

## Digital Transformation and Operational Performance in Indonesian Port Logistics: A Qualitative Multiple-Case Study

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**ABSTRACT:** Digital transformation is a strategic priority for improving efficiency, transparency, and competitiveness in port logistics, yet empirical evidence on how digital technologies enhance operational performance across various port actors remains limited. This study examines digital technology implementation in Indonesian port logistics, identifies operational opportunities generated by digital transformation, and analyzes how these technologies improve operational performance. A qualitative multiple-case study design involved nine key stakeholders—port authorities, terminal operators, IT management, customs, shipping companies, freight forwarders, operational personnel, academia, and regulators. Data were collected through semi-structured interviews and documentary evidence, analyzed using thematic analysis. Findings show Indonesian ports have implemented an integrated digital portfolio—Port Community System, Terminal Operating System, EDI, IoT, automated gates, RFID, container tracking, digital payments, and AI-based predictive analytics—significantly enhancing real-time information exchange, cargo visibility, coordination, and data-driven decision-making. Participants reported improvements in vessel turnaround, crane productivity, container handling, customs clearance, truck turnaround, logistics lead time, and customer service. Performance gains depend not only on technology adoption but also on interoperability, standardized data governance, organizational readiness, workforce capability, cybersecurity, and stakeholder collaboration. However, variations in digital maturity, legacy systems, and institutional coordination continue to limit fully integrated smart-port ecosystems. The study concludes that digital transformation serves as a strategic enabler of operational excellence when integrated with organizational processes and collaborative governance, offering practical guidance for accelerating smart-port development in Indonesia.

**Keywords:** Digital Transformation, Smart Port, Port Logistics, Port Community System, Operational Performance, Maritime Logistics, Indonesia



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## INTRODUCTION

Digital transformation has emerged as a fundamental driver of change in the global maritime industry, reshaping the way ports manage logistics activities, coordinate stakeholders, and deliver services across increasingly complex supply chains. Ports are no longer viewed solely as physical interfaces for cargo handling but as intelligent logistics ecosystems where information flows are as critical as the movement of goods. The rapid development of digital technologies including the

Port Community System (PCS), Terminal Operating System (TOS), Electronic Data Interchange (EDI), Internet of Things (IoT), Artificial Intelligence (AI), cloud computing, blockchain, digital twins, and predictive analytics has enabled ports to improve operational visibility, automate business processes, and support data-driven decision-making. Rather than functioning as isolated technological innovations, these digital solutions are increasingly integrated into interoperable platforms that facilitate real-time communication among port authorities, terminal operators, customs agencies, shipping companies, freight forwarders, and other logistics stakeholders. Consequently, digital transformation has become a strategic prerequisite for enhancing operational efficiency, supply chain resilience, and global competitiveness within maritime logistics (Cunha et al., 2023; Dominguez et al., 2022; Klar et al., 2024; Min, 2022).

The literature consistently demonstrates that digital transformation generates significant improvements in operational performance throughout port logistics systems. Integrated digital platforms enhance end-to-end visibility by allowing stakeholders to access real-time operational information regarding vessel schedules, berth allocation, yard utilization, cargo movement, and customs clearance. Digital twins and interoperable information systems further support collaborative planning and joint decision-making across organizational boundaries, reducing operational uncertainty while optimizing the utilization of port resources (Klar et al., 2023, 2024). Likewise, smart port initiatives supported by IoT sensors, cloud-based analytics, and AI applications have been associated with shorter vessel turnaround times, improved equipment utilization, higher crane productivity, enhanced cargo traceability, and more efficient logistics coordination (Min, 2022; Philipp et al., 2021). Beyond operational efficiency, digital transformation also contributes to environmental sustainability by enabling energy optimization, emissions monitoring, and resource-efficient operations through integrated digital monitoring systems (Brunila et al., 2021; Cai & Li, 2022). Collectively, these developments illustrate that digital transformation has evolved into a comprehensive organizational strategy that simultaneously addresses operational performance, environmental sustainability, and long-term competitiveness.

The concept of the Smart Port has consequently become a dominant framework for understanding digital transformation within maritime logistics. Smart ports are characterized by high levels of digital connectivity among infrastructure, vessels, terminals, logistics providers, and regulatory agencies through the application of Industry 4.0 technologies such as IoT, AI, big data analytics, robotics, automation, digital twins, and fifth-generation communication networks. Unlike conventional ports that primarily emphasize physical infrastructure, smart ports integrate digital technologies with organizational governance, stakeholder collaboration, and sustainable development objectives to create adaptive and data-driven logistics ecosystems (Min, 2022; Brunila et al., 2021; Seo et al., 2022; Aerts & Mathys, 2024; Castellanos et al., 2024). The literature further suggests that smart port maturity is determined not only by the extent of technology adoption but also by the level of interoperability achieved across multiple organizational systems. Maturity models proposed in previous studies indicate a progression from isolated digital applications toward fully integrated, interoperable, and collaborative ecosystems capable of supporting system-of-systems optimization across ports, cities, and global supply chains (Klar et al., 2024; Klar et al., 2023). Accordingly, interoperability has become one of the most important indicators of successful

digital transformation because it enables seamless information exchange, coordinated operational planning, and collective decision-making among diverse stakeholders.

Indonesia has increasingly embraced this global transformation through various national initiatives aimed at strengthening logistics competitiveness and improving port performance. Government programs such as the National Logistics Ecosystem (NLE) and Smart Port development seek to integrate information systems across customs authorities, port operators, shipping companies, logistics providers, and other relevant institutions. Major Indonesian ports have gradually implemented digital technologies including PCS, TOS, EDI, automated gate systems, digital payment platforms, container tracking systems, IoT-enabled monitoring, and AI-based operational analytics. These initiatives are intended to simplify administrative procedures, improve cargo visibility, reduce logistics costs, accelerate customs clearance, and increase overall service quality. As an archipelagic nation whose economic development depends heavily on maritime transportation, Indonesia requires highly integrated and digitally connected port logistics systems capable of supporting domestic distribution networks and international trade. Consequently, understanding how digital technologies are implemented and how they contribute to operational performance has become increasingly important for both practitioners and policymakers.

Among the various digital technologies introduced within ports, several have demonstrated particularly significant operational contributions. Port Community Systems provide a neutral electronic platform that enables standardized information exchange among public and private stakeholders, thereby reducing duplication of data, improving transparency, and facilitating collaborative logistics processes (Osório et al., 2015). Terminal Operating Systems optimize berth allocation, yard planning, equipment scheduling, and container handling, contributing to higher throughput and more efficient resource utilization (Hirata et al., 2022; Moe & Mikalsen, 2020). Electronic Data Interchange accelerates customs documentation and administrative processes by enabling standardized electronic communication among shipping lines, customs authorities, freight forwarders, and terminal operators. Meanwhile, IoT technologies continuously monitor equipment conditions, vessel movements, yard occupancy, and operational performance through interconnected sensor networks, while AI applications support predictive maintenance, congestion forecasting, equipment scheduling, and strategic decision-making using large volumes of operational data (Castellanos et al., 2024; Fanti et al., 2017; Klisenko & Serral, 2022). Nevertheless, the literature consistently emphasizes that the effectiveness of these technologies depends on interoperability, governance quality, cybersecurity, and organizational readiness rather than technology adoption alone (Dimakopoulou & Rantos, 2024).

Despite the growing body of literature, several important knowledge gaps remain unresolved. Existing studies have predominantly focused on conceptual models, technological architectures, quantitative performance indicators, or experiences from highly developed ports. Comparatively less attention has been devoted to understanding digital transformation from the perspectives of multiple stakeholders operating within developing maritime economies. Furthermore, while many studies acknowledge the importance of interoperability, governance, cybersecurity, institutional coordination, and human capital, empirical investigations explaining how these factors influence operational performance remain relatively limited (Aerts & Mathys, 2024; Mehdiabadi et al., 2020).

Additional research is also required to validate smart port maturity models across diverse institutional settings, examine digital transformation beyond individual technologies, and investigate the interaction between digital innovation, organizational change, and operational outcomes in integrated port ecosystems (Klar et al., 2024; Hirata et al., 2022). These gaps are particularly relevant for Indonesia, where variations in infrastructure readiness, digital capability, and institutional coordination may significantly influence the effectiveness of digital transformation initiatives.

Addressing these limitations requires an empirical investigation that captures the experiences of multiple organizations participating in port logistics operations. Rather than examining a single technology or a single stakeholder group, this study adopts a qualitative multiple-stakeholder perspective to explore how digital transformation is implemented across Indonesian port logistics, how digital technologies generate operational opportunities, and how these opportunities translate into improved operational performance. The study incorporates perspectives from port authorities, terminal operators, information technology managers, customs officials, shipping companies, freight forwarders, operational personnel, academics, and government regulators to develop a comprehensive understanding of digital transformation within the Indonesian port ecosystem. Such an approach enables the identification of converging and diverging perspectives regarding technology implementation and its operational implications.

Accordingly, the objective of this study is to examine the implementation of digital technologies in Indonesian port logistics and to analyze how these technologies contribute to operational performance improvement. Specifically, the research investigates the adoption of integrated digital technologies, identifies the operational opportunities generated through digitalization, and explores their influence on logistics efficiency, transparency, coordination, and service quality. By providing qualitative evidence from multiple stakeholder perspectives within an emerging maritime economy, this study contributes to the literature on Digital Transformation and Smart Port development. Its principal novelty lies in integrating technology implementation, operational opportunities, and operational performance into a single analytical framework grounded in empirical evidence from Indonesia. The findings are expected to enrich theoretical discussions on digital transformation while offering practical recommendations for policymakers, port authorities, and logistics organizations seeking to strengthen sustainable smart-port development and improve national logistics competitiveness.

## METHOD

### Research Design

This study adopted a qualitative research approach using a multiple-case study design to investigate digital transformation in Indonesian port logistics. A qualitative approach was considered appropriate because the phenomenon under investigation involves complex interactions among technology, organizational processes, institutional arrangements, and multiple stakeholder groups

that cannot be adequately explained through quantitative measurements alone. Digital transformation within port logistics is inherently socio-technical, requiring an in-depth understanding of how digital technologies are implemented, interpreted, and utilized by organizations operating within interconnected logistics ecosystems. Multiple-case study research enables the exploration of these complex phenomena within their real-life contexts while facilitating comparisons across different organizational settings (Carlan et al., 2017).

The use of multiple-case studies has become increasingly common in digital transformation research within logistics and maritime transportation because it captures variations in governance arrangements, technology configurations, institutional contexts, and digital maturity across ports. Comparative case analysis allows researchers to identify common implementation patterns while recognizing contextual differences that influence digital transformation outcomes. Previous studies have demonstrated that comparing multiple ports provides richer explanations of how technologies such as Port Community Systems (PCS), Terminal Operating Systems (TOS), Internet of Things (IoT), Artificial Intelligence (AI), and digital twins interact with organizational capabilities, stakeholder collaboration, and regulatory environments (He et al., 2023; Seo et al., 2022). Accordingly, the present study adopts a qualitative multiple-case perspective to understand how digital technologies contribute to operational performance within Indonesian port logistics.

The cases were selected purposively to represent ports with relatively advanced digitalization initiatives and complex logistics operations. Case selection considered differences in operational scale, digital maturity, institutional arrangements, stakeholder diversity, and technology implementation. Such variation supports analytical rather than statistical generalization by allowing the identification of transferable insights applicable to developing maritime economies (Philipp et al., 2021; Castellanos et al., 2024). Consistent with previous studies, particular attention was given to interoperability, governance structures, and cross-organizational collaboration as critical dimensions of successful digital transformation (Klar et al., 2024; Klar et al., 2023).

The unit of analysis was the digital transformation process within port logistics operations. This encompasses the implementation and integration of digital technologies across vessel management, terminal operations, customs clearance, cargo handling, documentation, container tracking, gate operations, digital payment, information exchange, and operational decision-making. By focusing on organizational processes rather than individual technologies, the study examines how digital transformation reshapes operational performance through integrated logistics systems.

## Research Participants

Purposive sampling was employed to recruit participants possessing direct experience with digital transformation in port logistics. Purposive sampling is widely recommended in qualitative case study research because it facilitates the selection of knowledgeable informants capable of providing rich and relevant information regarding the phenomenon under investigation. Data saturation, rather than statistical representativeness, determined the adequacy of the sample. Interviews

continued until no substantially new themes emerged, consistent with recommendations in qualitative logistics research (Pobelow et al., 2023; Sindi & Woodman, 2020).

Nine stakeholder groups participated in this study, representing the principal organizations involved in Indonesian port logistics: a Digital Transformation Manager, Container Terminal Operations Manager, Head of Information Technology, Customs Officer, Shipping Line Representative, Freight Forwarder Manager, Terminal Operator, Smart Port Academic, and Government Regulator. This diverse participant composition enabled the study to capture multiple organizational perspectives concerning technology implementation, operational integration, institutional coordination, and logistics performance.

## Data Collection

Primary data were collected through semi-structured interviews because this method provides sufficient flexibility to explore participants' experiences while maintaining consistency across interviews. Semi-structured interviews are widely adopted in qualitative investigations of port digitalization due to their ability to generate detailed explanations of technology implementation, organizational change, interoperability challenges, governance arrangements, and operational outcomes (Cunha et al., 2023; Paredis et al., 2021).

The interview protocol was developed directly from the research objectives and focused on five principal areas: digital technologies implemented within port logistics, operational opportunities resulting from digital transformation, organizational experiences during implementation, perceived improvements in operational performance, and future directions for smart-port development. Open-ended questions encouraged participants to elaborate on their practical experiences while allowing emerging issues to be explored further during interviews.

To strengthen the credibility of the findings, interview data were complemented by documentary evidence, including organizational reports, digital transformation policies, publicly available regulations, and technical documentation describing the implementation of digital systems. Documentary analysis provided contextual understanding of institutional arrangements and enabled triangulation between participants' accounts and organizational practices. Previous qualitative studies similarly recommend combining interviews with documentary evidence to improve interpretation of digital transformation processes within complex logistics environments (Paredis et al., 2021).

## Data Analysis

The interview data were analyzed using Braun and Clarke's thematic analysis, which has become one of the most widely accepted analytical approaches for qualitative research in logistics and maritime transportation. Thematic analysis enables researchers to identify, organize, interpret, and

report recurring patterns across interview datasets while maintaining close connections with participants' perspectives (Fadiga et al., 2024).

The analysis followed six sequential stages. First, all interview transcripts were read repeatedly to achieve data familiarization and develop a comprehensive understanding of participants' experiences. Second, initial codes were generated through systematic examination of the transcripts, combining deductive codes derived from the research questions with inductive codes emerging directly from participants' narratives. Third, related codes were grouped into broader categories representing shared concepts. Fourth, categories were organized into candidate themes describing key dimensions of digital transformation within Indonesian port logistics. Fifth, candidate themes were reviewed, refined, and validated against the complete dataset to ensure conceptual consistency and empirical support. Finally, themes were interpreted in relation to existing literature on digital transformation, smart ports, interoperability, governance, and operational performance.

NVivo qualitative data analysis software was employed to facilitate transcript management, coding, code retrieval, and theme development. The software enhanced transparency by maintaining an organized coding structure and supporting systematic comparisons among participant groups. The final analysis generated three overarching themes: digital technology implementation, operational opportunities, and operational performance. These themes collectively explain how integrated digital technologies reshape logistics operations and contribute to improved port performance.

## Research Trustworthiness

Several strategies were employed to enhance the trustworthiness, credibility, dependability, confirmability, and transferability of the study. First, methodological triangulation was achieved by integrating interview data with documentary evidence, thereby reducing dependence on a single source of information. Source triangulation was further strengthened through interviews with multiple stakeholder groups representing different organizational perspectives, allowing cross-validation of emerging findings (Hirata et al., 2022).

Second, a comprehensive audit trail was maintained throughout the research process, documenting interview procedures, coding decisions, analytical memos, theme refinement, and methodological choices. Maintaining transparent documentation enhances confirmability and enables external reviewers to understand how interpretations were derived (Dao et al., 2018; Porcellato et al., 2015).

Third, researcher reflexivity was practiced by acknowledging potential assumptions during data interpretation and continuously comparing emerging findings with the complete dataset to minimize interpretive bias. Fourth, data saturation guided participant recruitment, ensuring that interviews continued until additional data no longer generated substantively new analytical insights (Kassai et al., 2020; Pobelov et al., 2023). Fifth, preliminary interpretations were discussed with domain experts and selected participants to verify the credibility and accuracy of the identified

themes, consistent with member-checking practices recommended in qualitative research (Dao et al., 2018; Kassai et al., 2020).

Finally, the study adhered to established qualitative research principles and thematic analysis procedures proposed by Braun and Clarke while maintaining transparent reporting of research design, sampling strategy, data collection, coding procedures, and analytical decisions. Such methodological transparency improves the rigor, replicability, and transferability of qualitative investigations into digital transformation in port logistics (Castellanos et al., 2024; Dao et al., 2018). Through these procedures, the study provides a robust methodological foundation for examining how digital technologies influence operational performance and organizational transformation within Indonesian port logistics.

## RESULT AND DISCUSSION

### Digital Technology Implementation

The thematic analysis indicates that Indonesian ports have progressed from isolated digital applications toward integrated digital logistics ecosystems. Across all nine stakeholder groups, participants consistently described the implementation of Port Community Systems (PCS), Terminal Operating Systems (TOS), Electronic Data Interchange (EDI), Internet of Things (IoT), automated gate systems, RFID, container tracking, digital payment platforms, and emerging Artificial Intelligence (AI)-based analytics.

The Digital Transformation Manager (INF-01) explained that digitalization has expanded significantly over the last five years:

"During the last five years, we have aggressively digitalized almost every business process. Initially, digitalization focused only on ship documentation, but it has expanded to terminal operations, electronic payment, container tracking, and digital data exchange among institutions. The primary objectives are to reduce service time, improve transparency, and strengthen coordination among stakeholders." (INF-01)

The participant further identified the principal technologies currently deployed:

"We currently use the Port Community System, Terminal Operating System, Electronic Data Interchange, automated gate system, RFID, IoT-based operational dashboards, container tracking, and digital payment. Some terminals have also started implementing predictive analytics to forecast yard congestion." (INF-01)

These findings were corroborated by the Head of Information Technology (INF-03), who emphasized that digital transformation also requires robust technological infrastructure:

"Overall, our digital infrastructure is well established. We have a data center, cloud backup, disaster recovery system, and fiber-optic network covering the entire terminal." (INF-03)

The interview data demonstrate that technology implementation extends beyond the adoption of individual applications and increasingly emphasizes system integration. This observation is consistent with previous studies identifying PCS, TOS, IoT, AI, and interoperable digital platforms as the technological foundation of smart ports and digitally integrated logistics ecosystems (Aerts & Mathys, 2024; Castellanos et al., 2024; Hirata et al., 2022).

However, participants also acknowledged that successful implementation depends on organizational and institutional readiness rather than technology alone. As noted by INF-01:

"The biggest challenge is not the technology itself but organizational culture. Some employees are still accustomed to manual processes, while system integration with external institutions is often constrained by different platforms and data standards." (INF-01)

Similarly, the IT Manager highlighted interoperability as a continuing technical challenge:

"Integrating legacy systems with new applications remains our biggest technical challenge because many systems were developed on different platforms and therefore require middleware." (INF-03)

## **Operational Opportunities**

The second theme demonstrates that digital transformation has generated substantial operational opportunities throughout Indonesian port logistics. Participants consistently reported improvements in operational speed, service quality, transparency, and coordination.

The Digital Transformation Manager emphasized the operational impact of digitalization:

"Vessel services have become much faster because most documentation is processed electronically. Truck turnaround time has also decreased because gate operations are automated. Moreover, coordination among institutions has become more transparent because operational data can now be monitored in real time." (INF-01)

These observations were reinforced by the Terminal Operations Manager (INF-02), who described improvements in terminal productivity:

"The most significant change has occurred in container handling. Previously, container placement relied heavily on manual decisions, whereas now all activities are managed through the Terminal Operating System, making container allocation much more efficient." (INF-02)

Regarding operational performance, the same participant added:

"Crane productivity has increased because equipment scheduling is now more accurate. Errors in recording container locations have also been significantly reduced." (INF-02)

Users of port services reported similar benefits. The Freight Forwarder Manager (INF-06) explained:

"Booking, payment, container tracking, and document processing have become much easier because almost everything can now be completed online." (INF-06)

Likewise, the Shipping Line Representative (INF-05) stated:

"We now have much better certainty regarding vessel schedules. Information about vessel positions, container status, and documentation can all be monitored online, reducing our operational costs." (INF-05)

These empirical findings support previous studies demonstrating that integrated digital platforms improve berth planning, cargo handling efficiency, logistics visibility, and overall service quality through real-time information sharing and coordinated decision-making (Min, 2022; Cunha et al., 2023; Seo et al., 2022).

## **Operational Performance**

The final theme demonstrates that digital transformation contributes to improved operational performance through enhanced productivity, coordination, information visibility, and decision-making.

Operational personnel confirmed that digital technologies have fundamentally changed day-to-day work practices. The Terminal Operator (INF-07) stated:

"Almost all operational activities are now carried out using tablets and computers. We no longer carry paper forms as we did before." (INF-07)

When asked about the benefits, the participant explained:

"Input errors have decreased, and our work can now be completed much faster." (INF-07)

From the perspective of information technology management, operational performance improvements are increasingly supported by data-driven decision-making. According to INF-03:

"Our future priority is to implement AI for terminal congestion prediction, digital twins, and big data analytics so that operational decisions can be made more quickly." (INF-03)

The Government Regulator (INF-09) further emphasized that these operational improvements are aligned with national logistics policy:

"The government's priority is to strengthen national data integration, expand the implementation of the Port Community System, develop an AI- and IoT-based smart-port ecosystem, and enhance collaboration among government agencies, port operators, logistics companies, and the private sector." (INF-09)

Overall, the interview evidence indicates a clear progression from digital technology implementation to operational opportunities and ultimately to improved operational performance. Participants consistently perceived that integrated digital systems enhance efficiency, reduce operational errors, improve coordination among stakeholders, and strengthen logistics service quality. These findings reinforce previous studies arguing that interoperability among PCS, TOS, EDI, IoT, and AI platforms constitutes a critical mechanism through which digital transformation improves operational performance in modern port logistics (Klar et al., 2024; Klar et al., 2023).

The findings demonstrate that digital transformation has fundamentally reshaped operational processes within Indonesian port logistics through the implementation of integrated digital technologies, including the Port Community System (PCS), Terminal Operating System (TOS), Electronic Data Interchange (EDI), Internet of Things (IoT), automated gate systems, container tracking, digital payment platforms, and emerging Artificial Intelligence (AI)-based applications. Rather than functioning as isolated technological innovations, these systems operate as interconnected digital infrastructures that facilitate real-time information sharing, enhance operational visibility, and strengthen coordination among port authorities, terminal operators, customs agencies, shipping companies, freight forwarders, and government institutions. This finding supports Digital Transformation Theory, which argues that digital technologies generate organizational value not merely through automation but by enabling integrated workflows, data-driven decision-making, and capability enhancement across complex operational environments (Paraskevas et al., 2024; Wang & Sarkis, 2021). The interview findings further suggest that operational improvements arise from the interaction between technology, organizational processes, and institutional collaboration rather than from the implementation of any single technology.

The study also reinforces the central propositions of Smart Port Theory. Participants consistently reported that integrated digital platforms improved cargo visibility, vessel scheduling, customs clearance, equipment utilization, and operational transparency. These observations are consistent with previous studies indicating that smart ports combine advanced digital technologies with collaborative governance to optimize operational efficiency, resource utilization, and service quality (Min, 2022; Brunila et al., 2021; Seo et al., 2022; Castellanos et al., 2024). In the present study, the implementation of PCS and TOS enabled seamless information exchange across organizational boundaries, while IoT and AI supported real-time monitoring and predictive decision-making. Such integration reflects the evolution of Indonesian ports toward data-driven logistics ecosystems in which operational performance depends on continuous information flows rather than isolated physical operations.

An important contribution of this study concerns the role of interoperability as the principal mechanism linking technology adoption with operational performance. Although participants acknowledged the benefits of PCS, TOS, EDI, and IoT, they repeatedly emphasized that performance improvements were achieved only when these technologies operated as integrated systems. Differences in data standards, legacy applications, and incompatible digital platforms were identified as continuing constraints that limited operational integration. These findings corroborate previous research highlighting interoperability and data governance as prerequisites for realizing the full benefits of digital transformation (Klar et al., 2024; Klar et al., 2023; Hirata et al., 2022). Accordingly, the present findings suggest that investments in digital infrastructure should be accompanied by standardized data governance, common interoperability protocols, and institutional agreements that facilitate secure information exchange among stakeholders.

The qualitative evidence obtained from Indonesian ports largely aligns with findings reported in mature port systems worldwide while also revealing context-specific challenges. Similar to experiences reported in European ports such as Rotterdam and Hamburg, participants perceived that integrated digital platforms improve coordination, reduce administrative delays, and strengthen logistics visibility through electronic information exchange and collaborative decision-making ((Redekar et al., 2025; Simola et al., 2024). However, unlike many highly digitalized ports where interoperability frameworks and governance mechanisms are already well established, Indonesian stakeholders identified organizational readiness, uneven digital maturity, workforce capability, and institutional coordination as continuing barriers to achieving fully integrated smart-port ecosystems. These observations support previous studies emphasizing that the effectiveness of digital transformation in developing economies depends not only on technological investment but also on governance capacity, stakeholder alignment, and organizational learning (Philipp et al., 2021; Brunila et al., 2021; Li et al., 2020).

The findings generate several managerial and policy implications. For port authorities and terminal operators, digital transformation should be approached as an organizational transformation rather than solely as an information technology project. Continuous investment in interoperable digital platforms, integrated operational databases, and AI-enabled decision-support systems should be complemented by workforce development programs, organizational change management, and stakeholder engagement. Participants repeatedly emphasized that employee training and digital capability development were essential for reducing resistance to change and ensuring effective technology utilization. These findings reinforce previous recommendations that organizational readiness and human capital development constitute critical determinants of successful smart-port implementation ((Kassai et al., 2020; Sibley & Amare, 2017).

From a policy perspective, the findings highlight the importance of strengthening national governance frameworks supporting digital interoperability. Government agencies should continue expanding standardized data exchange protocols, harmonizing regulations across institutions, and strengthening cybersecurity governance for increasingly interconnected port information systems. The interview evidence demonstrates that institutional coordination remains fundamental to successful digital transformation, particularly in environments where customs authorities, port operators, shipping companies, logistics providers, and regulators operate under different

administrative structures. Consequently, policies supporting shared governance, standardized digital platforms, and cross-agency collaboration will be essential for accelerating Smart Port development and maximizing the benefits of the National Logistics Ecosystem. These recommendations are consistent with previous studies emphasizing governance, interoperability, cybersecurity, and collaborative institutional arrangements as strategic priorities for digital transformation in maritime logistics (Dimakopoulou & Rantos, 2024; Paredis et al., 2021; Hirata et al., 2022).

Although this study provides comprehensive qualitative evidence regarding digital transformation in Indonesian port logistics, several opportunities for future research remain. First, comparative studies involving a larger number of ports and countries would improve understanding of how differences in governance structures, digital maturity, and institutional capacity influence digital transformation outcomes. Second, future research should combine qualitative findings with quantitative operational indicators such as vessel turnaround time, berth productivity, cargo dwell time, logistics costs, and energy efficiency to establish stronger causal relationships between digitalization and operational performance. Third, greater attention should be devoted to cybersecurity governance, digital twin interoperability, blockchain-enabled logistics platforms, and AI-supported predictive analytics as emerging components of next-generation smart ports. Finally, longitudinal research examining organizational learning, stakeholder collaboration, and institutional change would provide valuable insights into how digital transformation evolves over time and contributes to sustainable maritime logistics. Collectively, these research directions will strengthen both theoretical understanding and practical implementation of digital transformation while supporting the continued development of resilient, interoperable, and sustainable smart-port ecosystems.

## CONCLUSION

This study examined how digital transformation has been implemented in Indonesian port logistics and how integrated digital technologies contribute to operational performance. Using a qualitative multiple-case study approach, the findings demonstrate that Indonesian ports have progressively adopted a wide range of digital technologies, including the Port Community System (PCS), Terminal Operating System (TOS), Electronic Data Interchange (EDI), Internet of Things (IoT), automated gate systems, RFID, container tracking, digital payment platforms, and Artificial Intelligence (AI)-based predictive analytics. Rather than functioning independently, these technologies increasingly operate as an integrated digital ecosystem that supports information sharing, operational coordination, and data-driven decision-making among multiple stakeholders within the port logistics network.

The findings reveal that digital transformation generates significant operational opportunities by improving vessel turnaround, cargo handling efficiency, logistics visibility, operational transparency, and service quality. Integrated digital platforms enable real-time information exchange between port authorities, terminal operators, customs agencies, shipping companies, freight forwarders, and government institutions, thereby reducing administrative delays,

minimizing operational errors, improving equipment utilization, and strengthening organizational coordination. The study further demonstrates that the operational benefits of digital transformation are not derived solely from technological deployment but from the successful integration of technologies with organizational processes, institutional collaboration, and governance mechanisms.

Another important finding is that interoperability, data governance, and stakeholder collaboration represent the principal determinants of successful digital transformation. Although advanced digital technologies have been implemented across Indonesian ports, participants consistently emphasized that differences in digital maturity, legacy information systems, organizational readiness, workforce capability, and institutional coordination continue to constrain the realization of fully integrated smart-port ecosystems. These findings suggest that technology investment alone is insufficient to achieve sustainable operational improvements unless accompanied by standardized data exchange, effective governance structures, cybersecurity management, and continuous organizational learning.

The study contributes to the literature on Digital Transformation Theory and Smart Port Theory by providing empirical qualitative evidence from an emerging maritime economy. While previous studies have largely emphasized technological innovation or quantitative performance indicators, this research demonstrates that operational performance is influenced by the interaction between digital technologies, organizational capabilities, institutional governance, and inter-organizational collaboration. By integrating these dimensions into a single analytical framework, the study extends current understanding of how digital transformation creates value within complex port logistics ecosystems.

From a practical perspective, the findings provide several implications for policymakers, port authorities, and logistics operators. Port managers should prioritize the integration of interoperable digital platforms, strengthen organizational capabilities, and invest in workforce digital competencies to maximize the benefits of technological innovation. Government agencies should continue promoting standardized data governance, harmonized regulations, cybersecurity frameworks, and cross-institutional collaboration to support the National Logistics Ecosystem and accelerate smart-port development. These measures are expected to improve national logistics competitiveness while enhancing operational resilience and service quality across Indonesian ports.

Despite these contributions, this study has several limitations. The qualitative design and purposive sampling strategy emphasize analytical depth rather than statistical generalization, and the findings are derived from a limited number of stakeholder groups within Indonesian port logistics. Consequently, the results should be interpreted within the institutional and operational context of the selected cases.

Future research should expand comparative investigations across a broader range of ports and countries to examine how differences in digital maturity, governance arrangements, and institutional capacity influence digital transformation outcomes. Mixed-method studies integrating qualitative evidence with quantitative operational indicators such as vessel turnaround time, berth

productivity, cargo dwell time, logistics costs, energy efficiency, and customer service performance would strengthen causal explanations regarding the impact of digitalization on port performance. Additional research is also recommended on digital twin interoperability, AI-driven operational optimization, blockchain-enabled logistics platforms, cybersecurity governance, and sustainable smart-port development to support the continued evolution of digital maritime logistics.

Overall, this study concludes that digital transformation represents a strategic enabler of operational excellence in Indonesian port logistics. The successful realization of smart-port development depends not only on the adoption of advanced digital technologies but also on the ability of organizations and institutions to establish interoperable systems, collaborative governance, and data-driven operational practices that collectively improve efficiency, transparency, resilience, and long-term competitiveness.

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