

DIGITAL TRANSFORMATION IN SUPPLY CHAIN MANAGEMENT: THE IMPACT OF BLOCKCHAIN TECHNOLOGY IMPLEMENTATION ON OPERATIONAL EFFICIENCY

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Abstract

Digital transformation in supply chain management has encouraged companies to adopt innovative technologies to improve efficiency and competitiveness. One technology that is increasingly being implemented is blockchain, which offers transparency, security, and automation in supply chain management. However, the integration of blockchain with existing systems still faces various challenges, including technical barriers, workforce readiness, and the need for clearer regulations. This study aims to analyze the impact of blockchain technology implementation on operational efficiency in supply chain management. The research method used is a qualitative approach with literature analysis from various relevant sources. The data obtained will be systematically reviewed to identify patterns, challenges, and potential for blockchain technology development in the supply chain. The results of the study show that blockchain can improve product traceability, speed up transactions, and reduce operational costs in the supply chain. The implementation of this technology also has the potential to change the competitive landscape of the industry by creating a more efficient and transparent system. Therefore, an appropriate integration strategy and regulatory support are needed to ensure wider and more sustainable blockchain adoption.

Keywords: Digital Transformation, Supply Chain Management, Blockchain Technology, Operational Efficiency.

A. INTRODUCTION

In recent decades, digital transformation has become a key element in the changing global industrial landscape. Companies across sectors are facing increasing pressure to adopt new technologies to improve their efficiency and competitiveness. One area that has undergone significant change is supply chain management, where the challenges of managing the flow of goods, information, and finances continue to grow as business operations become more complex. Globalization and the growth of e-commerce have pushed companies to optimize supply chain processes to be faster, more transparent, and more accurate. However, challenges such as inefficiency, data errors, late deliveries, and security risks are still common obstacles (Frank et al., 2019).

As digital technology advances, there is a need to find solutions that can improve efficiency and security in the supply chain. Digital transformation that includes automation, artificial intelligence-based data, and the use of other advanced technologies has become a key strategy in analyzing these challenges. One innovation that has received widespread attention in recent years is the application of blockchain

technology in the supply chain. Companies across industries are starting to consider blockchain as a tool that can improve transparency, security, and operational efficiency in ways that have never been possible before (Attaran, 2020).

The increasing need for data visibility and integrity in the supply chain is driving the exploration of blockchain technology. Cases showing inefficiencies in traditional supply chains, such as product counterfeiting, lack of traceability of goods, and administrative errors that cause delays and additional costs, further emphasize the need for fundamental changes in supply chain management systems. In addition, growing customer expectations for speed of delivery and transparency in product tracking are increasingly pushing companies to seek more sophisticated solutions in managing their supply chains (Rogerson & Parry, 2020).

In the context of the global industry, many companies are beginning to realize that conventional solutions are no longer sufficient to handle the complexity and dynamics of the modern supply chain. Reliance on manual systems or fragmented technologies often hampers operational efficiency and creates uncertainty in decision-making. Blockchain technology offers a promising alternative with its ability to create a decentralized and tamper-proof transaction recording system. This has the potential to reduce the inefficiencies that have been a constraint in traditional supply chain management (Raja Shanti & Muthuswamy, 2022).

In addition to technological factors, government regulations and policies also play a role in encouraging the adoption of digital solutions in the supply chain. Several countries have begun to develop regulations that support the application of blockchain technology in various sectors, including logistics and international trade. Standardization of operational procedures based on advanced technology is becoming increasingly important in increasing the competitiveness of companies in the global market. With clearer regulatory support, the implementation of blockchain in the supply chain is expected to grow further and provide broader benefits to the industry (Dubey et al., 2023).

Although blockchain adoption still faces challenges in terms of initial investment, integration with existing systems, and resistance to change, companies that have implemented this technology are beginning to feel the benefits. Various reports have shown that blockchain can improve operational efficiency by reducing bureaucracy, increasing product traceability, and minimizing the risk of fraud and administrative errors. The success of several companies in implementing blockchain has further encouraged other organizations to explore and trial the application of this technology on a wider scale (Habib et al., 2022).

With the increasing adoption of blockchain technology in the supply chain, questions have arisen regarding the real impact it can have on operational efficiency. This study aims to explore how the application of blockchain technology can transform supply chain management and the extent of its impact on increasing efficiency, security, and traceability in operational processes. By understanding the implications of this digital transformation, it is hoped that this study can provide deeper insights for stakeholders in the supply chain industry and encourage the implementation of more innovative solutions in the future.

B. LITERATURE REVIEW

1. Digital Transformation

The concept of digital transformation in general is about adopting technology to increase productivity, create value, and improve social welfare. Digital transformation does not only focus on the application of technology in business processes or public services, but also reflects a fundamental change in the way individuals, organizations, and societies interact with technology. In an increasingly connected world, digital transformation enables automation, higher efficiency, and continuous innovation in various sectors, from the economy to government. With technological advances such as artificial intelligence, cloud computing, and big data, digital transformation has become a major force shaping global social and economic dynamics (Chen et al., 2021).

Digital transformation is defined as a social phenomenon or cultural evolution that reflects a fundamental transition in society, where digital technology is increasingly rooted in culture and everyday life. This process not only impacts the industrial and business world, but also communication patterns, education, and social interactions. The current digital generation grows up with easy access to information and technology-based services, which directly changes expectations about the efficiency and quality of services provided by the government and the private sector. In addition, digital transformation does not occur in a vacuum; it is influenced by various factors such as regulation, infrastructure readiness, and public acceptance of technological change (Leal-Rodriguez et al., 2023).

Digital transformation is an evolution that involves various resources, including the use of digital technology, to produce significant changes in existing structures, processes, values, positions, and ecosystems. This transformation is not just about adopting new technology, but also reflects changes in mindset, business models, and organizational governance. With the right approach, digital transformation can increase the competitiveness of a country or organization by creating a more adaptive and data-driven business model. In the industrial world, for example, digital transformation enables the use of automation technology in manufacturing, which increases efficiency and reduces human error. Meanwhile, in the government sector, the adoption of digital technology can increase transparency and accountability in public services (Plekhanov et al., 2023).

Digital transformation is a complex and ongoing effort that can substantially shape society and digital life through technological innovation. In its development, digital transformation brings not only opportunities, but also challenges, such as cybersecurity threats, digital divides, and changes in the labor market. Therefore, the success of digital transformation depends on the readiness of human resources in adopting technology and policies that support an inclusive and sustainable digital ecosystem. Through the right strategy, digital transformation can be a powerful tool in creating positive change, increasing efficiency, and driving more inclusive and equitable economic growth (Van Veldhoven & Vanthienen, 2022).

2. Supply Chain Management

According to P. Tyagi, a supply chain is a system where an organization distributes its production goods and services to its customers. This chain is also a

network of various interconnected organizations that have the same goal, namely to organize the procurement and distribution of these goods as well as possible. Meanwhile, according to Schroeder, a supply chain is a series of business processes and information that provide products or services from suppliers to companies and distribute them to consumers (Fu et al., 2022).

So in conclusion, a supply chain is a network system in a company that is connected, interdependent and mutually beneficial in an organization that works together to control, regulate and develop the flow of materials, products, services and information from suppliers, companies, distributors, stores or retailers, and supporting companies such as logistics service companies to customers as end users (Wiedmer & Griffis, 2021).

According to J. A. O'Brien, Supply Chain Management (SCM) is a cross-functional inter-company system that uses information technology to help support and manage relationships between several of the company's main business processes and with suppliers, customers, and business partners. Levi defines supply chain management as an approach used to achieve efficient integration of suppliers, manufacturers, distributors, retailers, and customers (Badwan, 2024). The main activities included in the SCM classification are:

- a. New product design activities (Product Development), raw material acquisition activities (Procurement).
- b. Production and inventory planning activities (Planning and Control), production activities (Production).
- c. Delivery/distribution activities (Uemura Reche et al., 2022).

SCM performance measures include:

- a. Quality (customer satisfaction level, customer loyalty, delivery accuracy)
- b. Time (total replenishment time, business cycle time)
- c. Cost (total delivered cost, added value efficiency)
- d. Flexibility (quantity and specifications) (Negi, 2021).

SCM can also be interpreted as an organizational network that involves upstream and downstream relationships, in different processes and produces value in the form of goods/services in the hands of the final customer (ultimate customer/end user).

In its implementation, SCM has several basic components, including:

- a. Plan

The beginning of SCM success is in the process of determining the SCM strategy. The main objective of the strategy formulation process is to achieve efficiency and cost effectiveness and ensure the quality of the products produced until they reach consumers (Khedr, 2024).

- b. Source

The company must choose a credible raw material supplier who is able to support the production process to be carried out. Therefore, the SCM manager must be able to set prices, manage the delivery and payment of raw materials, and maintain and improve business relationships with suppliers (Tarigan et al., 2021).

c. Make

This component is the manufacturing stage. The SCM manager makes a schedule of activities needed in the production process, product testing, packaging and preparation for product delivery. This stage is the most important stage in SCM. The company must also be able to measure quality, production output, and worker productivity (Helo & Hao, 2022).

d. Deliver

The company fulfills orders from consumer requests, manages a network of storage warehouses, selects distributors to deliver products to consumers, and organizes the payment system (Kmiecik, 2022).

e. Return

SCM planners must create a flexible and responsive network for defective products from consumers and form a consumer complaint service that has problems with the products delivered. Companies need to make regular business performance reports. So that company leaders can find out the changes in business performance that have been made in accordance with the initial objectives of the SCM that have been set (Siagian et al., 2021).

3. Blockchain Technology

Blockchain is a distributed database that is shared across every node (system) connected to a computer network. Unlike traditional centralized databases, blockchain allows every participant in the network to have the same copy of the data, creating a system that is more transparent and difficult to manipulate. As a digital database, blockchain stores information in an electronic format designed to ensure the security, integrity, and traceability of data. Blockchain's popularity is growing due to its use in cryptocurrency systems, such as Bitcoin, which utilize this technology to record transactions securely and decentralized without relying on a central authority. In other words, blockchain allows individuals and organizations to transact with a high level of security, reducing dependence on traditional financial institutions or other intermediaries (Kalajdjieski et al., 2023).

The main innovation in blockchain lies in its ability to guarantee the trustworthiness and security of data records without the need for a third party as an intermediary in the verification process. In traditional systems, transactions or data exchanges usually have to go through certain institutions that act as validators, such as banks or financial authorities. However, in blockchain, this process is replaced by a consensus mechanism that ensures that every change or transaction is validated by the network itself. This not only increases efficiency and reduces transaction costs, but also minimizes the risk of data manipulation and abuse of authority. By using strong encryption technology and consensus mechanisms such as Proof of Work (PoW) or Proof of Stake (PoS), blockchain can provide a high level of security, making it almost impossible to change or forge data stored in it (Tseng & Shang, 2021).

The main difference between traditional databases and blockchains lies in their data storage structure. Blockchains group information into blocks of data, which are then linked to each other sequentially to form a chain. Each block has a certain storage capacity, and when the block is full, it is locked and linked to the previous block, creating a permanent and immutable chain of data. This mechanism ensures that any

changes in the blockchain are clearly traceable and cannot be deleted, making it very suitable for applications that require high transparency and security, such as financial record-keeping systems, smart contracts, and logistics and supply chains (Zaabar et al., 2021).

In contrast, in traditional databases, information is organized in a table format that allows for more flexible reading, modification, or deletion of data. However, this flexibility can also be a disadvantage, especially in the context of security, because data can be modified or deleted without a clear trace. The blockchain structure based on blocks and chains of data creates an immutable data timeline once implemented in a decentralized system. In other words, every transaction or change that occurs in the blockchain will remain permanently recorded, providing a higher level of transparency compared to conventional databases. Therefore, blockchain is increasingly being adopted in various sectors that require a reliable and manipulation-resistant record-keeping system (Sicari et al., 2022).

C. METHOD

This research will be conducted using a qualitative approach to analyze the application of blockchain technology in supply chain management and its impact on operational efficiency and industrial competitiveness. Digital transformation in the supply chain changes operational patterns by introducing more automated and accurate systems, allowing companies to optimize resources and reduce the risk of human error. Integrating blockchain with existing management systems also presents its own challenges, especially in terms of technical barriers, workforce readiness, and the need for clearer regulations. However, with the right implementation strategy, blockchain can be an innovative solution to improve traceability, speed up transactions, and reduce operational costs in the global supply chain. Through a qualitative approach, research data will be obtained from various relevant sources, including previous research results and studies that are still related to this topic. After the data has been collected, the next step is to process and analyze the information systematically to identify patterns, challenges, and potential developments of this technology. With this method, the research is expected to provide comprehensive insights into the effectiveness of blockchain in improving supply chain efficiency and its implications for industry and future regulations (Pahleviannur et al., 2022).

D. RESULT AND DISCUSSION

1. Digital Transformation in Supply Chain Management

The digital transformation of supply chain management has fundamentally changed how companies manage their operations, from sourcing raw materials to distributing finished products to consumers. Digitalization has enabled a shift from traditional systems that often rely on manual record-keeping to more automated and data-driven systems. This shift has had a major impact on operational patterns, with companies now able to access information in real time, reduce reliance on paper-based processes, and increase accuracy in tracking inventory and movement of goods. With a more integrated system, companies can reduce the risk of human error, which has long been a major factor in supply chain inefficiencies. The speed of data processing

has also increased significantly, enabling faster decision-making based on more accurate analysis.

In the digital era, technology plays a key role in improving operational efficiency and accuracy in supply chain management. Automation powered by artificial intelligence and machine learning enables companies to more accurately analyze market demand trends, optimize inventory strategies, and anticipate potential disruptions in distribution. In addition, Internet of Things (IoT)-based technologies further strengthen transparency in the supply chain by enabling real-time tracking of goods through sensors connected to a central system. Thus, companies can reduce waiting time in shipping goods, increase supply reliability, and minimize waste due to errors in stock calculations. The use of data analytics also contributes greatly to predicting customer consumption patterns, so that companies can adjust production and distribution capacity more flexibly.

Although the benefits of digitalization in the supply chain are significant, its implementation is not without challenges that companies must face. One of the main challenges is the high initial investment to adopt new technologies, including the cost of hardware, software, and employee training to adapt to the new system. Many companies, especially small and medium-sized companies, face financial constraints in carrying out this transformation, so they tend to still rely on existing traditional systems. In addition, another challenge is the complexity of integrating various technologies that often come from different vendors. It is not uncommon for companies to face difficulties in aligning new systems with legacy infrastructure that has been embedded in their operations for years. The process of migrating data from legacy systems to digital platforms can also be a technical obstacle that requires considerable time and resources.

Another aspect that is a challenge is resistance to change within the organization itself. Not all employees or stakeholders are ready to accept the shift towards a more digital system, especially for those who are used to conventional methods. Concerns about job losses due to automation are often one of the factors that hinder the adoption of new technologies in the supply chain. Therefore, companies must strive to not only provide technical training but also build an organizational culture that supports digital transformation. Data security is also a crucial issue in the application of digital technology in the supply chain. As more and more information is stored in cloud-based systems, the risk of cyber attacks and data theft increases. Companies must ensure that their security systems are able to protect data from external threats and internal errors that can have fatal consequences for the continuity of their operations.

With all the challenges, digital transformation in supply chain management remains an unavoidable step for companies that want to remain competitive in the global market. Innovation in digital technology continues to grow, providing opportunities for companies to improve operational efficiency and provide better service to customers. With the right strategy, careful planning, and targeted investment, companies can use digitalization as a tool to strengthen their competitiveness in an increasingly digitalized era.

2. Blockchain and Supply Chain Operational Efficiency

Blockchain technology has become one of the innovations that has the potential to fundamentally change the landscape of supply chain management, especially in terms of increasing operational efficiency. With its decentralized nature and distributed ledger-based nature, blockchain presents a more transparent, secure, and difficult-to-manipulate transaction recording mechanism. In a complex supply chain, where many parties are involved ranging from raw material suppliers, manufacturers, distributors, to retailers and end consumers, the need for a system that can ensure data integrity becomes very important. Blockchain is able to provide a solution to this problem by allowing all parties involved to access the same information in real time without the risk of unilateral data changes or falsification. This not only increases transparency but also builds trust among supply chain actors, because every transaction recorded in the system can be verified by all parties who have access to the network.

Security is also an important aspect in the application of blockchain in the supply chain. In traditional systems, information stored in centralized databases is vulnerable to cyber-attacks and manipulation by irresponsible parties. Blockchain overcomes this challenge by using cryptographic mechanisms that ensure that every recorded transaction cannot be changed or deleted without the consent of the majority of entities participating in the network. This creates a safer environment for companies to protect their critical data, including information about product origins, production processes, and distribution-related data. Thus, the risk of fraud and counterfeiting of goods can be significantly minimized, especially in industries that rely heavily on global supply chains such as pharmaceuticals, food, and logistics. Consumers also benefit from this more transparent system, as they can easily track information about the products they buy, including the source of raw materials and the processes they have gone through before they reach them.

In addition to transparency and security, blockchain also contributes to improving operational efficiency through transaction automation. In conventional systems, the process of recording and verifying transactions often takes a long time because it has to go through various layers of bureaucracy and manual procedures. Blockchain introduces the concept of smart contracts, which are digital contracts that automatically execute certain provisions when previously agreed conditions are met. With smart contracts, many administrative processes that were previously carried out manually can be automated, thereby reducing waiting times and increasing the speed of transaction processing. For example, in the context of a supply chain, payments to suppliers can be processed automatically after the blockchain system confirms that goods have been shipped and received according to the specified specifications. This eliminates the need for intermediaries and speeds up the flow of funds within the system, ultimately improving overall operational smoothness.

Blockchain-powered automation also has an impact on increasing the accuracy of delivery of goods. In the traditional supply chain model, delays often occur due to a lack of coordination between the various parties involved. With blockchain, every entity in the supply chain can have full visibility into the movement of goods in real time. This allows companies to immediately identify bottlenecks or disruptions in the delivery process and take corrective action more quickly. Additionally, because

blockchain allows for more accurate asset tracking, companies can more easily optimize their resource allocation, both in terms of inventory storage and more efficient shipping route planning. Thus, blockchain not only helps speed up the distribution process but also ensures that goods arrive at their destination in a condition that meets predetermined quality standards.

The application of blockchain technology in the supply chain also brings benefits in terms of reducing operational costs. One of the main causes of inefficiency in conventional systems is the reliance on intermediaries to verify transactions and resolve disputes that occur along the supply chain. With blockchain, many of these tasks can be automated through a decentralized mechanism, eliminating the need for third parties who usually charge extra for their services. Additionally, because blockchain allows for more accurate and immutable audits, companies can reduce expenses related to regulatory compliance and dispute resolution that require lengthy investigation processes. Thus, blockchain not only helps improve operational efficiency but also contributes to creating a more cost-effective and sustainable supply chain system.

While there are still various challenges in implementing blockchain, including high initial investment costs and the need for adequate technological infrastructure, the long-term benefits offered by this technology make it increasingly attractive to companies looking to increase their competitiveness. With the development of the digital ecosystem, more and more companies are starting to explore the potential of blockchain as a solution to improve operational efficiency in their supply chains. As this technology matures and increases support from various stakeholders, in the future blockchain could become a new standard in managing a more transparent, secure and efficient global supply chain.

3. Blockchain Integration with Existing Supply Chain Management Systems

Integrating blockchain with existing supply chain management systems is one of the main challenges in implementing this technology. Given that many companies have invested significant resources in existing systems, the transition to blockchain cannot be done instantly without a mature strategy. One of the main approaches in this integration is the use of a hybrid system, where blockchain is used as an additional layer that increases transparency and efficiency, while existing systems continue to run for certain functions. This approach allows companies to gradually adopt blockchain without disrupting ongoing operations. In addition, companies can identify specific areas in their supply chain that will benefit the most from blockchain, such as transaction recording, asset tracking, or product certification verification, so that implementation can be carried out gradually and measurably.

In this integration process, companies must also consider the compatibility of blockchain with the existing technology infrastructure. Traditional supply chain management systems often use Enterprise Resource Planning (ERP) or Supply Chain Management (SCM) software that has been customized according to business needs. Therefore, blockchain integration must be carried out by ensuring that existing data can be accessed and converted into a format that is compatible with blockchain-based systems. One strategy that can be implemented is the use of Application Programming Interface (API) to connect the blockchain to the existing system. With the right API,

companies can ensure that the data recorded in the blockchain remains in sync with the ERP or SCM system, so that there is no duplication or inconsistency of data that can hinder operations.

In addition to integration strategies, technical barriers are one of the main challenges in implementing blockchain in the supply chain. One of the biggest barriers is scalability, because decentralized blockchain systems often experience limitations in terms of transaction speed and data storage capacity. In a supply chain that involves thousands of transactions every day, companies must find solutions that can ensure that the blockchain is able to handle large transaction volumes without sacrificing efficiency. One approach that can be used is the implementation of blockchain with a lighter consensus mechanism, such as Proof of Authority (PoA) or Delegated Proof of Stake (DPoS), which can speed up the transaction verification process compared to traditional mechanisms such as Proof of Work (PoW). In addition, the use of sidechain technology or layer-2 solutions can help increase blockchain capacity without burdening the main network.

Another technical barrier is related to interoperability, where companies often have to deal with various blockchain platforms that have different standards. To ensure that blockchain can be integrated with various existing systems, efforts are needed to develop standards that are widely accepted in the supply chain industry. Several initiatives have emerged in an effort to create interoperability between different blockchains, such as the use of cross-chain protocols that allow data transfer between different blockchain networks. With interoperability standards in place, companies can avoid the risk of dependence on a particular vendor and ensure that their systems remain flexible to future technological developments.

In addition to technical challenges, blockchain integration in the supply chain also brings significant changes in work patterns and workforce readiness. The implementation of blockchain not only changes the way data is managed but also changes the workflow across departments involved in the supply chain. For example, with smart contracts automating many transaction processes, administrative roles that were previously responsible for verifying transactions and manual recording are reduced. This requires changes in organizational structures and redistribution of tasks for workers affected by automation. Therefore, companies need to develop training and upskilling strategies for their workforce so that they can understand how blockchain works and utilize this technology optimally in their daily operations.

Workforce readiness is also a determining factor in the success of blockchain integration. Many workers in the supply chain industry are accustomed to traditional systems and may be reluctant or lack the necessary skills to work with blockchain-based technologies. To overcome this, companies can adopt a gradual education and training-based approach. Training programs specifically designed to understand the basic concepts of blockchain, how smart contracts work, and the application of this technology in the context of the supply chain can help improve the understanding and skills of the workforce. Additionally, companies can also take advantage of more intuitive user interface-based solutions, so workers without technical backgrounds can still operate blockchain-based systems without difficulty.

While there are challenges in integrating blockchain with existing supply chain management systems, the long-term benefits offered by this technology make it an

increasingly attractive solution for companies. With the right approach, companies can overcome technical barriers, ensure interoperability with existing systems, and improve the readiness of their workforce for the changes brought by blockchain. As the digital ecosystem evolves and adoption of this technology increases across industries, integrating blockchain into the supply chain can be a strategic move that brings greater efficiency, transparency, and security to overall business operations.

4. Long-Term Implications of Blockchain Implementation in Supply Chain Management

The long-term implications of blockchain implementation in supply chain management have a broad impact on business sustainability and the dynamics of industry competition. Blockchain-based digital transformation not only increases efficiency and transparency in operations, but also changes the competitive landscape in various sectors. Companies that adopt this technology faster can gain significant competitive advantages, especially in terms of product traceability, reduced operational costs, and increased transaction security. In the long term, businesses that do not immediately adapt to this innovation risk being left behind, as customers, business partners, and regulators increasingly demand a more transparent and efficient supply chain system. Blockchain also allows companies to build a more open business ecosystem, where collaboration between various stakeholders in the supply chain becomes easier and more efficient. Thus, blockchain not only creates competitive advantages for companies that implement it, but also influences industry standards as a whole, encouraging more business players to follow this trend to stay relevant in global competition.

In addition to its impact on industry competition, the use of blockchain in the supply chain opens up opportunities for wider expansion, especially in the logistics sector. This technology can be integrated with various transportation, storage, and distribution management systems, thereby increasing efficiency and accuracy in delivery. One of the main benefits that blockchain offers in the logistics sector is the ability to ensure more accurate traceability, especially in the distribution of products that require strict supervision, such as food, pharmaceuticals, and luxury goods. With blockchain, every movement of goods can be recorded permanently in a system that cannot be changed or manipulated, reducing the risk of errors, theft, or counterfeiting of products. The application of this technology also speeds up the process of insurance claims and dispute resolution in shipping goods, because all the necessary information can be verified directly through encrypted blockchain records. As the need for more responsive and adaptive logistics systems grows, blockchain will increasingly become the standard in global supply chain management.

The potential for expanding the use of blockchain in the logistics sector is also supported by the increasing adoption of Internet of Things (IoT) and artificial intelligence (AI) technologies. Integration of blockchain with IoT sensors allows for real-time monitoring of product conditions, for example in the delivery of goods that require a certain temperature or humidity. Data obtained from these sensors can be automatically recorded in the blockchain, providing greater transparency to all parties involved. In addition, the use of AI in blockchain data analysis can help identify patterns that can improve operational efficiency and optimize the overall supply

chain. With the rapid development of technology, the implementation of blockchain in the logistics sector not only improves the efficiency of existing processes but also opens up opportunities for new innovations that can change the way the logistics industry works as a whole.

However, to achieve the full potential of blockchain implementation in the supply chain, it is necessary to develop policies and regulations that support the adoption of this technology. So far, many countries are still in the exploration stage regarding blockchain regulations, especially in terms of data protection, compliance with industry standards, and transaction monitoring. Without clear regulations, many companies are reluctant to fully adopt blockchain due to the legal uncertainty that accompanies it. Therefore, governments and regulatory authorities need to work with industry players to create a legal framework that can provide certainty for businesses, while ensuring that the technology is used responsibly and safely. The development of supportive regulations can also help encourage investment in blockchain infrastructure, allowing more companies to access the technology without having to face excessive bureaucratic barriers.

Policy development prospects also include efforts to encourage standardization in blockchain implementation across industries. Currently, one of the main challenges in blockchain implementation is the lack of interoperability between the various platforms and protocols used by different companies. Without widely accepted standards, blockchain integration into the supply chain can be a complex and expensive process. Therefore, initiatives are needed from governments and industry organizations to develop technology standards that allow blockchain to be used more widely and flexibly. Standardization can also help ensure that blockchain can be integrated with existing systems, reducing technical barriers that are often major obstacles to implementing new technologies.

In the future, developing policies that support blockchain implementation will not only help companies adopt this technology, but will also have a positive impact on the economy as a whole. With clearer regulations and more mature infrastructure, blockchain can become the foundation for a more efficient, secure, and transparent global trading system. The long-term sustainability of the implementation of this technology depends not only on the readiness of the industry to adopt it, but also on the support of governments and policymakers in creating an environment conducive to innovation. With the right strategy, blockchain has the potential to become a key element in the digital transformation of supply chains, bringing greater efficiency and increasing the competitiveness of industries on a global scale.

E. CONCLUSION

The application of blockchain technology in supply chain management has a significant impact on operational efficiency, transparency, and industrial competitiveness. Digital transformation in the supply chain changes operational patterns by introducing more automated and accurate systems, allowing companies to optimize resources and reduce the risk of human error. Integrating blockchain with existing management systems also presents its own challenges, especially in terms of technical barriers, workforce readiness, and the need for clearer regulations. However, with the right implementation strategy, blockchain can be an innovative solution to

improve traceability, speed up transactions, and reduce operational costs in the global supply chain. In the long term, blockchain adoption will not only have an impact on the company's internal efficiency, but will also change the competitive landscape of the industry and open up opportunities for expansion for the logistics sector. The success of implementing this technology is highly dependent on the readiness of the business ecosystem and regulatory support that can ensure wider and more sustainable adoption. Therefore, synergy is needed between industry players, governments, and regulatory authorities to create standards that allow blockchain to be integrated more effectively. With the development of the right policies, blockchain has the potential to become a key element in the digital transformation of the supply chain, creating a more transparent, efficient, and highly competitive system in the era of globalization.

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