



The Influence of Digitalization on Integrated Logistics Management in Contemporary Port Operations

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Abstract. Digitalization has become the driving force behind transformation in the logistics sector, particularly at seaports, which serve as key nodes in the global supply chain. Indonesian ports face persistent challenges such as high logistics costs and long vessel turnaround times. By implementing digital technologies such as the Port Community System (PCS), Artificial Intelligence (AI), and Blockchain, ports can enhance operational efficiency, accelerate service processes, and improve transparency and accountability. Digital systems also enable real-time integration among stakeholders, contributing to faster cargo flow and reduced national logistics costs. However, the implementation of digitalization is not without significant barriers, including limited information and communication technology (ICT) infrastructure, low digital competencies among the workforce, and high initial investment costs. Furthermore, ports face organizational cultural resistance to change and cybersecurity risks that threaten operational continuity. Smaller ports in developing countries often struggle to adopt these technologies independently due to budget constraints. To overcome these challenges, synergy between the government, port operators, and technology providers is essential. Programs such as the National Logistic Ecosystem (NLE) represent a strategic step to accelerate sustainable digital adoption. With a holistic approach encompassing technology, human resources, and business processes, digitalization can become a key catalyst in enhancing the competitiveness of Indonesian ports on a global scale.

Keywords: Digitalization, Ports, Logistics, Blockchain, Artificial Intelligence, Operational efficiency, National Logistic Ecosystem Indonesian ports on a global scale.

1. INTRODUCTION

One of the main pillars supporting the evolution of the logistics industry, particularly within seaports, is digitalization. Ports play a vital role in the global supply chain as hubs of international trade. However, prolonged vessel waiting times and high logistics costs remain significant obstacles. Integrated terminal management systems and digital consumer platforms are examples of digital technologies that can be implemented in Indonesian ports to reduce national logistics costs and enhance international port competitiveness (Safuan, 2022).

Beyond automating administrative procedures, the application of digital technologies in ports also involves the integration of systems across various stakeholders. For instance, Pelindo has introduced automated gates (autogates) at several ports to minimize the risk of illegal levies and to accelerate the movement of vehicles and goods in and out of port areas. This initiative supports the government's effort to create more efficient and transparent port operations (Sutrisno, 2024). Furthermore, digital platforms such as *Logee Port*, developed by PT Telkom Indonesia, allow customs clearance companies (*Perusahaan Pengurusan Jasa Kepabeanan*, PPJK) to independently perform transactions, including truck bookings and cashless payments.

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These innovations not only improve operational efficiency but also enhance the transparency of port logistics processes.

Despite the increasing adoption of digital technologies, challenges remain—particularly in transforming corporate culture and mindset. In many ports, digitalization often involves merely transitioning from manual workflows to digital ones, without significant adjustments to business procedures or attitudes. This indicates that human capital capabilities and organizational culture are just as critical to the success of digitalization as the technologies themselves (Wresti, 2019).

A key element in the successful implementation of digitalization is the readiness of human resources. A digitally unskilled workforce requires continuous training and development to effectively utilize new technologies. In addition, the availability of adequate information and communication technology (ICT) infrastructure is a fundamental prerequisite to enable smooth adoption of digital systems in ports (MDPI, 2022).

Beyond internal factors, the high upfront expenditures required for system development, hardware acquisition, and personnel training pose additional challenges—especially for smaller ports with limited financial capacity. Therefore, to enhance national logistics competitiveness and accelerate the adoption of digital technologies, government policy support through initiatives such as the National Logistics Ecosystem (NLE) is essential (KemenkoMarves, 2022).

In conclusion, integrating digitalization into contemporary port logistics management requires a comprehensive strategy that addresses business processes, technology, and human resources. The aim of this study is to examine how digitalization impacts the competitiveness and operational efficiency of ports, as well as to identify implementation challenges and potential solutions.

2. RESEARCH METHOD

This study employs a qualitative approach using a literature review method. A literature review is a research technique conducted by collecting various references such as books and scholarly journals that are relevant to the topic and objectives of the study (Danial E., 2009). This approach aims to explore a set of hypotheses related to the research questions and serves as a foundational framework for discussing the findings. According to some scholars, literature review is a data collection method that focuses on written sources, including books, encyclopedias, academic journals, newspapers, magazines, and other documents (Syaodih, 2007).

In this research, the data used are secondary in nature—data not obtained directly from the research object but sourced from documents or third-party information (Alayida et al., 2023b). Most of the analyzed information is derived from secondary sources such as books, academic articles, and online news platforms that discuss issues related to the Fourth Industrial Revolution, digital transformation, logistics digitalization, the logistics business, and the concept of e-logistics.

The data collected through the literature review were analyzed using a descriptive method. The analysis process involved several stages, including data reduction, information triangulation, drawing conclusions based on the researcher's interpretation, and data verification to ensure validity (Miles & Huberman, 2019). This approach enables the researcher to develop a comprehensive understanding of the studied phenomenon from both theoretical and practical perspectives.

3. RESULTS AND DISCUSSION

Information technology has had a profound impact on the development of companies and industries in the era of the Fourth Industrial Revolution. Technologies aimed at achieving work efficiency have been widely adopted across the logistics sector. The concept of digitalization has revolutionized port and logistics management, confronting several challenges and producing notable impacts, particularly in terms of operational efficiency. Scientific evidence highlights that digitalization enhances the operational effectiveness of port management, improves transparency, and enables data-driven decision-making. For instance, ports can reduce vessel waiting times by up to 25% through the implementation of Port Community Systems (PCS) (World Bank, 2021).

The ability of digital systems to connect multiple stakeholders—including customs authorities, logistics companies, and terminal operators—enables real-time information exchange. By leveraging digitalization, logistics efficiency can increase by as much as 30%, while also improving coordination and accelerating processes (Tyagi, 2025). Nevertheless, there are considerable drawbacks associated with digitalization, especially in relation to the demand for reliable ICT infrastructure and digitally skilled labor. The full adoption of technology is often hindered by persistent issues of digital readiness, particularly in ports located in developing countries. Major barriers to digitalization in port and logistics management include high initial investment costs, in addition to technological and human resource constraints. Significant expenditures are required for software development, hardware procurement, and workforce training.

According to research published on ResearchGate (2021), small ports face substantial difficulties in financing their own digital transformation. Despite these obstacles, the benefits of digitalization are substantial. Indonesia's National Logistics Ecosystem (NLE), a government-driven initiative, exemplifies how institutional support can accelerate the adoption of digital technologies within the port industry. Statements from the Coordinating Minister for Maritime and Investment Affairs reinforce the importance of digitalization in enhancing national logistics competitiveness.

Digitalization also opens up opportunities for ports to be more deeply integrated into global supply chain networks. By adopting technologies such as the Internet of Things (IoT), Artificial Intelligence (AI), and blockchain, ports can improve cargo visibility, enhance security, and increase accuracy in cargo handling and goods movement. Smart ports have the potential to become the logistics hubs of the future (Rodrigue, 2020). However, it is crucial to recognize the risks associated with digitalization, particularly those related to cybersecurity. Interconnected digital systems are vulnerable to cyberattacks, which could disrupt port operations entirely. To mitigate these risks, robust and sustainable digital security policies are essential.

Collaboration among governments, port operators, and technology providers is critical to the success of digital transformation. Comparative cases from developing countries emphasize that cooperation, sustained investment, and regulatory frameworks that encourage innovation are key success factors. Ports such as Rotterdam and Singapore serve as exemplary models of digitalization, showcasing the importance of collaborative governance and forward-thinking policy in achieving digital excellence.

Blockchain

Blockchain technology was first conceptualized in the early 1990s, but it did not receive widespread attention until the emergence of Bitcoin in 2009 (Larrier, 2021). Blockchain is a distributed digital ledger system that offers decentralization, transparency, anonymity, and a high degree of auditability (Wang, 2019). The academic community has shown significant interest in this technology, and it is now being adopted across various fields, including managing electronic health records, safeguarding medical data, and tracing the origins of food products. Substantial advancements have been recorded; over 75% of blockchain-related patents originate from the United States (Yang & Hwang, 2020). The value of blockchain patents is notably strong—particularly in the software industry for their originality, and in the hardware industry for their broad applicability (Kim, 2020).

Blockchain is increasingly being applied in the fields of accounting and auditing to improve transparency and reduce the risk of fraud. Overall, blockchain remains an evolving technology, with new applications continuously being discovered and developed (Wang S. Z., 2021).

Two of the primary advantages of using blockchain in supply chain management are enhanced visibility and audit traceability. Blockchain enables supply chain participants to quickly trace the origin of goods and monitor their movement transparently—both of which are crucial for ensuring compliance with trade regulations. Ultimately, the technology can streamline procedures and reduce reliance on intermediaries by facilitating the digitalization and disintermediation of the supply chain. This leads to greater efficiency and potential cost savings.

Additional benefits include the use of smart contracts and improved data security. The robust cryptographic features of blockchain ensure the authenticity and integrity of data, making it difficult for unauthorized parties to alter or tamper with information (Pournader, 2020). Smart contracts are digital agreements that can be automatically executed according to predefined rules encoded on the blockchain. These can automate many supply chain procedures, reducing the likelihood of human error and fraud.

Organizations can reap several benefits from blockchain adoption, including increased trust among stakeholders, improved operational efficiency, enhanced sustainability, and greater transparency. Moreover, blockchain holds the potential to reduce dependence on paper documentation, simplify transit routing, and facilitate information sharing across stakeholders in the maritime industry. However, high implementation costs and the level of technological sophistication required remain significant barriers (Jović, 2020).

Table 1. Category, Indicator, Estimated Impact (%), Description

Category	Indicator	Estimated Impact (%)	Description
Operational Efficiency	Reduction in loading/unloading time	Up to 40%	Enabled by automation and integrated workflows
	Faster processing of logistics documents	60–80%	Enabled by smart contracts and digital documentation
	Reduction in physical document usage	95%	Nearly all documents can be transacted digitally
Data Security	Reduced risk of data manipulation/fraud	Up to 90%	Encrypted data cannot be altered without network-wide consensus
	Audit trail integrity	100%	All transactions are permanently recorded on the blockchain
Traceability & Visibility	Real-time container tracking	Up to 85%	Transparency from point of origin to final destination
	Compliance with regulations and customs	Around 70%	Data can be automatically validated by relevant authorities
Trust & Collaboration	Increased trust among logistics partners	Up to 60%	Shared immutable data builds inter-organizational trust

	Data-sharing capacity among entities in a blockchain system	3–5x increase	Compared to centralized or siloed data systems
Cost Savings	Reduction in logistics operational costs	20–30%	Time, labor, and error minimization lead to efficiency
	Cost reduction from documentation errors and delays	Up to 50%	Smart contracts reduce manual delays
Environmental Sustainability	Reduction in paper and printing consumption	80–95%	Digital documents replace physical printing
	Reduction in port emissions and energy consumption	15–25%	Improved berthing efficiency and ship movement

The main barriers to blockchain adoption in Singapore’s maritime industry have been identified as trust, regulatory concerns, system interoperability, and the need for standardization. Bauk (2022) proposed a conceptual framework that integrates the use of distributed relational databases and cryptocurrency-based payment systems to facilitate the implementation of blockchain technology in maritime and port management. To better understand the potential of this technology across various maritime zones, further research is also recommended (Zhou, 2020).

One notable application involves the development of a blockchain-based model to enhance vessel traffic efficiency at ports. This model allows stakeholders such as shipping agents, terminal operators, tugboat companies, pilot stations, and government authorities to share information via a secure and transparent blockchain system.

A significant barrier to adoption in developing countries such as South Africa and Montenegro is the lack of awareness and understanding of blockchain technology (Kapidani, 2021). From one perspective, blockchain enables decentralized and transparent transactions in the port sector, ultimately improving cargo tracking, data integrity, and trust among stakeholders (Durán, 2021).

Recent developments have included the construction of Proof of Concept (PoC) projects aimed at demonstrating how blockchain technology can be applied in real-world scenarios, especially in inter-port communities and roll-on/roll-off (RoRo) transportation systems. A conceptual framework has also emerged to support blockchain adoption in the maritime industry, encompassing technical aspects, governance structures, and business models (Pu, 2021).

Finally, Kornienko (2023) emphasized that one of the most promising applications of blockchain in maritime logistics lies in automating workflows and transactions, fostering trusted relationships among business partners, and developing open and secure databases using

smart contracts to store ship-related information, including global risks affecting maritime transport.

Artificial Intelligence (AI)

Artificial Intelligence, commonly referred to as AI, is the capability of machines to mimic human thought patterns and cognitive functions. However, does this imply that AI will be able to completely replace humans in the workforce? The truth is that human intelligence and the unique abilities possessed by individuals cannot be entirely replaced by current technology.

Artificial intelligence refers to the process of enabling machines—such as computers—to behave in ways that resemble human intelligence. AI-based algorithms are capable of performing tasks that typically require human reasoning and intelligence. For these systems to operate effectively, input data must first be processed and converted into meaningful information.

AI systems are often able to learn from human behavior patterns and adapt accordingly, which means that direct human instruction is not always necessary for their operation. In essence, AI technologies are designed to think and act in ways that closely resemble human behavior and decision-making processes.

The role and benefits of Artificial Intelligence (AI) in logistics have significantly influenced workforce dynamics by enhancing the effectiveness and efficiency of logistics processes. In the transportation and warehousing industries, AI streamlines data collection, analysis, and inventory management procedures while accelerating operations through the use of robots capable of processing hundreds of packages per hour. AI also plays a critical role in improving demand forecasting by utilizing historical data, thereby enabling companies to develop more effective production and distribution plans.

By analyzing various data sources, AI can predict delays and optimize delivery routes, ultimately enhancing the reliability of transportation systems. Automating routine tasks such as data entry, claims processing, and inventory checks helps expedite service delivery while minimizing the risk of human error.

AI also contributes to the enhancement of human resource performance by enabling HR departments to manage employee data more analytically and systematically. Moreover, integrating AI with other technologies—such as the Internet of Things (IoT)—fosters innovation and unleashes human creativity in developing tech-based logistics solutions.

A tangible example of this transformation is the use of autonomous vehicles, which reduce operational costs and allow for multitasking by relegating human workers to supervisory roles while AI handles driving functions. The *Pronto* program at the Port of

Rotterdam demonstrates the effectiveness of AI in managing vessel operations—from arrival to port coordination—underscoring AI’s vital role in reducing logistics costs through process optimization services.

4. CONCLUSION

Port and logistics development is increasingly accelerated by digitalization, which enhances data accuracy and transparency while promoting system integration and operational efficiency. Automation, improved forecasting, and smarter logistics management are made possible through technologies such as blockchain and artificial intelligence (AI). Digitalization has the potential to drastically reduce logistics costs and shipping lead times, as demonstrated by initiatives such as autogate systems, the Logee Port digital platform, and integrated management systems.

However, technological advancement alone does not guarantee the success of digital transformation. Human resource readiness, adequate information and communication technology (ICT) infrastructure, and organizational cultural change are also critical factors. Strategic and cooperative solutions are required to address challenges such as cybersecurity threats, limited digital literacy, and high initial investment costs.

To accelerate digitalization adoption and enhance the global competitiveness of Indonesian ports, government support through initiatives such as the National Logistics Ecosystem (NLE) is essential.

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