that the pharmaceutical product maintains its optimal state throughout distribution and storage. Furthermore, identifying and resolving errors within the supply chain can be expedited.

The third step in the process involves

a. the prescription of medication,
b. consultation with a healthcare professional, and
c. the subsequent receipt of the prescribed medicine.

The integration of blockchain technology will unify the operations of prescribing, consulting, and getting pharmaceuticals, creating a more interconnected entity. Physicians can electronically record prescriptions on the blockchain, enabling automated verification of medicine availability, appropriate dosage, and potential interactions with other medications. Pharmacists can readily retrieve these prescriptions and offer consultations to consumers with more convenience. The act of a patient acquiring medication is documented on the blockchain, generating a secure and readily available transaction record.

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Moreover, including interoperability will serve as a crucial component inside the blockchain-enabled pharmaceutical supply chain. All relevant parties, including suppliers of raw materials, producers of pharmaceuticals, distribution entities, healthcare facilities, pharmacies, medical practitioners, and individuals receiving medical treatment, will have the capability to access and exchange information securely. Implementing this measure is expected to result in a reduction of bureaucratic processes, the elimination of potential irregularities, and the facilitation of enhanced collaboration to ensure the safety and efficiency of the medication supply chain. Blockchain technology will enhance the drug supply chain's transparency, integration, and efficiency. Implementing this measure is expected to improve the security of the pharmaceutical supply chain, mitigate the potential hazards associated with counterfeit products or dubious raw materials, and facilitate expedited and precise distribution of medications to individuals in need. Blockchain technology holds significant potential to revolutionize the management of drug supply chains and enhance the availability and safety of medicines throughout society.

DISCUSSIONS

What are the primary obstacles that must be addressed when deploying Blockchain technology inside the Pharmaceutical Supply Chain? (Research Question 1).

Achieving interoperability poses a significant barrier to successfully integrating blockchain technology inside the pharmaceutical supply chain. Given the extensive number of stakeholders involved in the drug supply chain, disparate blockchain systems must be able to communicate and effortlessly share data effectively. Furthermore, it is imperative to address the challenge of establishing consistent data standards and protocols to ensure the uniformity and compatibility of data across various platforms. This is crucial to fully harness the potential benefits of blockchain technology in enhancing transparency and efficiency within the pharmaceutical supply chain.

What advantages might be derived from utilizing Blockchain and Smart Contracts inside the Medicines Supply Chain? (Research Question 2).

Utilizing blockchain technology and smart contracts inside the pharmaceutical supply chain yields notable benefits. Implementing blockchain technology enhances transparency and security by facilitating real-time tracking of all stages involved in drug production, distribution, and storage. Smart contracts enable the automation of contract execution, thereby mitigating the occurrence of human errors and expediting the processing of orders. By implementing these measures, the likelihood of counterfeit medications is diminished, the efficiency of supply is maximized, and adherence to regulatory standards is guaranteed. Furthermore, implementing blockchain technology facilitates monitoring and controlling temperature and storage conditions, ensuring the preservation of medicinal product quality and mitigating wastage.

CONCLUSION

In the study titled "Innovative Role of Blockchain Technology in Pharmaceutical Supply Chain Digital Transformation: An Enterprise Architecture Perspective," the innovative role of blockchain technology in transforming pharmaceutical supply chains is analyzed from an enterprise architecture perspective. This study examines the significance of utilizing blockchain technology to overcome track and trace challenges in the drug supply chain, particularly those involving the participation of multiple entities and the threat of counterfeit pharmaceuticals. One of the critical outcomes of this study is the enormous potential of blockchain technology for enhancing the transparency and safety of the pharmaceutical supply chain. Blockchain enables all entities in the supply chain, from the manufacturer to the final patient, to have real-time access to data regarding the transportation of pharmaceuticals. This helps ensure that the delivered medication is authentic and not counterfeit. This technology also generates an unalterable audit trace, which can aid in monitoring the quality and safety of drugs throughout the supply chain. In addition, this study proposes implementing a model that utilizes blockchain technology, the InterPlanetary File System (IPFS), to enhance drug tracking in the pharmaceutical supply chain. Consequently, this model provides a safer and more effective solution for combating counterfeit drugs and monitoring issues in the supply chain. In addition to the technical benefits, this research also emphasizes the importance of considering human aspects in the implementation of blockchain technology in the pharmaceutical supply chain. This includes considering

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privacy, trust, and security concerns when using this technology. In an era where personal information has become exceedingly valuable, safeguarding user privacy must be a top priority for any blockchain-based solution. However, the research acknowledges obstacles to implementing blockchain technology in the pharmaceutical supply chain, including the potential need for regulatory changes. In addition, greater emphasis must be placed on education and training to ensure that stakeholders at all levels comprehend and can correctly implement these technologies. This study reveals how blockchain can be an innovative and useful instrument for digital transformation in the pharmaceutical industry. Implementing blockchain technology in the pharmaceutical supply chain could be the key to addressing future challenges in providing safe and affordable medicines to the public if it is carefully and persistently considered.

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