Blockchain in Action: Enhancing Transparency and Traceability in the Pharmaceutical Supply Chain - A Case Study from Vietnam

Trong Tien, Hoang
International School, Vietnam National University, Hanoi, Vietnam
tienht@vnu.edu.vn

Cong Doan, Truong
International School, Vietnam National University, Hanoi, Vietnam
tcdoan@vnu.edu.vn

ABSTRACT

This study explores the critical role of digital advancements in supply chain management within the pharmaceutical industry, particularly focusing on the potential of blockchain technology to rectify the prevailing information access imbalance. The research establishes the link between the importance of increased transparency and traceability of pharmaceutical products and the prospective solutions that blockchain technology can offer. To substantiate this, we propose a novel application to facilitate end-to-end inclusion in the supply chain process. This application, developed to suit the specific requirements of the Vietnamese pharmaceutical industry, records pertinent product details in a centralized MS SQL database. A selection of these details is then transferred to a blockchain network, enhancing traceability and transparency by rendering the information immutable, verifiable, and widely accessible. It also underscores the promising horizon of integrating blockchain technology into supply chain management for the establishment of more efficient, resilient, and transparent systems in the era of digital transformation.

CCS CONCEPTS

• **Information systems** → Information systems applications; Enterprise information systems; Enterprise applications.

KEYWORDS

blockchain, pharmaceutical supply, digital transformation

ACM Reference Format:
Trong Tien, Hoang and Cong Doan, Truong. 2023. Blockchain in Action: Enhancing Transparency and Traceability in the Pharmaceutical Supply Chain - A Case Study from Vietnam. In *2023 4th Asia Service Sciences and Software Engineering Conference (ASSE 2023), October 27–29, 2023, Aizu-Wakamatsu City, Japan.* ACM, New York, NY, USA, 6 pages. https://doi.org/10.1145/3634814.3634832

1 INTRODUCTION

Supply chain management is the comprehensive orchestration of planning, organizing, and overseeing the movement of goods and services from suppliers to customers [1]. It encompasses the entirety of the supply chain, from procuring raw materials to delivering finished goods to the final consumer. While the terminology might be of recent origin, the needs and related processes are as ancient as the concept of the supply chain itself [2]. Over the past few decades, an unprecedented trend of digital transformation has emerged in the realm of supply chain management. Technologies such as artificial intelligence [3], machine learning [4], the internet of things [5], advanced analytics [6], and blockchain [6] have individually and collectively disrupted traditional business models across various sectors. More importantly, they have reshaped the mechanisms of supply chain operations. Despite the significant potential of digital transformation, its application varies notably across industries and regions [7]. For instance, the retail industry has undergone a transformation that leaves it unrecognizable compared to its state in the 1990s [8], while other sectors, such as the pharmaceutical industry, have adopted digital advancements at a comparatively slower pace.

Digital transformation within the pharmaceutical industry has initially unfolded through the digitization of documents and processes [9]. This change began as grassroots initiatives undertaken at the individual level, without a centralized orchestrator. The transformation first affected manufacturers, distributors, and hospitals, all key entities involved in the production, transportation, and consumption of pharmaceutical products. Digitization has enhanced efficiency and reduced costs across the industry, enabling more agile and swift responses to requests [10]. However, the fundamental business model and inter-entity relationships within the industry have remained largely unaltered. Specifically, the industry landscape continues to be dominated by a small number of large manufacturers possessing exclusive intellectual property. In contrast, there is a larger pool of distributors, retailers, hospitals, and medical centers, which consume these pharmaceutical products. This imbalance is not only reflected in the number of players but also in terms of data concentration. This data concentration subsequently necessitates a trust-based data query approach, wherein the validity of data can only be checked against the ledgers of the buyer and seller. Regulators are typically provided with derived or secondary data. Such a process disadvantages other stakeholders whose interests are embedded within these transactions. Accessing data involves a prolonged process of data requests, waiting periods, and uncertainty surrounding responses. This issue represents a key challenge that needs addressing in the ongoing digital transformation of the pharmaceutical industry.

This issue of information access imbalance is not confined to the pharmaceutical sector; it is also pervasive within banking and finance industries. As a remedy, the banking sector has suggested deploying a dedicated third-party entity to verify transactions. However, this strategy presents a new challenge, specifically, the added

Permission to make digital or hard copies of all or part of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. Copyrights for components of this work owned by others than the author(s) must be honored. Abstracting with credit is permitted. To copy otherwise, or republish, to post on servers or to redistribute to lists, requires prior specific permission and/or a fee. Request permissions from permissions@acm.org.
ASSE 2023, October 27–29, 2023, Aizu-Wakamatsu City, Japan
© 2023 Copyright held by the owner/author(s). Publication rights licensed to ACM.
ACM ISBN 979-8-4007-0853-4/23/10…$15.00
https://doi.org/10.1145/3634814.3634832

financial burden on the participants involved in the process [11]. This predicament is ubiquitous in any traditional industry that operates based on peer-to-peer verification systems. Amidst these scenarios, blockchain has emerged as a cost-effective and scalable technology. It promotes transparency and serves to equalize data imbalances, thereby addressing this systemic issue. Blockchain is a decentralized, distributed ledger technology that securely records data across numerous computers globally. Its main advantages in promoting transparency include its decentralized nature, ensuring no single point of failure or control; its immutability, creating an unalterable, permanent record of transactions; and its transparency, allowing all participants to trace and verify transactions. Furthermore, it ensures high-level security through cryptographic algorithms and fosters a trustless system where participants don't need to trust each other, but instead rely on the system's protocol. The inherent characteristics of blockchain technology make it an ideal solution to promote cost-effective transparency, particularly within the pharmaceutical industry. Firstly, pharmaceutical products significantly impact consumer health and well-being, thus necessitating an additional layer of transparency. Secondly, these products require meticulous handling, given factors like expiration dates and the nuances of distribution and delivery processes. Here, blockchain's traceability proves to be highly beneficial. In unfortunate instances where product malfunctions necessitate a recall, this traceability becomes vital in identifying and retracting the specific items quickly and accurately. Lastly, because the data is stored across distributed nodes, it is highly resistant to alterations and resilient against potential natural disasters.

While the pharmaceutical industry is indeed recognized as high-stake, its adoption of blockchain technology has been comparatively hesitant. The majority of research has primarily analyzed the potential applications, benefits, and drawbacks of blockchain in this industry, without extending to concrete solution development. For instance, Uddin, Salah, Jayaraman, Pesic and Ellahham [12] and Tseng, Liao, Chong and Liao [13] both concurred that blockchain is ideally suited for drug traceability and regulatory management. However, neither study elaborated on these ideas to develop tangible solutions. The pharmaceutical industry in Vietnam mirrors global trends with its integration of advanced technologies into supply chain management. However, the state of reporting transparency and traceability is strikingly similar to international practices. Fragmented applications of digitalization technologies by individual stakeholders are commonplace, and a clear lack of guidelines or a central orchestrator to effectively manage the process is evident. Additionally, the demand for transparency in the logging of pharmaceutical products is higher than ever, driven by three significant factors. First, the government's ongoing recognition of the stakes involved with pharmaceutical products has led to the enactment of numerous regulations on manufacturing and distribution since 2010. Second, in the post-COVID era, the necessity for preemptive monitoring of pandemic risks and pharmaceutical inventory has been underscored, thereby heightening the need for centralized public management of such products. Third, multiple instances of pharmaceutical product recall due to defects have intensified the call for a more efficient logging system. This system would ideally operate with a higher frequency and grant broader access to a larger pool of stakeholders, potentially extending to end consumers. Such advancements would enhance the traceability of pharmaceutical products, contributing to safer practices and outcomes within the industry.

Consequently, this article aims to bridge the gap between the identified need for enhanced transparency in the pharmaceutical industry and the provision of a viable solution. It proposes a workflow for end-to-end inclusion and presents a simulation of a minimum viable product (MVP). This initiative leverages the untapped potential of blockchain technology to enhance transparency and traceability within Vietnam's pharmaceutical industry. In doing so, we aim to illuminate a path forward that harnesses the unique capabilities of blockchain, moving closer to realizing its full benefits within this critical sector. Emerging from a recognized need within the National Hospital of Endocrinology in Vietnam, the application was developed to connect relevant stakeholders throughout the supply chain. Records detailing the different stages that pharmaceutical products pass through are logged into a centralized Microsoft SQL Server database. Selected information from these records is then uploaded to a blockchain network to enhance traceability and transparency. To assess the viability of the application, a rigorous testing strategy was devised and implemented. The following sections will detail the architect of this application and outline the approach used to evaluate its effectiveness.

2 METHODOLOGY

2.1 Solution Architect's Decision

The choice of MS SQL Server as a backend database management system for the PharmaFlow application is influenced by several key considerations. MS SQL Server is an enterprise-grade relational database management system (RDBMS) that offers robustness, flexibility, and high performance. Its strength lies in its ability to manage large volumes of data while maintaining speed and efficiency. It supports a wide range of operations, including complex queries and transactions, making it suitable for handling intricate processes and data flows of a pharmaceutical supply chain. Security is also a strong suit for MS SQL Server. It offers solid data encryption and robust user access controls, making it an optimal choice for handling sensitive healthcare data. Moreover, MS SQL Server provides excellent scalability, which is crucial for an expanding application like PharmaFlow. It can easily handle an increasing dataset and the growth in user numbers. Additionally, MS SQL Server is backed by Microsoft, ensuring professional support and abundant online resources for troubleshooting, which contributes to the smooth operation of the PharmaFlow application.

Looking to the future, PharmaFlow should consider transitioning to a cloud-based database solution. The benefits of cloud computing, including cost-effectiveness, scalability, accessibility, and disaster recovery capabilities, make it an attractive proposition. Notably, cloud services offer on-demand resources, allowing PharmaFlow to scale up or down based on demand, leading to efficient resource utilization and cost savings. Several cloud-based database solutions could fit PharmaFlow's needs. Microsoft Azure SQL Database, a cloud version of MS SQL Server, offers the familiarity of the MS SQL Server with the advantages of a cloud-based service. Amazon RDS for SQL Server is another strong candidate, providing the robust capabilities of Amazon's cloud infrastructure. Google Cloud SQL is

also a viable option, offering seamless integration with other Google Cloud services. Each of these solutions has its unique strengths, and the choice would depend on PharmaFlow's specific requirements and future growth strategies.

On the other hand, ASP.NET was chosen as the front-end programming framework due to its vast capabilities and benefits. Developed by Microsoft, ASP.NET is an open-source, server-side web application framework that allows for the creation of dynamic web pages. It offers a rich toolbox and designer in the Visual Studio integrated development environment, simplifying the process of application design and development. One of the principal advantages of ASP.NET is its high performance [14]. It is compiled rather than interpreted, making it faster than scripting languages. Also, ASP.NET is language-independent, meaning developers can choose the language they are most comfortable with or that is best suited to the application requirements [15]. ASP.NET supports three distinct development models (MVC, Web Pages, and Web Forms), which offer flexibility in meeting specific application needs. Its in-built Windows authentication and per-application configuration ensure the application's security and robustness. Moreover, ASP.NET is supported by Microsoft, ensuring regular updates, vast libraries, and ongoing support for developers.

Building on ASP.NET's capabilities, the Model-View-Controller (MVC) pattern was chosen for the development of the PharmaFlow application. MVC is a design pattern that separates an application into three interconnected components, promoting clean architecture and organized code. The Model component corresponds to all the data-related logic that a user works with. This can represent either the data being transferred between the View and Controller components or any other business logic-related data. Implementing the MVC pattern offers several advantages. It provides full control over the application's behavior compared to the traditional event-driven development approach. It also supports asynchronous technique, which helps developers to develop fast-loading applications. Lastly, MVC allows for efficient code reusability and parallel development, since the separation of components allows developers to work on individual components without affecting the overall application.

The strategic choice of MySQL and ASP.NET for developing the PharmaFlow application reflects an essential balance between illustrating a concept effectively and emulating real-world scenarios. MySQL, chosen for the backend, offers a robust and scalable database management system that aligns closely with real-world enterprise architecture. Its capabilities in handling large datasets, executing complex queries, and maintaining speed and efficiency make it an excellent fit for the complex and data-intensive operations of a pharmaceutical supply chain. Meanwhile, ASP.NET serves as the frontend framework, chosen for its rich development environment and fast, flexible development capabilities. While ASP.NET may not be universally used in real-world applications, its ability to create dynamic web pages quickly, along with its high performance and security, make it a valuable tool for this demonstration project. The combined strengths of MySQL and ASP.NET provide a comprehensive, efficient, and reliable platform that effectively showcases the potential of blockchain technology in enhancing transparency and traceability in the pharmaceutical industry. This demonstration acts as a stepping stone towards more sophisticated, scalable, and integrated solutions in the future.

2.2 Blockchain Integration

One of the distinguishing features of PharmaFlow is its integration of blockchain technology. This revolutionary advancement in the digital landscape is well-recognized for its transformative potential in promoting transparency, traceability, and data security. The application of blockchain technology in PharmaFlow empowers end users with the ability to independently verify the integrity and transparency of the entire workflow. It ensures that every step in the pharmaceutical product's journey is captured, permanently recorded, and made readily available for review. This feature is of paramount importance in the pharmaceutical industry where accountability and traceability are crucial.

Blockchain's innate characteristic of being an immutable and decentralized ledger aligns perfectly with the objectives of PharmaFlow. Every step in the pharmaceutical product's lifecycle is meticulously recorded and permanently stored on the blockchain. This leads to a comprehensive, tamper-proof trail of information that can be audited at any point in time, thereby enhancing transparency and instilling a heightened level of trust among all stakeholders. By employing cryptographic principles, PharmaFlow ensures the security of the data, thereby preventing any unauthorized alterations or access, adding another layer of credibility to the process.

PharmaFlow, by opting for BigchainDB for blockchain integration and hosting it on localhost, reaps numerous advantages for our purpose of simulating interactions within a blockchain network. BigchainDB is a distributed database with blockchain characteristics that include decentralization, immutability, and native asset support. This makes it an ideal choice for establishing a proof-of-concept model where we want to emulate blockchain functionality without deploying a full-fledged blockchain. As a localhost, it also provides a controlled environment, facilitating easier debugging and testing processes. The ability to ensure data integrity and transparent transactions via BigchainDB makes it an attractive choice for this application. It also demonstrates how blockchain technology can help facilitate supply chain management processes such as traceability and verification.

However, it's essential to note that this choice of BigchainDB and localhost isn't without its limitations and is specifically designed for simulation purposes. The usage of localhost restricts the blockchain network to a single machine, which doesn't fully capture the decentralized nature of real-world blockchain applications. Additionally, BigchainDB might not be suitable for large scale production environments that require high data processing capabilities. In a real-world scenario, we would likely use a mainnet of a popular blockchain platform, such as Ethereum or Hyperledger Fabric. These platforms provide the decentralization, security, scalability, and robustness needed for complex, real-world operations. Alternatively, the architecture might take the form of a private network of blockchain nodes that only connects relevant supply chain stakeholders, providing data duplication for external query requests. This approach maintains the integrity and privacy of the data while still promoting transparency and accessibility.

Figure 1: Business Process Flow Chart

2.3 Business Process Proposal

PharmaFlow is an application designed to provide comprehensive and seamless management of various supply chain processes, offering a robust and interconnected workflow to effectively meet the needs of its users. The workflow begins with the Product Management function where users can add, delete, or edit product lists. This ensures all product details are meticulously recorded and updated, providing a strong foundation for subsequent steps. Following this, the Manufacturing Process Management function utilizes information from the product lists to manage and update the status and quantity of products manufactured. This plays a critical role in accurately tracking production details, marking an important step in the supply chain.

The workflow continues with the Transport Process Management function which comes into play once the manufacturing process is completed. Data, including product type and quantity, is pushed by manufacturing users to specific transporters. Users assigned the transport process roles then take charge, updating and maintaining the statuses of shipments. Following the transport stage, the Distribution Process Management function receives data from the previous step, allowing distribution users to monitor these records and update the status of distribution accordingly. The final stages include the Accreditation Process Management function, which verifies the data after distribution is completed. If checked results align with expectations, the data is uploaded to BigChainDB; otherwise, it is logged as 'Failed'. The application culminates its comprehensive workflow with the Verification process. Here, users can scan QR codes to verify product records on BigChainDB, displaying either a 'verification success' or 'verification failed' message based on the match. In essence, PharmaFlow showcases a strong commitment to maintaining transparency, traceability, and efficiency throughout each stage of the supply chain process.

With the unique combination of a well-thought-out workflow and the strength of blockchain technology, PharmaFlow successfully creates an environment where traceability is not just a concept but a reality. From verifying the source of raw materials used in manufacturing to tracking the final distribution of the pharmaceutical product, every single transaction can be traced, verified, and audited. This level of transparency serves to promote greater accountability among stakeholders, improve regulatory compliance, and significantly mitigate the risk of counterfeiting and other fraudulent practices in the industry. It contributes to fostering a culture of transparency and trust in the sector.

3 RESULT

To evaluate PharmaFlow's functionality, the authors executed a comprehensive series of tests, utilizing both black-box and white-box testing strategies. The black box testing strategy was primarily employed to verify PharmaFlow's functionality against the stated requirements. The test results were then utilized to finetune the program.

Once the comprehensive black-box testing phase was complete, the process transitioned into the white-box testing phase. In this phase, the authors delved into the internals of the program, creating test cases based on its internal structure. The main objective during this phase was to confirm that the system could function efficiently under stress and to optimize the code base accordingly. A comprehensive test case system was devised to test the functionality of PharmaFlow:

Table 1: Test Case Summary

No	Testing Area	Number of cases
1	Unit Test	2
2	Integration Evaluation	9
3	System Examination	12
4	Functional Validation	11
5	Edge Cases Assessment	5
6	Interface Evaluation	4
7	Compatibility Check	9
8	Performance Analysis	5
9	Data Inspection	16

- In the **unit testing** phase, cases were designed to test the system's ability to handle new admin account creations with both valid and duplicate information, focusing on its ability to respond appropriately to each situation.
- During the **integration testing** phase, various aspects of user interaction with the system were tested. This included account creation and login, product search, viewing product catalogs and details, and testing different management functionalities such as consignment, product, and process management.
- The **system testing** phase aimed to ensure the security and efficiency of the system. Test cases were created to check the robustness of the login process, the two-factor and email-based authentication mechanisms, the system's response times, and its load-handling capacity. Also, the consistency, responsiveness, and accessibility of the user interface were evaluated.
- **Functionality testing** focused on testing links, product viewing capabilities, quality control, random code generation and stamp printing, as well as internal and product traceability. It also examined how the system handles problem situations.
- In the **interface testing** phase, the connections between the application, web server, and database server were evaluated to ensure smooth and seamless communication.
- **Compatibility testing** checked the system's functionality across a variety of browsers such as Chrome, Microsoft Edge, Coc Coc, Safari, and Internet Explorer, and devices including computers, laptops, MacBooks, and tablets.
- The **performance testing** phase evaluated the system's ability to load pages and server responses on both mobile and computer platforms, as well as its load capacity, stability, and compatibility across various mobile devices.
- Finally, the **data testing** phase evaluated the processing and management of product and procedure data, with a focus on the active box and consignment management data.

These exhaustive tests were aimed at ensuring that PharmaFlow not only met the functional requirements but also performed optimally across a range of platforms, devices, and user scenarios.

These exhaustive tests were aimed at ensuring that PharmaFlow not only met the functional requirements but also performed optimally across a range of platforms, devices, and user scenarios. The successful completion of all test cases demonstrates the robustness and reliability of PharmaFlow, paving the way for its deployment in real-world scenarios. This comprehensive testing phase has ensured that PharmaFlow can deliver a seamless experience to its users while maintaining the highest levels of data security and operational efficiency.

4 CONCLUSION

The research discussed in this study offers an in-depth examination of the existing landscape of supply chain management within the pharmaceutical industry, with a focus on the transformative potential and persisting challenges of digital advancements. A specific emphasis was placed on the potential application of blockchain technology in addressing a key issue in this sector - information access imbalance.

Throughout the research, we have proposed and explored a practical use case for blockchain technology within the Vietnamese pharmaceutical industry. The development of an application, designed to enhance transparency and traceability of pharmaceutical products, has highlighted the potential of blockchain. The implemented process involves logging critical product information into

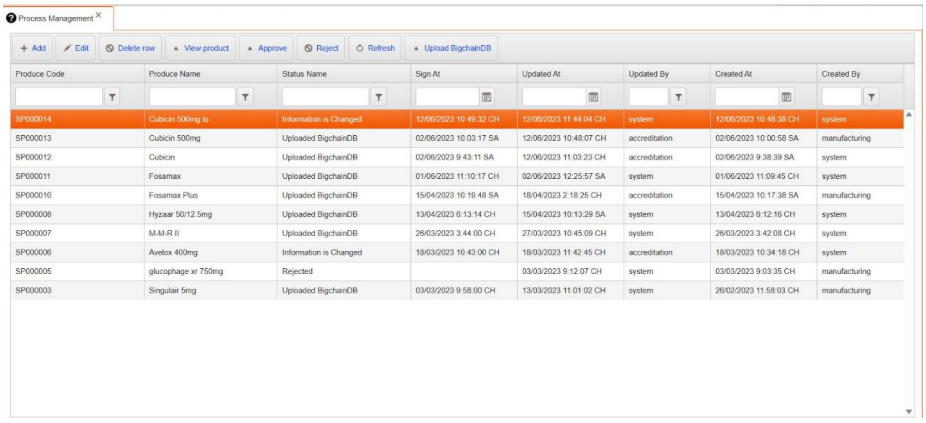

Figure 2: Product Management Interface

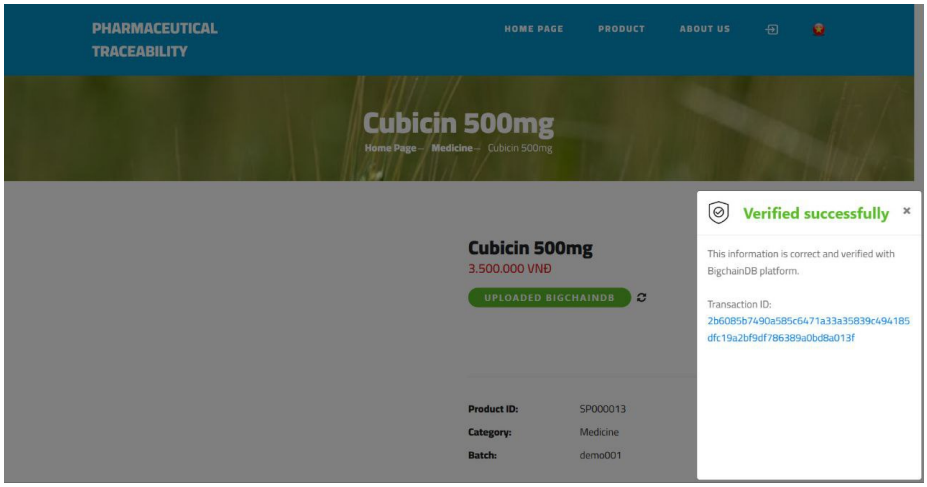

Figure 3: Verification Success Screen

a centralized MS SQL database, followed by the selection and uploading of crucial data to a blockchain network. This application allows the logged information to become immutable, verifiable, and accessible, offering enhanced accountability and streamlined responses to potential product issues.

The viability of this application was extensively tested, yielding promising results that validate the potential of blockchain technology in this context. However, the journey towards seamless integration and wider adoption is not without its challenges. As the incorporation of blockchain technology within the industry is still in its early stages, future work will need to address technical and regulatory hurdles, advocate for broader understanding and acceptance of the technology, and ensure interoperability with existing systems.

Looking forward, this research aims to stimulate further exploration and adaptation of blockchain technology not only within the pharmaceutical industry, but in all sectors where enhanced traceability and transparency are of paramount importance. Although the present application serves as a viable model for small-scale operations, the quest for scalable solutions that cater to larger networks remains a future endeavor. This endeavor includes the integration of diverse technological platforms among stakeholders, along with the development of a user-friendly query system to allow end-users access to critical data.

In summary, this study has underlined the potential of blockchain technology in addressing a longstanding challenge in the pharmaceutical industry - the imbalance in information access. While it has demonstrated the implementation of blockchain technology in a practical, small-scale use case, it also opens avenues for its expansion and integration into larger, more complex systems. As digital transformation continues to reshape industries globally, the integration of blockchain technology into supply chain management promises more efficient, resilient, and transparent systems, presenting a promising horizon for the future.

REFERENCES

[1] Stadtler, H. Supply chain management: An overview. *Supply chain management and advanced planning: Concepts, models, software, and case studies* (2014), 3-28.
[2] Lummus, R. R. and Vokurka, R. J. Defining supply chain management: a historical perspective and practical guidelines. *Industrial management & data systems* (1999).
[3] Min, H. Artificial intelligence in supply chain management: theory and applications. *International Journal of Logistics: Research and Applications*, 13, 1 (2010), 13-39.
[4] Tirkolaee, E. B., Sadeghi, S., Mooseloo, F. M., Vandchali, H. R. and Aeini, S. Application of machine learning in supply chain management: a comprehensive overview of the main areas. *Mathematical problems in engineering*, 2021 (2021), 1-14.
[5] Ben-Daya, M., Hassini, E. and Bahroun, Z. Internet of things and supply chain management: a literature review. *International Journal of Production Research*, 57, 15-16 (2019), 4719-4742.
[6] Rozados, I. V. and Tjahjono, B. *Big data analytics in supply chain management: Trends and related research*. City, 2014.
[7] Garay-Rondero, C. L., Martinez-Flores, J. L., Smith, N. R., Morales, S. O. C. and Aldrette-Malacara, A. Digital supply chain model in Industry 4.0. *Journal of Manufacturing Technology Management*, 31, 5 (2020), 887-933.
[8] Chaffey, D., Edmundson-Bird, D. and Hemphill, T. *Digital business and e-commerce management*. Pearson UK, 2019.
[9] Finelli, L. A. and Narasimhan, V. Leading a digital transformation in the pharmaceutical industry: reimagining the way we work in global drug development. *Clinical pharmacology & therapeutics*, 108, 4 (2020), 756-761.
[10] Loonam, J., Eaves, S., Kumar, V. and Parry, G. Towards digital transformation: Lessons learned from traditional organizations. *Strategic Change*, 27, 2 (2018), 101-109.
[11] Scott, S. V., Van Reenen, J. and Zachariadis, M. The long-term effect of digital innovation on bank performance: An empirical study of SWIFT adoption in financial services. *Research Policy*, 46, 5 (2017), 984-1004.
[12] Uddin, M., Salah, K., Jayaraman, R., Pesic, S. and Ellahham, S. Blockchain for drug traceability: Architectures and open challenges. *Health informatics journal*, 27, 2 (2021), 14604582211011228.
[13] Tseng, J.-H., Liao, Y.-C., Chong, B. and Liao, S.-w. Governance on the drug supply chain via gcoin blockchain. *International journal of environmental research and public health*, 15, 6 (2018), 1055.
[14] Al-Ghrairi, A. H. T., Mohammed, A. A. and Saeed, H. M. An Application of Web-based E-Healthcare Management System Using ASP. Net. *Webology*, 18, 1 (2021).
[15] Amadin, I. and Nwelih, E. An Empirical Comparison Of: HTML, PHP, COLDFUSION, PERL, ASP .NET, JAVASCRIPT, VBSCRIPT, PYTON AND JSP. *Global Journal of Computer Science and Technology*, 10, 12 (2010), 9-17.