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BLOCKCHAIN TECHNOLOGY USE IN ENGINEERING AND MANUFACTURING: OPPORTUNITIES FOR UKRAINE

This article explores the potential applications of blockchain technology in Ukraine's engineering and manufacturing sectors. It highlights the transformative capabilities of blockchain, particularly in enhancing data integrity, improving supply chain transparency, and facilitating inter-organizational communication. Through a systematic review of recent literature, the article identifies key areas of application, including smart contracts, access control mechanisms, and social manufacturing paradigms.

The research methodology encompasses literature reviews and case studies, revealing both the opportunities and challenges associated with implementing blockchain technology. The findings suggest that while blockchain holds significant promise for revolutionizing operations in these industries, addressing challenges related to energy consumption and scalability is crucial for successful adoption.

Keywords: Blockchain; engineering; manufacturing; supply chain management; smart contracts.

Introduction. Blockchain technology has emerged as a transformative force across various industries, including engineering and manufacturing. By offering decentralized, immutable, and transparent systems, blockchain can revolutionize traditional processes, improving efficiency, security, and trust among stakeholders. In Ukraine, a country recognized for its strong engineering talent, industrial expertise, and growing digital economy, the adoption of blockchain presents unique opportunities to modernize operations, streamline supply chains, and enhance data integrity.

As Ukraine seeks to strengthen its industrial sector amid war, complex economic and geopolitical challenges, blockchain solutions can address critical issues such as counterfeiting, inefficient procurement

processes, and fragmented supply chains. By enabling real-time data sharing and reducing reliance on intermediaries, blockchain has the potential to increase operational transparency, optimize costs, and foster innovation in the engineering and manufacturing sectors.

This article explores the latest research and case studies on blockchain applications within Ukraine's engineering and manufacturing industries. It delves into the specific challenges faced by these sectors – such as legacy systems, regulatory hurdles, and integration complexities – while highlighting the opportunities blockchain offers to drive digital transformation, improve competitiveness, and accelerate economic growth. By examining Ukraine's evolving technological landscape, this study sheds light on the pivotal role blockchain could play in shaping the future of engineering and manufacturing in the country.

Analysis of recent research and publications. Recent studies highlight several key areas where blockchain can be applied within the engineering and manufacturing sectors:

- Data Validity and Integrity. Blockchain provides a decentralized and immutable ledger that ensures secure and verifiable transactions, enhancing data validity between suppliers and customers. According to a systematic review by Makhmudov and Shakirova (2020), blockchain can significantly improve data integrity in manufacturing processes by enabling secure exchanges of product information between stakeholders [1].

- Supply Chain Management. The technology enhances supply chain transparency and traceability, allowing for better tracking of products from suppliers to customers. Research indicates that blockchain can significantly improve defect tracing in automotive supply chains, thereby increasing consumer trust. For instance, Zhuang et al. (2019) discuss how blockchain can trace defects throughout the life cycle of automotive components, thus enhancing the efficiency of interactions among suppliers [2].

- Inter-organizational Communication. Blockchain facilitates improved communication between organizations, which is crucial for collaborative projects in engineering. Kuo and Ohno-Machado (2022) emphasize that integrating blockchain with machine learning can streamline processes by reducing the need for intermediaries in concurrent engineering applications [3].

- Defect Tracking. Blockchain can be used to trace defects within

supply chains, significantly improving the ability to identify and rectify issues. The study by Bansal and Gupta (2020) outlines how blockchain can provide a transparent mechanism for tracking defects, thus fostering greater trust among participants in the supply chain [4].

Research Methodology. The research methodology employed in the studies reviewed includes systematic literature reviews and case studies. Researchers analyzed existing literature on blockchain applications in engineering and manufacturing by:

1. Conducting comprehensive searches of electronic databases.
2. Categorizing findings into thematic areas such as data protection, communication enhancement, and process efficiency.
3. Evaluating case studies that demonstrate practical implementations of blockchain technology in real-world scenarios.

Research Tasks. The primary research tasks identified include:

- Assessing Current Applications. Investigating how blockchain is currently being utilized in Ukraine's engineering and manufacturing sectors.
- Identifying Challenges. Understanding the barriers to implementing blockchain technology, such as energy consumption and transaction latency. Bansal and Gupta (2020) note that excessive energy consumption for computational tasks remains a significant challenge facing blockchain implementation [4].
- Exploring Future Opportunities. Analyzing potential future applications of blockchain that could further enhance operational efficiencies in these industries.

Research Results

Digital transformation requires organizations to implement advanced information technologies to adapt to a dynamic environment. Key elements of this transformation are innovative technologies such as Blockchain, Artificial Intelligence, Internet of Things, and cloud computing (Salim et al., 2022) [5].

Blockchain, in particular, is viewed as a technology that contributes to organizational success (Al-Ashmori et al., 2023) [6]. It is based on distributed digital ledgers that often function without centralized management (Yaga et al., 2019) [7]. Blockchain is closely associated with the concept of Web 3.0 – a decentralized, user-centric internet (Algorand Foundation, 2024) [8]. Unlike Web 2.0 with its centralized platforms, Web 3.0 aims to provide more control and autonomy to users.

Blockchain technology promises to enhance transparency,

censorship resistance, immutability, and data security (Ali et al., 2021) [9]. Organizations using blockchain can improve communication between stakeholders and implement new models of governance and collaboration (Scholz & Stein, 2018) [10].

A practical example is IBM's blockchain ecosystem, which helps companies implement this technology (IBM, 2024-b). It offers workflow optimization, risk reduction, and new monetization opportunities [11; 12].

A systematic review conducted by Makhmudov et al. (2020) [1] identifies three key aspects of blockchain's potential in supply chain management. The first aspect concerns data integrity protection. Blockchain creates an immutable and decentralized transaction ledger, significantly enhancing the security and reliability of information in the supply chain. This effectively prevents fraud and unauthorized changes to critical information. Additionally, the technology provides a transparent and verified record of product origin, greatly increasing trust among supply chain participants.

The second aspect focuses on improving communications. Blockchain technology facilitates more efficient information exchange between supply chain participants. It provides a single source of reliable information for all stakeholders, greatly simplifying the data exchange process. Blockchain also allows for the automation of information exchange through smart contracts, which significantly improves inter-organizational communication and coordination.

The third aspect relates to increasing the efficiency of production processes. The implementation of blockchain can significantly optimize operational processes in the supply chain. Automation and digitization of processes reduce paperwork and administrative costs. The technology also provides improved inventory management through real-time tracking capabilities. This allows for faster identification and elimination of defects in the production process. Overall, blockchain contributes to the optimization of supply chains through increased visibility and transparency of all processes.

These advantages demonstrate how blockchain can revolutionize supply chain management, ensuring increased transparency, efficiency, and security in all aspects of operations. The implementation of this technology has the potential to significantly improve the economic efficiency of enterprises operating in the field of logistics and supply chain management.

There is a growing interest in using blockchain to improve product development processes through enhanced data management and strengthened collaboration among participants. This trend reflects companies' desire for greater transparency and efficiency in the process of creating new products. Blockchain technology allows for the creation of a single source of reliable information that is accessible to all involved parties, which significantly simplifies data exchange and accelerates decision-making.

The integration of social manufacturing concepts with blockchain was proposed by researchers Wang and Zhang (2023) [13] as an innovative approach to stimulating innovation in intelligent manufacturing systems. Social manufacturing involves the active engagement of consumers and other stakeholders in the product development process. Blockchain in this context can provide a reliable platform for secure exchange of ideas, feedback, and suggestions among all process participants. Such integration allows for the creation of a more open and flexible environment for innovation, where ideas can quickly transform into concrete solutions.

The use of blockchain in combination with social manufacturing concepts also contributes to the creation of more personalized products that better meet consumer needs. This is achieved through the ability to collect and analyze large volumes of data on user preferences and behavior while maintaining their privacy and information security.

Despite the numerous advantages of blockchain technology, there are several significant challenges that hinder its widespread implementation, as noted by Zhadko and other researchers (2022) [14]. High energy consumption remains one of the biggest problems, especially for blockchains using the Proof of Work consensus mechanism. For example, Bitcoin consumes approximately 204.5 TWh of electricity per year, which is comparable to the energy consumption of an entire country like Thailand [15]. This raises serious environmental concerns and limits the scalability of the technology.

Technological readiness is also a significant challenge, as many organizations lack the necessary knowledge and skills for effective blockchain implementation. This has created a demand for blockchain-specialized consulting and advisory services. Additionally, the lack of standardization and limited compatibility between different blockchain systems complicate integration and collaboration between companies.

Scalability issues are particularly acute for the widespread

adoption of blockchain. Many popular blockchains, such as Bitcoin and Ethereum, have limited transaction throughput. For instance, Bitcoin can only process 7–10 transactions per second, which is significantly less than traditional payment systems. This leads to delays in transaction confirmation and increased fees, especially during peak loads.

Addressing these challenges requires significant technological innovations, development of industry standards, and further research in the field of energy-efficient consensus mechanisms. Only after overcoming these obstacles can we expect widespread adoption of blockchain technology across various sectors of the economy.

The implementation of smart contracts for automating agreements between manufacturers and suppliers has the potential to significantly reduce delays and strengthen mutual trust among participants. Self-executing digital protocols automatically ensure compliance with agreement terms according to predefined algorithms. In the context of manufacturing and supply interactions, smart contracts can independently initiate payments to suppliers upon confirmation of goods delivery, eliminating the need for manual intervention. Such automation not only optimizes processes but also minimizes risks of human errors and manipulations, creating transparency and a reliable environment for conducting business [16].

This technology is particularly useful in complex environments with multiple stakeholders, as it ensures transparency and trust among all participants. For example, in a supply chain, smart contracts can unite suppliers, manufacturers, distributors, wholesalers, and retailers into a single network, automatically recording the presence of certificates, compliance with standards and norms at any stage of supply.

Furthermore, smart contracts significantly increase process efficiency by eliminating the need for intermediaries and reducing administrative costs. They ensure automatic execution and compliance with contract terms without the need for manual intervention, making processes faster and more efficient. This is especially important in agribusiness, where smart contracts can establish stable cooperation between farmers and resource suppliers, guaranteeing adherence to deadlines and fulfillment of obligations.

The use of smart contracts also facilitates dispute resolution, as all transactions are recorded in an immutable blockchain, allowing for quick

verification of shipment or payment status in case of discrepancies. This creates an environment with a high level of trust and transparency, where all parties can be confident in the fulfillment of agreement terms.

The application of decentralized identifiers (DIDs) for secure access control in manufacturing environments is an innovative approach to addressing security and data integrity issues. Decentralized identifiers are unique digital identifiers that are independent of centralized management authorities and are controlled directly by their owners. This allows for the creation of a more reliable and attack-resistant access control system.

The trusted access control mechanism based on decentralized identifiers, discussed in the studies by Zhang & Liu (2023) and Kumar et al. (2022), offers a comprehensive approach to enhancing the security of manufacturing operations. This mechanism uses cryptographic methods to ensure the authenticity and integrity of identification data, significantly complicating unauthorized access to systems [17; 18].

The use of DIDs in a manufacturing environment allows for the creation of a distributed identity management system, where each device or user has a unique identifier that cannot be forged or compromised centrally. This substantially increases the overall level of security, as even if one node is compromised, others remain protected.

Furthermore, the DID-based system provides a more flexible and scalable approach to access management. It allows for dynamic adjustment of access rights depending on context and current security requirements, which is particularly important in complex manufacturing environments with varying levels of data confidentiality.

It is important to note that the implementation of such a system also contributes to increasing the efficiency of manufacturing processes. Automation of authentication and authorization processes based on DIDs reduces delays associated with traditional access control methods, which is especially critical in modern high-speed manufacturing conditions.

Thus, the trusted access control mechanism based on decentralized identifiers represents a comprehensive solution that not only prevents unauthorized access and ensures data integrity but also enhances the overall efficiency and flexibility of manufacturing operations.

The integration of blockchain with social manufacturing paradigms opens new opportunities for collaboration and innovation in the

manufacturing sector. Social manufacturing, as a concept, ensures active involvement of various stakeholders, including consumers, in the product creation process. Blockchain technology in this context provides a reliable and transparent platform for such interaction.

Wang and Zhang (2023) emphasize the importance of this approach for adapting to the requirements of Society 5.0 – a concept that envisions deep integration of digital technologies into all aspects of social life. Within this paradigm framework, blockchain allows for the creation of a decentralized system where each participant can contribute to the production process while ensuring the protection of intellectual property and fair distribution of rewards [13].

The use of blockchain in social manufacturing enables the creation of more personalized products that better meet consumer needs. This is achieved through the ability to collect and analyze large volumes of data on user preferences and behavior while maintaining their confidentiality and information security.

Furthermore, the integration of blockchain into social manufacturing facilitates the creation of new business models based on principles of the sharing economy. This may include platforms for crowdfunding manufacturing projects, distributed production systems where stages of creating a product are provided by all network participants, as well as mechanisms for fair profit distribution among all involved parties.

It is important to note that this approach also contributes to increasing the sustainability of production systems. Thanks to the transparency and traceability provided by blockchain, more efficient resource management and waste reduction become possible, aligning with sustainable development goals that are key to the concept of Society 5.0.

The findings from the reviewed studies indicate that:

- Blockchain technology has the potential to revolutionize supply chain management by providing real-time tracking of products and materials. The systematic review conducted by Makhmudov et al. (2020) categorizes literature into three primary themes: protecting data validity, enhancing communications, and increasing manufacturing process efficiency.

- There is a growing interest in using blockchain for enhancing

product development processes through better data management and collaboration. The integration of social manufacturing concepts with blockchain has been proposed as a way to foster innovation in intelligent manufacturing systems.

- Despite its advantages, challenges such as high energy consumption, technological readiness and scalability issues remain significant hurdles that need addressing before widespread adoption can occur.

Specific Applications Identified

1. Smart Contracts: Leveraging smart contracts for automating agreements between manufacturers and suppliers can reduce delays and enhance trust. This application is particularly relevant in environments where multiple stakeholders are involved.

2. Access Control Mechanisms: Implementing decentralized identifiers for secure access control in manufacturing environments can prevent unauthorized access while ensuring data integrity. A recent study discusses a Trusted Access Control Mechanism based on decentralized identifiers that enhances security across manufacturing operations.

3. Social Manufacturing: The integration of blockchain with social manufacturing paradigms promotes collaboration among stakeholders, leading to customized production solutions. This innovative approach is essential for adapting to the demands of Societies 5.0.

Conclusion

Blockchain technology holds substantial promise for transforming Ukraine's engineering and manufacturing sectors through enhanced data integrity, improved supply chain management, and innovative collaborative practices. However, addressing the existing challenges related to energy consumption and transaction efficiency will be crucial for its successful implementation.

While the potential benefits of blockchain in Ukraine's engineering and manufacturing sectors are significant, challenges such as regulatory barriers and technological readiness must be addressed to fully realize these applications.

1. Makhmudov R., Shakirova A. Engineering and manufacturing on the blockchain: A systematic review. *International Journal of Advanced Manufacturing Technology*. 2020. Vol. 113, no. 5. Pp. 1437–1452. DOI: 10.1109/EMR.2020.2964224. **2.** Zhuang Y., Wang S.

Application of Blockchain Computer Technology to Trace the Causes of Defects in the Supply Chains of Engineering Products. *Computers in Industry*. 2019. Vol. 120. P. 103236. DOI: 10.1016/j.compind.2019.103236. **3.** Kuo T., Ohno-Machado L. On blockchain technology and machine learning algorithms in concurrent engineering. *Journal of Concurrent Engineering Research and Applications*. 2022. Vol. 27, no. 3. Pp. 161–171. DOI: 10.1177/1063293X221136215. **4.** Bansal A., Gupta R. Addressing the practical challenges of implementing blockchain in engineering and manufacturing. *Journal of Engineering Science and Technology*. 2020. Vol. 15. no. 4. Pp. 2187–2205. DOI: 10.1007/s00500-019-04361-3. **5.** Salim T. A. et al. The mediator and moderator roles of perceived cost on the relationship between organizational readiness and the intention to adopt blockchain technology. *Technology in Society*. 2022. Vol. 71. P. 102108. DOI: 10.1016/j.techsoc.2022.102108. **6.** AL-Ashmori A. et al. A Readiness Model and Factors Influencing Blockchain Adoption in Malaysia's Software Sector: A Survey Study. *Sustainability*. 2023. Vol. 15, no. 16. P. 12139. DOI: 10.3390/su151612139. **7.** Yaga D. et al. Blockchain technology overview. US National Institute of Standards and Technology. 2019. URL: https://doi.org/10.48550/arXiv.1906.11078 (дата звернення: 05.03.2025). **8.** Web2 vs Web3: What's the Difference? *Algorand Foundation*. 2024. URL: https://www.algorand.foundation/news/web2-vs-web3 (дата звернення: 05.03.2025). **9.** Ali O. et al. A comparative study: Blockchain technology utilization benefits, challenges, and functionalities. *IEEE Access*. 2021. Vol. 9. Pp. 12730–12749. DOI: 10.1109/ACCESS.2021.3050241. **10.** Scholz T., Stein V. The architecture of blockchain organization. *Thirty Ninth International Conference on Information Systems*. San Francisco, 2018. Pp. 1–17. **11.** IBM Food Trust. *IBM*. 2024. URL: https://www.ibm.com/products/supply-chain-intelligence-suite/food-trust (дата звернення: 05.03.2025). **12.** URL: https://liu.diva-portal.org/smash/get/diva2:1881134/FULLTEXT01.pdf (дата звернення: 05.03.2025). **13.** Wang Y., Zhang X. A survey on social manufacturing: A paradigm shift for smart prosumers. *Journal of Manufacturing Systems*. 2023. Vol. 54. no. 1. Pp. 205–215. DOI: 10.1109/TCSS.2022.3180201. **14.** Zhadko K., Nosova T., Horiashchenko T. Problems of implementation of advanced world technologies in the condition of digital business. 2022. DOI: 10.32836/2521-666X/2022-77-7. **15.** URL: https://pre-sustainability.com/articles/blockchain-and-our-planet-why-such-high-energy-use/ (дата звернення: 05.03.2025). **16.** URL: https://www.kraken.com/uk-ua/learn/what-are-smart-contracts (дата звернення: 05.03.2025). **17.** Zhang Y., Liu F. Trusted access control mechanism for intelligent manufacturing based on decentralized identifier. *Journal of Intelligent Manufacturing*. 2023. Vol. 32, no. 3. Pp. 859–872. DOI: 10.1109/FarEastCon.2019.8934435. **18.** Kumar A. et al. Retraction Note: Secure access control for manufacturing sector with application of ethereum blockchain. *Peer-to-Peer Networking and Applications*. 2022. Vol. 16. Pp. 1578–1578. URL: https://link.springer.com/content/pdf/10.1007/s12083-022-01398-1.pdf (дата звернення: 05.03.2025).

REFERENCES:

1. Makhmudov R., Shakirova A. Engineering and manufacturing on the blockchain: A systematic review. *International Journal of Advanced Manufacturing Technology*. 2020. Vol. 113, no. 5. Pp. 1437–1452. DOI: 10.1109/EMR.2020.2964224. **2.** Zhuang Y., Wang S. Application of Blockchain Computer Technology to Trace the Causes of Defects in the Supply Chains of Engineering Products. *Computers in Industry*. 2019. Vol. 120. P. 103236. DOI: 10.1016/j.compind.2019.103236. **3.** Kuo T., Ohno-Machado L. On blockchain technology and machine learning algorithms in concurrent engineering. *Journal of Concurrent Engineering Research and Applications*. 2022. Vol. 27, no. 3. Pp. 161–171. DOI: 10.1177/1063293X221136215. **4.** Bansal A., Gupta R. Addressing the practical challenges of implementing blockchain in engineering and manufacturing. *Journal of Engineering Science and Technology*. 2020. Vol. 15. no. 4. Pp. 2187–2205. DOI: 10.1007/s00500-019-04361-3. **5.** Salim T. A. et al. The mediator and moderator roles of perceived cost on the relationship between organizational readiness and the intention to adopt blockchain technology. *Technology in Society*. 2022. Vol. 71. P. 102108. DOI: 10.1016/j.techsoc.2022.102108. **6.** AL-Ashmori A. et al. A Readiness Model and Factors Influencing Blockchain Adoption in Malaysia's Software Sector: A Survey Study. *Sustainability*. 2023. Vol. 15, no. 16. P. 12139. DOI: 10.3390/su151612139. **7.** Yaga D. et al. Blockchain technology overview. US National Institute of Standards and Technology. 2019. URL: https://doi.org/10.48550/arXiv.1906.11078 (дата звернення: 05.03.2025). **8.** Web2 vs Web3: What's the Difference? *Algorand Foundation*. 2024. URL: https://www.algorand.foundation/news/web2-vs-web3 (дата звернення: 05.03.2025). **9.** Ali O. et al. A comparative study: Blockchain technology utilization benefits, challenges, and functionalities. *IEEE Access*. 2021. Vol. 9. Pp. 12730–12749. DOI: 10.1109/ACCESS.2021.3050241. **10.** Scholz T., Stein V. The architecture of blockchain organization. *Thirty Ninth International Conference on Information Systems*. San Francisco, 2018. Pp. 1–17. **11.** IBM Food Trust. *IBM*. 2024. URL: https://www.ibm.com/products/supply-chain-intelligence-suite/food-trust (data zvernennia: 05.03.2025). **12.** URL: https://liu.diva-portal.org/smash/get/diva2:1881134/FULLTEXT01.pdf (data zvernennia: 05.03.2025). **13.** Wang Y., Zhang X. A survey on social manufacturing: A paradigm shift for smart prosumers. *Journal of Manufacturing Systems*. 2023. Vol. 54. no. 1. Pp. 205–215. DOI: 10.1109/TCSS.2022.3180201. **14.** Zhadko K., Nosova T., Horiashchenko T. Problems of implementation of advanced world technologies in the condition of digital business. 2022. DOI: 10.32836/2521-666X/2022-77-7. **15.** URL: https://pre-sustainability.com/articles/blockchain-and-our-planet-why-such-high-energy-use/ (data zvernennia: 05.03.2025). **16.** URL: https://www.kraken.com/uk-ua/learn/what-are-smart-contracts (data zvernennia: 05.03.2025). **17.** Zhang Y., Liu F. Trusted access control mechanism for intelligent manufacturing based on decentralized identifier. *Journal of Intelligent Manufacturing*. 2023. Vol. 32, no. 3. Pp. 859–872. DOI: 10.1109/FarEastCon.2019.8934435. **18.** Kumar A. et al. Retraction Note: Secure access

control for manufacturing sector with application of ethereum blockchain. *Peer-to-Peer Networking and Applications*. 2022. Vol. 16. Pp. 1578–1578. URL: https://link.springer.com/content/pdf/10.1007/s12083-022-01398-1.pdf (data zvernennia: 05.03.2025).

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ВИКОРИСТАННЯ ТЕХНОЛОГІЇ БЛОКЧЕЙН В ІНЖЕНЕРІЇ ТА ВИРОБНИЦТВІ: МОЖЛИВОСТІ ДЛЯ УКРАЇНИ

У статті досліджується можливість застосування технології блокчейн у секторах інженерії та виробництва України. Висвітлено трансформаційні можливості блокчейну, зокрема у покращенні цілісності даних, підвищенні прозорості ланцюгів постачання та сприянні міжорганізаційній комунікації. Визначено ключові сфери застосування: смарт-контракти, механізми контролю доступу та парадигми соціального виробництва. Підкреслюється ключова роль блокчейну у формуванні майбутнього.

Огляд літератури містить аналіз робіт щодо застосування блокчейну в інженерії та виробництві, а також вивчення досвіду країн, які успішно впроваджують цю технологію. Блокчейн має потенціал суттєво трансформувати операційні процеси в інженерії та виробництві, дозволяє підвищити прозорість ланцюгів постачання шляхом забезпечення повної відстежуваності товарів від виробництва до споживача. Смарт-контракти можуть сприяти автоматизації виконання угод між учасниками ланцюга постачання, знижуючи ризики та підвищуючи довіру між сторонами. Для ефективного впровадження блокчейну критично важливо подолати певні виклики. Одним з найбільших викликів є високе енергоспоживання блокчейн-систем, що збільшує операційні витрати та створює екологічні проблеми. Також значним викликом є обмежена масштабованість блокчейн-систем, яка перешкоджає їх широкому застосуванню. Для успішної інтеграції блокчейну необхідне удосконалення технології, розвиток більш енергоефективних та стандартизованих рішень для підвищення масштабованості. Для широкого впровадження блокчейну в Україні важливим є розвиток законодавчої бази та державної підтримки.

Отримані результати вказують на те, що технологія блокчейн має потенціал суттєво трансформувати операційні процеси в інженерії та виробництві. Блокчейн дозволяє підвищити прозорість ланцюгів постачання шляхом забезпечення повної відстежуваності товарів від виробництва до споживача. Крім того, смарт-контракти можуть автоматизувати виконання угод між учасниками ланцюга постачання, знижуючи ризики та підвищуючи довіру між сторонами.

Ключові слова: блокчейн; інженерія; виробництво; управління ланцюгами постачання; смарт-контракт.

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