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Implementation of Port Operations Digitalization at the Talang Duku Port Container Terminal Jambi

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Abstract: This study aims to analyze the implementation of port operational digital transformation through the adoption of the Nusantara Terminal Operating System (TOS), the operational performance following digitalization, and the challenges encountered during its implementation at the Talang Duku Container Terminal, Jambi. A descriptive qualitative approach was employed, with data collected through interviews and questionnaires involving terminal operational employees, information technology staff, terminal supervisors, and company management. The data were analyzed using thematic analysis supported by NVivo through coding, word-cloud visualization, an audit trail, and triangulation of sources, methods, and theories. The findings indicate that Nusantara TOS has integrated planning, billing, gate operations, loading and unloading, receiving, delivery, monitoring, and reporting into a real-time, data-based system. Digitalization has improved work efficiency, service speed, information accuracy, interdepartmental coordination, operational monitoring, decision-making, workplace safety, and service quality for port users. However, the implementation has not yet reached its optimal level due to network and signal instability, legacy-system integration issues, data-format differences, data-flagging problems, field-device readiness, and user adaptation. Therefore, optimizing digital transformation requires stronger information technology infrastructure, improved system integration, and continuous development of human resource competencies.

Keywords: Digital Transformation, Nusantara TOS, Port Operational Digitalization, Operational Performance, Container Terminal.

INTRODUCTION

Ports play a strategic role as key nodes in the national supply chain; poor port performance leads to increased logistics costs, prolonged loading and unloading times, and

disruptions in commodity distribution, all of which negatively impact national economic efficiency and trade competitiveness (Sunitiyoso et al., 2022)

In many container terminals, operational inefficiencies are not solely caused by physical infrastructure limitations but also by fragmented management systems, limited system integration, and the continued reliance on manual processes. International studies have shown that digitalization, automation, real-time data integration, and smart port technologies can improve terminal efficiency, operational transparency, equipment utilization, and service reliability.

Table 1. Throughput of PT IPC Terminal Petikemas Jambi (2018–2025)

NO.	URAIAN	TAHUN							
		2018	2019	2020	2021	2022	2023	2024	2025
1	DALAM NEGERI								
	BOX	15.804	12.475	11.902	12.381	14.679	11.267	13.803	11.166
	TEUS	17.051	13.641	13.309	14.096	16.263	13.566	16.051	13.215
2	LUAR NEGERI								
	BOX	23.431	22.797	19.676	20.289	17.615	16.134	15.016	9.552
	TEUS	31.925	32.891	27.146	27.602	23.861	21.430	19.761	12.492
3	TOTAL								
	BOX	39.235	35.272	31.578	32.670	32.294	27.401	28.819	20.718
	TEUS	48.976	46.532	40.455	41.698	40.124	34.996	35.812	25.707

Talang Duku Container Terminal in Jambi represents an important regional logistics node supporting the distribution of commodities in central Sumatra (Agustina, 2019). However, the terminal has experienced a substantial decline in container throughput, from 48,976 TEUs in 2018 to 25,707 TEUs in 2025, representing a decrease of more than 47%. Although external factors such as the COVID-19 pandemic and global economic slowdown contributed to this decline, persistent operational challenges indicate internal constraints, particularly the use of a semi-manual and insufficiently integrated terminal management system. These conditions have affected cargo-handling efficiency, service time, information flow, equipment utilization, and operational safety.

To address these challenges, PT Pelindo introduced TOS Nusantara, an integrated Terminal Operating System designed to connect vessel planning, equipment scheduling and dispatching, yard management, container tracking, gate operations, and billing within a unified digital platform. The implementation represents not merely a replacement of the previous IPC Terminal Operating System (ITOS), but a broader transformation from manual coordination toward integrated, real-time, and data-driven terminal operations. Accordingly, this study examines the implementation of digital transformation at Talang Duku Container Terminal, evaluates operational performance following digitalization, and identifies the technical, human-resource, organizational, and infrastructure-related challenges encountered during the implementation and adaptation process. By focusing on the interaction between systems, operational processes, and human factors, the study is expected to provide practical insights for strengthening digital transformation in regional ports and supporting similar initiatives across Indonesia.

METHOD

This study adopts a qualitative descriptive research design to examine operational changes following the implementation of TOS Nusantara at the Talang Duku Container Terminal Jambi. Informants were selected through purposive sampling, involving terminal operational employees, IT staff, supervisors, and management personnel directly involved in the system transition. Data were collected through semi-structured in-depth interviews, non-

participant observation, and documentation, supported by internal company reports, official publications, and relevant academic literature. The data were analyzed using thematic analysis, consisting of systematic coding, code categorization, theme identification, and thematic interpretation to identify operational changes, implementation challenges, user adaptation, and the impacts of TOS Nusantara on terminal performance. The qualitative data were analysed using NVivo through systematic coding and thematic classification to identify key patterns, relationships, and strategic findings.

RESULTS AND DISCUSSION

How is the digital transformation of port operations implemented at the Talang Duku Port Container Terminal in Jambi?

The digital transformation of port operations at the Talang Duku Jambi Container Terminal is implemented through the TOS Nusantara, which shifts operational processes from manual practices toward a more integrated, real-time, automated, and data-driven system. Its implementation covers system integration, real-time information, process automation, operational efficiency, decision-making support, human resource readiness, and service quality improvement.

Table 2. Summary of Digital Transformation

Dimension	Main Finding	Assessment
System Integration	Billing, gate, planning control, and field access are increasingly connected through TOS Nusantara.	Achieved
Real-Time Information	Container positions, status, and track-and-trace information are available more rapidly.	Achieved
Process Automation	Receiving, delivery, monitoring, recording, equipment assignment, and reporting are increasingly system-based.	Partially achieved
Operational Efficiency	Work is perceived as faster, more structured, and less dependent on manual coordination.	Achieved
Decision Support	System data supports monitoring, validation, reporting, and operational control.	Partially achieved
Human Resource Readiness	Users have adapted but still need training, assistance, and refreshment.	Partially achieved
Service Quality	Services are perceived as faster, more accurate, transparent, and easier to monitor.	Achieved

Source: Research Results

The findings indicate that digital transformation at the Talang Duku Jambi Container Terminal has successfully established a foundation for more integrated, real-time, and data-driven operations through the implementation of **TOS Nusantara**. This finding is consistent with Sahraoui et al., (2023), who demonstrated that the implementation of a Terminal Operating System (TOS) can improve terminal productivity and operational performance by facilitating more integrated management of activities from berth to gate. System integration, real-time information availability, operational efficiency, and service quality improvement emerged as the most prominent outcomes, supporting previous studies which emphasize that port digitalization can enhance information flows, operational efficiency, productivity, and coordination when supported by interoperable digital systems (Brunila et al., 2021). However, process automation, decision-making support, and human resource readiness remain partially developed, indicating that the terminal has not yet reached a fully mature stage of digital

transformation. This condition is consistent with Utama et al., (2024), who identified technology adoption, system integration, and differences in digital maturity as key challenges in the digital transformation of Indonesian ports. Although TOS Nusantara has improved workflow efficiency, coordination, monitoring, and information accessibility, several challenges persist, including network reliability, electricity supply, data integration, and user adaptation. Similar challenges have been highlighted by Brunila et al., (2021), particularly regarding system interoperability, technological infrastructure, information sharing, resource limitations, and the need for appropriate human resource competencies in port digitalization. Therefore, further improvements in IT infrastructure, system interoperability, and continuous employee training are required to achieve a more mature, resilient, and sustainable level of digital transformation.

What is the operational performance of the Talang Duku Port Container Terminal in Jambi following the implementation of port operational digitalization?

The implementation of TOS Nusantara has improved operational performance at the Talang Duku Jambi Container Terminal by increasing process efficiency, information accessibility, coordination effectiveness, resource utilization, and service quality. Prior to digitalization, several operational activities relied on additional personnel and manual information delivery, particularly in communicating container planning information to crane operators. Following the implementation of TOS Nusantara, planning data can be accessed directly through connected devices, reducing dependence on intermediary personnel and shortening coordination processes. Overall, the digital system has contributed to faster, more efficient, and better-integrated terminal operations.

Table 3. Comparative Analysis of Operational Performance Before and After TOS Nusantara Implementation

No.	Operational Performance Aspect	Before TOS Nusantara Implementation	After TOS Nusantara Implementation	Impact on Operational Performance
1	Operational Information Flow	Operational information still required manual coordination and communication for several activities.	Operational information can be accessed more rapidly and in real time through the integrated system.	Information delivery time is reduced, resulting in faster and more effective operational coordination.
2	Loading and Unloading	Operators required additional personnel to obtain certain container planning information.	Operators can directly access planned container information through devices connected to TOS Nusantara.	Operational activities become more independent, faster, and better coordinated.
3	Receiving and Delivery	Container location identification and status updating still involved several manual procedures.	Container locations can be identified and operational status can be updated directly through the system.	Service processing time and truck movement within the terminal become more efficient.
4	Coordination	Information exchange largely depended on direct communication between operational units.	Operational data can be accessed and shared by planning, gate, field operations, and monitoring units.	Coordination becomes faster and discrepancies in operational information are reduced.

No.	Operational Performance Aspect	Before TOS Nusantara Implementation	After TOS Nusantara Implementation	Impact on Operational Performance
5	Workforce Utilization	Additional personnel were required to support the delivery of operational information in the field.	Some information-delivery functions are performed through the digital system.	Workforce utilization becomes more efficient, allowing personnel to be reassigned to other operational functions.
6	Operational Monitoring and Control	Operational monitoring required the collection of information from several different units.	Operational progress can be monitored through data available within the system.	Monitoring becomes faster and provides stronger support for operational control and decision-making.
7	Equipment Utilization	Equipment instructions and movements were still influenced by manual coordination.	Operators can directly access container planning and location information through the system.	Equipment utilization becomes more systematic and unnecessary movements can be minimized.
8	Operational Safety	The involvement of additional personnel increased the number of workers present within operational areas.	Reduced dependence on supporting personnel decreases the presence of workers around equipment movement areas.	Workers' exposure to operational hazards can be reduced, thereby supporting a safer working environment.
9	Service Quality for Terminal Users	Service-related information required a longer time to obtain and verify.	Service status information can be accessed more rapidly, accurately, and transparently.	Services become more responsive and easier for terminal users to monitor.

Source: Research Results

The implementation of TOS Nusantara has improved operational performance at the Talang Duku Jambi Container Terminal by accelerating information flow, simplifying operational processes, and reducing dependence on manual communication. Digitalization supports more efficient receiving, delivery, and container-handling activities while optimizing the use of labor, equipment, and operational time.

The system also strengthens real-time monitoring, coordination, decision-making, and workplace safety by reducing unnecessary personnel in operational areas. However, these improvements remain dependent on reliable networks, servers, field devices, and technical support. Overall, TOS Nusantara has enhanced the quality, efficiency, and responsiveness of terminal operations, although the findings primarily reflect informants' perceptions of improved operational processes rather than quantitative productivity measurements.

What obstacles and challenges are encountered during the process of implementing and adapting to digital transformation at the Talang Duku Port Container Terminal in Jambi?

The implementation of TOS Nusantara at the Talang Duku Jambi Container Terminal has positively improved operational efficiency, coordination, and service quality. However, its implementation also faces several challenges, particularly related to system reliability, IT infrastructure, data migration and integration, human resource adaptation, and the need for continuous training and technical support.

Discussion

Implementation of Port Operational Digital Transformation

The implementation of digital transformation at the Talang Duku Jambi Container Terminal was examined through interviews and questionnaires involving operational employees, IT staff, terminal supervisors, and management. The findings indicate that the transition from IPC Terminal Operating System (ITOS) to TOS Nusantara has transformed terminal operations into a more integrated, automated, real-time, and data-driven system. The implementation has strengthened the integration of planning, execution, monitoring, and reporting processes while supporting operational efficiency, decision-making, human resource readiness, and service quality. However, further improvement is required in system integration, IT infrastructure reliability, continuous user training, and periodic system evaluation to ensure sustainable operational and service performance.

Operational Performance after Digitalization

The operational performance of the Talang Duku Jambi Container Terminal was assessed through interviews and questionnaires involving operational employees, IT staff, terminal supervisors, and management. The findings indicate that TOS Nusantara has improved service speed, information accessibility, coordination, and the organization of loading and unloading, receiving, and delivery activities. Digitalization has also enhanced the efficiency of time, labor, and operational resources through real-time access to container planning, position, and status information. In addition, reduced reliance on manual communication and unnecessary personnel in operational areas has supported more effective monitoring, decision-making, productivity, and workplace safety. However, further optimization requires regular performance measurement, improved system and network reliability, full utilization of TOS Nusantara features, and continuous user competency development.

Challenges and Constraints of Implementation

The challenges associated with TOS Nusantara implementation were identified through interviews and questionnaires involving operational employees, IT staff, terminal supervisors, and management. The findings indicate that digital transformation involves both technical and non-technical challenges, including legacy system integration, data format differences, network and signal instability, power and device disruptions, data flagging issues, user adaptation, further training needs, and changes in SOPs and work patterns. These challenges demonstrate that successful digitalization depends not only on system implementation but also on reliable IT infrastructure, consistent data integration, organizational readiness, and user competency. Therefore, continuous training, technical support, infrastructure improvement, and periodic system adjustments are required to ensure the sustainable implementation of TOS Nusantara.

Results of Management Using NVivo

Source: Research Results

Figure 1. Word Cloud Method

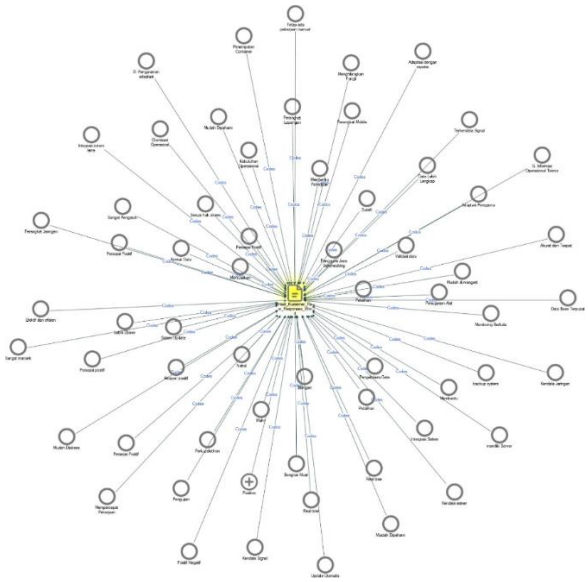
Overall, the word cloud indicates that TOS Nusantara is predominantly associated with easier processes, faster operations, greater efficiency, improved data management, and better service quality. However, since word clouds only reflect word frequency, the findings should be interpreted together with thematic coding, respondent quotations, and interview analysis to provide a more comprehensive understanding of digital transformation at the Talang Duku Jambi Container Terminal. as systematic coding and theme development are important for strengthening the rigor and interpretive depth of qualitative analysis (Allsop et al., 2022).

Table 4. NVivo Coding Results

Main Theme	Key Sub-Codes	Concise Interpretation
Work Process Transformation	Complete data; efficiency; real-time information; system updates; signal constraints	TOS Nusantara supports more integrated, efficient, and real-time workflows, although connectivity issues may affect system performance.
Information Accessibility	Accurate information; easy access; real-time data; signal constraints	Operational information becomes more accurate, accessible, and timely, supporting faster coordination and monitoring.
Work Efficiency	Faster processes; structured workflow; reduced manual activities	Digitalization accelerates operational activities and reduces reliance on manual processes, although some manual intervention remains necessary.
User Adaptation	Repetitive learning; initial difficulties; training needs; ease of use	User competence improves through practical experience and training, despite initial adaptation difficulties.
Service Quality	Self-checking; efficiency; service satisfaction; transparency	Digitalization improves service speed, transparency, accessibility, and overall service efficiency.
Technical Implementation	System testing; training; operational requirements; system integration	Implementation involves system testing, user preparation, and integration with operational requirements and supporting systems.
Operational Information Management	Automatic updates; access control; centralized database; data validation	The system enables controlled, centralized, and continuously updated operational data to support monitoring and decision-making.
Operational Automation	Equipment assignment; gate management; loading and unloading; container positioning	TOS Nusantara automates key terminal processes, improving operational consistency, coordination, and monitoring.
Technical Constraints	Data format; legacy-system integration; network; field devices; system disruptions	Technical challenges mainly concern data compatibility, connectivity, system integration, and supporting equipment reliability.
User and Infrastructure Readiness	Mobile devices; training; network equipment; servers; backup systems	Effective system utilization depends on user competence, adequate IT infrastructure, and reliable backup support.

Source: Research Results

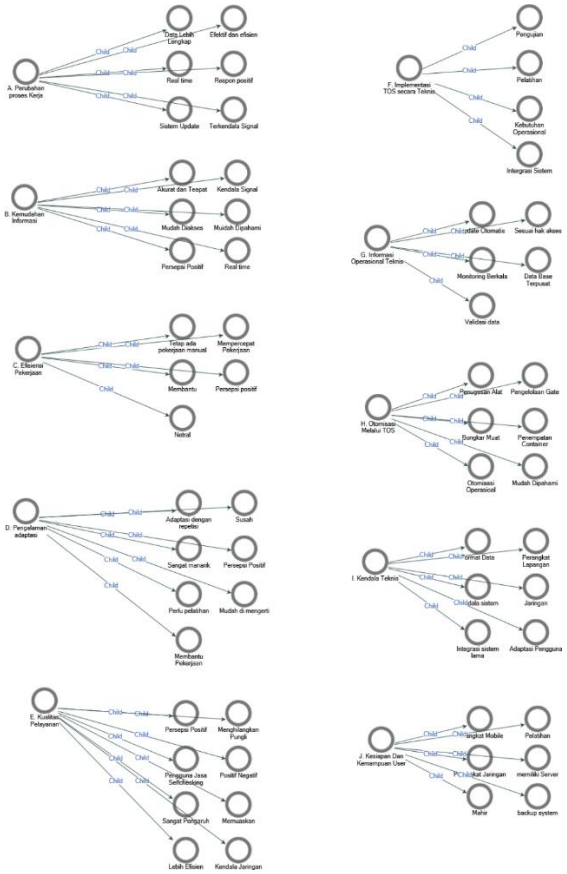
If illustrated, the result would look like this:



Source: Research Results

Figure 2. Node Method

Furthermore, the results of the thematic analysis of the interviews are shown in the figure below:



Source: Research Results

Figure 3. Node Method

Results of Triangulation Data Analysis

Table 5. Triangulation Results

Type of Triangulation	Source / Method	Key Findings	Validation
Source Triangulation	Terminal Operational Staff	TOS Nusantara simplifies operational activities, accelerates workflows, improves efficiency, and reduces manual processes.	Consistent with IT staff and supervisor findings on faster terminal operations.
	IT Staff	The system is integrated with billing, gate, planning, and yard-access functions, although network and data-integration constraints remain.	Confirms that digitalization has been implemented but is not yet technically optimal.
	Terminal Supervisor	Digitalization accelerates coordination, improves productivity, and supports operational decision-making.	Reinforces the finding that the system contributes positively to terminal performance.
	Company Management	Digitalization improves performance, cost efficiency, operational safety, and customer service.	Supports the strategic importance of digitalization for terminal performance improvement.
Methodological Triangulation	Open-ended Questionnaires and Interviews	Most respondents stated that the system is easier, faster, more accurate, and supportive of service delivery.	Provides the primary empirical basis for the study findings.
	NVivo Word Cloud	Dominant terms included “easy,” “better,” “fast,” “system,” “service,” and “efficient.”	Supports the generally positive perception of operational digitalization.
	NVivo Coding	Major themes included work-process changes, information accessibility, efficiency, adaptation, service quality, technical implementation, and technical constraints.	Validates interview findings through systematic thematic categorization.
Theoretical Triangulation	Port Digitalization Theory	Digitalization is reflected in system integration, real-time information, automation, efficiency, decision support, workforce readiness, and service quality.	Field findings are consistent with the theoretical dimensions applied in the study.
	Information Systems Theory	An effective information system should provide accurate, accessible, integrated data and support decision-making.	Consistent with findings on real-time data, centralized databases, data validation, and monitoring.
	Terminal Operational Performance Theory	Operational performance is reflected in service speed, productivity, resource efficiency, and service quality.	Findings indicate improvements in loading/unloading, receiving/delivery, coordination, and user services.

Source: Research Results

Based on data triangulation across multiple sources, methods, and theoretical perspectives, the findings indicate that the implementation of **TOS Nusantara** has significantly supported the digital transformation of operational activities at the Talang Duku Jambi Container Terminal. The system has enabled greater integration across operational planning, billing, gate activities, field operations, monitoring, and reporting. Its implementation was supported by system testing, operational adjustments, system integration, user training, and the

provision of supporting technological infrastructure. Overall, digitalization has contributed to faster, more effective, and more efficient operational processes by reducing manual activities, accelerating cargo handling, receiving, and delivery processes, and improving coordination and operational monitoring.

The findings further demonstrate that TOS Nusantara improves the availability, accuracy, accessibility, and real-time management of operational information through centralized databases, automated data updates, and validation mechanisms, thereby strengthening data-driven monitoring and decision-making. Users generally showed positive acceptance of the system, although continuous training and technical assistance remain necessary to optimize system utilization. Several implementation challenges were identified, including network instability, differences in data formats, integration with legacy systems, equipment readiness, technical system disruptions, and variations in user adaptability. Despite these constraints, digital transformation has positively influenced service quality by improving service speed, accuracy, transparency, accessibility, and reducing manual interactions. Therefore, sustainable optimization should focus on strengthening network reliability, data integration, backup infrastructure, system maintenance, and periodic user competency development to support long-term improvements in terminal productivity, operational safety, and service performance.

CONCLUSION

This study concludes that the digital transformation of Talang Duku Container Terminal through the implementation of TOS Nusantara is shaped by the interdependence of system integration, operational processes, technological infrastructure, human resource readiness, and managerial support. Based on data obtained from terminal operational employees, IT staff, terminal supervisors, and company management, the findings indicate that the transition from ITOS to TOS Nusantara has transformed terminal operations toward a more integrated, real-time, and data-driven working environment, particularly in planning, monitoring, loading and unloading, receiving, delivery, gate operations, and reporting.

The implementation has contributed to improvements in operational efficiency, service speed, information accessibility, interdepartmental coordination, data accuracy, and workplace safety by reducing reliance on manual processes and minimizing the need for additional personnel in operational risk areas. However, several technical and organizational constraints remain, including network and signal stability, supporting equipment limitations, integration with legacy systems, differences in data formats, specific system issues such as data flagging, as well as challenges related to user adaptation, changes in work patterns, training requirements, and consistent system utilization. Consequently, the successful implementation of TOS Nusantara cannot be achieved through technological deployment alone, but requires continuous improvement of digital infrastructure, stronger system integration, sustained human resource capacity development, standardized operational procedures, and consistent managerial support. Such an integrated approach is essential for optimizing the benefits of digital transformation, improving terminal productivity and service quality, strengthening operational safety, and supporting Talang Duku Container Terminal in developing a more efficient, responsive, and sustainable port operating environment.

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