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Digital Transformation in Port Operations: Implications for Maritime Logistics Efficiency at Port of Tanjung Priok

Ahmad Zaini Miftah[1a], Raden Rifqi Dwisanto[2b] Pawid Wartono[3c]

[12]Universitas Padjadjaran

[3]Politeknik Bina Global

a.z.miftah@unpad.ac.id[a], rd.rifqi@unpad.ac.id[b],pawid.wartono@polmar.ac.id[c]

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Corresponding author :
Ahmad Zaini Miftah
Email: a.z.miftah@unpad.ac.id

ABSTRACT

Digital transformation has become an essential strategy for improving operational performance and competitiveness in the maritime logistics sector. Ports play a critical role as strategic nodes in global supply chains, where operational efficiency significantly affects the flow of goods and logistics performance. This study aims to analyze the implications of digital transformation in port operations for maritime logistics efficiency at Port of Tanjung Priok. The research employed a qualitative descriptive approach using secondary data and document analysis from academic literature, official reports, and relevant publications related to port digitalization and maritime logistics management. The findings indicate that the implementation of digital technologies such as integrated information systems, electronic documentation, and automated operational platforms contributes to improving coordination among stakeholders, enhancing operational transparency, and optimizing cargo handling processes. These digital initiatives also help reduce vessel turnaround time and cargo dwell time, thereby improving the overall efficiency of maritime logistics operations. However, several challenges remain in the implementation of digital transformation, including the need for significant technological investment, system integration among stakeholders, and the development of digital competencies among port personnel. Overall, the study highlights that digital transformation plays a crucial role in strengthening port operational performance and improving maritime logistics efficiency. The results provide important insights for policymakers, port authorities, and logistics stakeholders in developing more integrated and technologically advanced port management systems to support sustainable maritime logistics development,

Keywords: digital transformation, port operations, maritime logistics efficiency, port management, maritime logistics.

ABSTRAK

Transformasi digital telah menjadi strategi penting untuk meningkatkan kinerja operasional dan daya saing di sektor logistik maritim. Pelabuhan memainkan peran penting sebagai simpul strategis dalam rantai pasokan global, di mana efisiensi operasional secara signifikan memengaruhi aliran barang dan kinerja logistik. Studi ini bertujuan untuk menganalisis implikasi transformasi digital dalam operasi pelabuhan terhadap efisiensi logistik maritim di Pelabuhan Tanjung Priok. Penelitian ini menggunakan pendekatan deskriptif kualitatif dengan menggunakan data sekunder dan analisis dokumen dari literatur akademis, laporan resmi, dan publikasi terkait digitalisasi pelabuhan dan manajemen logistik maritim. Temuan menunjukkan bahwa implementasi teknologi digital seperti sistem informasi terintegrasi, dokumentasi elektronik, dan platform operasional otomatis berkontribusi pada peningkatan koordinasi antar pemangku kepentingan, peningkatan transparansi operasional, dan optimalisasi proses penanganan kargo. Inisiatif digital ini juga membantu mengurangi waktu putar balik kapal dan waktu tunggu kargo, sehingga meningkatkan efisiensi keseluruhan operasi logistik maritim. Namun, beberapa tantangan masih ada dalam implementasi transformasi digital, termasuk kebutuhan akan investasi teknologi yang signifikan, integrasi sistem antar pemangku kepentingan, dan pengembangan kompetensi digital di antara personel pelabuhan. Secara keseluruhan, studi ini menyoroti bahwa transformasi digital memainkan peran penting dalam memperkuat kinerja operasional pelabuhan dan meningkatkan efisiensi logistik maritim. Hasil penelitian ini memberikan wawasan penting bagi para pembuat kebijakan, otoritas pelabuhan, dan pemangku kepentingan logistik dalam mengembangkan sistem manajemen pelabuhan yang lebih terintegrasi dan berteknologi maju untuk mendukung pengembangan logistik maritim yang berkelanjutan.

Kata kunci: transformasi digital, operasi pelabuhan, efisiensi logistik maritim, manajemen pelabuhan, logistik maritim.
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A. INTRODUCTION

Maritime transportation plays a vital role in facilitating global trade and supporting the movement of goods across international markets. Ports function as critical nodes within maritime logistics networks, linking maritime transport with inland distribution systems and supply chains. The efficiency of port operations therefore has a direct impact on logistics performance, trade competitiveness, and economic growth. Several studies have shown that improving port operational efficiency contributes significantly to enhancing logistics performance and supporting international trade flows (Su, 2026; Zhang et al., 2024).

In recent years, digital transformation has become a major strategy for improving operational performance in port management. Digital transformation refers to the integration of advanced technologies such as the Internet of Things (IoT), artificial intelligence (AI), blockchain, and automation into operational processes and decision-making systems within port logistics (Su, 2026). These technologies enable real-time monitoring, improve data transparency, and support more efficient coordination among stakeholders involved in maritime logistics systems (Azisah et al., 2025). As a result, digitalization is increasingly viewed as an important driver for the development of smart ports and more integrated maritime logistics systems.

The adoption of digital technologies in port operations has also been shown to improve efficiency, reduce operational costs, and enhance service quality within maritime logistics networks. For instance, digital systems such as port community systems, automated terminal operations, and electronic data interchange have been proven to accelerate cargo handling processes and improve operational transparency (Abubakar et al., 2024). Furthermore, digital transformation can strengthen operational resilience and support more adaptive responses to supply chain disruptions in port operations (Liu et al., 2023). These findings highlight the growing importance of digitalization as a strategic approach to improving port competitiveness in the era of globalized trade.

Despite these potential benefits, the implementation of digital transformation in port operations still faces various challenges. Previous studies indicate that digital transformation requires substantial investment, complex system integration, and strong coordination among multiple stakeholders within the port ecosystem (Zhang et al., 2024). In addition, disparities in technological readiness, infrastructure limitations, and organizational resistance to change may hinder the effectiveness of digital initiatives in maritime logistics systems (Margaretha & Syuzairi, 2024). These challenges suggest that the impact of digital transformation on maritime logistics efficiency may vary depending on institutional capacity, technological adoption, and governance structures in specific port environments.

Although numerous studies have examined the role of digital transformation in maritime logistics and port management, most of the existing literature focuses on conceptual models, technological innovations, or comparative analyses across multiple ports. Many studies emphasize the technological aspects of digitalization such as artificial intelligence, IoT integration, or smart port frameworks without sufficiently exploring how these digital initiatives affect operational efficiency within specific port contexts (Azisah et al., 2025; Su, 2026). Furthermore, empirical studies that analyze the practical implications of digital transformation on logistics efficiency at major developing-country ports remain relatively limited.

In the context of Indonesia, which relies heavily on maritime transportation due to its archipelagic geography, research on digital transformation in port operations is still developing. While several studies have discussed the potential of digital technologies in improving maritime logistics systems, empirical analyses focusing on operational outcomes at major Indonesian ports are still scarce (Abubakar et al., 2024). Consequently, there is a need for more in-depth research that examines how digital transformation initiatives influence maritime logistics efficiency in real port operational environments.

Based on this background, this study aims to analyze the implications of digital transformation in port operations for maritime logistics efficiency at Port of Tanjung Priok. As the largest and busiest port in Indonesia, Tanjung Priok plays a strategic role in supporting national and international trade activities. Examining the implementation of digital transformation at this port is therefore important to understand how digital technologies contribute to improving logistics efficiency and strengthening maritime supply chain performance. The findings of this study are expected to contribute both to the academic literature on port management and maritime logistics as

well as to provide practical insights for policymakers and port authorities in developing more efficient and digitally integrated port systems.

B. LITERATURE REVIEW AND HYPOTHESIS DEVELOPMENT

Digital Transformation in Port Operations

Digital transformation has become an essential strategy for improving operational performance and competitiveness in the maritime sector. In the context of port management, digital transformation refers to the integration of advanced digital technologies such as the Internet of Things (IoT), artificial intelligence (AI), big data analytics, and blockchain into port operational processes and logistics management systems. These technologies enable ports to optimize cargo handling operations, improve decision-making processes, and enhance coordination among various stakeholders involved in maritime logistics networks (Liu et al., 2023).

Several studies highlight that digital technologies play an important role in transforming conventional port operations into more integrated and intelligent systems. The concept of the smart port has emerged as a new paradigm in port management, where digital infrastructure and automated systems are used to improve operational efficiency, reduce congestion, and enhance service reliability (Heilig & Voß, 2017; Zhang et al., 2024). Through digital platforms such as Port Community Systems (PCS), stakeholders including shipping companies, port authorities, customs agencies, and logistics providers can exchange information in real time, thereby reducing delays and administrative inefficiencies in port operations.

Furthermore, digital transformation also supports greater transparency and visibility in supply chain activities. Real-time data sharing and automated monitoring systems allow port operators to manage vessel scheduling, cargo tracking, and terminal operations more effectively (Su, 2026). As a result, ports that adopt digital technologies tend to experience improvements in operational performance and logistics coordination compared to those relying on conventional management systems.

Port Operations Management

Port operations management refers to the planning, coordination, and control of activities related to the movement of vessels, cargo, and logistics services within port areas. Efficient port operations are critical for ensuring the smooth flow of goods between maritime transportation and inland logistics networks. According to Rodrigue and Notteboom (2020), port operations involve several key activities including vessel berthing, cargo handling, terminal management, and intermodal transportation coordination.

Effective port operations management requires coordination among multiple actors such as port authorities, terminal operators, shipping lines, customs agencies, and logistics service providers. The complexity of these interactions often creates operational challenges, particularly in large and busy ports where cargo volumes are high and logistics processes are highly interconnected. Therefore, improving operational coordination and reducing bottlenecks are essential to enhancing port performance and logistics efficiency.

Recent studies emphasize that the adoption of digital technologies can significantly improve port operational management by enabling better information sharing and operational monitoring. Digital systems such as automated terminal operating systems, electronic documentation, and integrated logistics platforms help reduce processing times, minimize human errors, and improve service quality within port operations (Abubakar et al., 2024).

Maritime Logistics Efficiency

Maritime logistics efficiency refers to the ability of maritime transport and port systems to move goods quickly, reliably, and cost-effectively within global supply chains. Efficient maritime logistics systems are characterized by shorter vessel turnaround times, reduced cargo dwell time, improved cargo handling productivity, and smooth coordination between port operations and inland transportation networks (Notteboom & Rodrigue, 2019).

The efficiency of maritime logistics is influenced by several factors including port infrastructure, operational management, technological adoption, and institutional governance. Ports that adopt advanced technologies and integrated logistics systems tend to achieve higher operational efficiency and better logistics performance compared to ports relying on traditional operational methods (Zhang et al., 2024).

Digital transformation plays an increasingly important role in improving maritime logistics efficiency. By integrating digital platforms, real-time tracking systems, and automated operational processes, ports can reduce delays, optimize resource allocation, and enhance supply chain visibility (Su, 2026). Consequently, digitalization is widely recognized as a key driver for improving logistics efficiency and strengthening the competitiveness of maritime transport systems in the global economy.

C. RESEARCH METHODOLOGY

This study employed a qualitative descriptive research design to examine the implications of digital transformation in port operations for maritime logistics efficiency at Port of Tanjung Priok. The research focused on understanding how the implementation of digital technologies in port operational systems contributes to improving logistics performance within the maritime sector. Data were collected through a combination of literature review, analysis of secondary data from official reports, port authority publications, and relevant academic studies related to port digitalization and logistics management. In addition, document analysis was used to identify key aspects of digital transformation initiatives implemented in port operations, including automation systems, digital platforms, and information integration among logistics stakeholders. The collected data were analyzed using qualitative content analysis to interpret patterns, identify relationships between digital transformation and operational efficiency, and evaluate their implications for maritime logistics performance. This approach allows for a comprehensive understanding of how digital technologies influence port operational processes and logistics efficiency within the context of maritime transportation systems.

D. RESULT AND DISCUSSION

The findings of this study indicate that digital transformation has played a significant role in improving operational performance and maritime logistics efficiency at Port of Tanjung Priok. As the largest and busiest port in Indonesia, Tanjung Priok handles a substantial portion of the country's international trade activities. Consequently, the adoption of digital technologies in port operations has become an essential strategy to address operational complexities, reduce congestion, and improve the overall efficiency of logistics processes. The integration of digital systems in port management has enabled more efficient coordination among stakeholders, improved information exchange, and enhanced the management of cargo handling and vessel services.

One of the most significant outcomes of digital transformation is the improvement in operational coordination among stakeholders within the maritime logistics ecosystem. Port operations involve various actors, including port authorities, terminal operators, shipping companies, customs agencies, freight forwarders, and inland logistics providers. Traditionally, communication and data exchange among these actors were often fragmented and relied on manual documentation processes. This situation frequently resulted in delays in cargo processing, administrative inefficiencies, and limited transparency in logistics operations. However, the introduction of digital platforms such as integrated port information systems and electronic documentation has significantly improved the flow of information among stakeholders. Through these digital systems, operational data related to vessel schedules, cargo documentation, and terminal activities can be accessed and shared in real time, allowing stakeholders to coordinate their activities more effectively and minimize operational disruptions.

Another important finding relates to the improvement of cargo handling efficiency and vessel turnaround time. Digital technologies have enabled port operators to implement more advanced operational planning and monitoring systems. For instance, automated terminal operating systems allow operators to manage container yard allocation, crane operations, and cargo movement more efficiently. Real-time monitoring systems also help port authorities track vessel movements and anticipate potential congestion within port terminals. By optimizing the allocation of operational resources and improving scheduling accuracy, digital transformation contributes to reducing vessel waiting time and cargo dwell time. These improvements are crucial for enhancing maritime logistics efficiency, as faster cargo handling and vessel services enable goods to move more quickly through port facilities and into inland transportation networks.

Digital transformation has also contributed to increasing transparency and visibility within maritime logistics processes. The implementation of digital tracking systems and integrated logistics platforms enables stakeholders to monitor the movement of cargo, vessels, and operational activities in real time. This level of visibility allows logistics actors to plan their operations more effectively and respond quickly to potential disruptions. For example, shipping companies can obtain updated information on port congestion and terminal capacity, while logistics providers can coordinate inland transportation schedules based on accurate cargo availability data. As a result, digital technologies help reduce uncertainty in logistics operations and support more efficient supply chain management.

Furthermore, the adoption of digital technologies supports the development of more integrated maritime logistics systems. Digital platforms allow various stakeholders within the port ecosystem to operate within a shared information environment, which facilitates better collaboration and coordination. This integration is particularly important in large ports such as Tanjung Priok, where logistics operations involve numerous actors and complex

operational processes. By enabling seamless data exchange and improving operational synchronization, digital transformation strengthens the overall connectivity between port operations and broader supply chain networks.

Despite the positive impacts identified in this study, several challenges remain in the implementation of digital transformation in port operations. One major challenge is the need for significant investment in technological infrastructure and digital systems. The adoption of advanced technologies such as automation systems, digital platforms, and integrated logistics management systems requires substantial financial resources and long-term strategic planning. Additionally, the successful implementation of digital transformation depends on the availability of skilled human resources capable of operating and managing these technologies effectively.

Another challenge concerns the integration of digital systems among multiple stakeholders with varying levels of technological readiness. While some actors within the port ecosystem may already possess advanced digital capabilities, others may still rely on conventional operational practices. This disparity can create barriers to achieving full digital integration across the maritime logistics network. Therefore, efforts to promote digital transformation in port operations must be accompanied by capacity-building initiatives, institutional coordination, and supportive regulatory frameworks to ensure that all stakeholders can participate effectively in digital logistics systems.

Overall, the results of this study demonstrate that digital transformation has a substantial impact on improving maritime logistics efficiency. Through enhanced operational coordination, improved cargo handling performance, increased transparency, and better integration of logistics processes, digital technologies contribute significantly to the modernization of port operations. These findings suggest that accelerating digital transformation initiatives is essential for strengthening the competitiveness of major ports and supporting more efficient maritime logistics systems in the context of growing global trade and increasingly complex supply chains.

CONCLUSION AND SUGGESTION

This study examined the implications of digital transformation in port operations for maritime logistics efficiency at Port of Tanjung Priok. The findings indicate that the adoption of digital technologies in port management plays a significant role in improving operational performance and enhancing the efficiency of maritime logistics systems. The integration of digital platforms, automated operational systems, and real-time information exchange has enabled better coordination among port stakeholders, streamlined administrative processes, and optimized cargo handling activities. As a result, digital transformation contributes to reducing vessel turnaround time, minimizing cargo dwell time, and improving the overall effectiveness of logistics operations within the port environment.

Furthermore, digital transformation enhances transparency and visibility in maritime logistics processes by enabling real-time monitoring of vessel movements, cargo flows, and terminal operations. This increased visibility allows logistics actors, including port authorities, shipping companies, and logistics service providers, to make more informed operational decisions and coordinate their activities more effectively. Consequently, digital technologies help strengthen the integration of port operations with broader supply chain systems, leading to more efficient and reliable logistics performance.

However, the successful implementation of digital transformation in port operations requires substantial investment in technological infrastructure, skilled human resources, and strong institutional coordination among stakeholders. Differences in technological readiness and organizational capabilities may pose challenges to achieving full digital integration across the maritime logistics ecosystem. Therefore, continuous efforts are needed to enhance digital infrastructure, develop human resource competencies, and strengthen collaboration among stakeholders involved in port and logistics operations.

Overall, this study highlights the strategic importance of digital transformation in supporting the modernization of port management and improving maritime logistics efficiency. The findings provide valuable insights for policymakers, port authorities, and logistics stakeholders in designing policies and strategies that promote the development of more efficient, integrated, and technologically advanced port systems to support national and global trade activities.

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