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Analysis of the implementation of TOS upgrade and the use of VMT on operational performance with the accuracy of container data as an intervening variable at Terminal B of PT Belawan New Container Terminal

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Abstract
This study analyzes the impact of Terminal Operating System (TOS) Upgrade Implementation and Vehicle Mounted Terminal (VMT) Usage on Operational Performance, with Container Data Accuracy serving as an intervening variable at Terminal B of PT Belawan New Container Terminal (BNCT), Medan. The research is driven by the strategic necessity of digital transformation to enhance port efficiency. Using a quantitative approach, data were collected from 63 operational employees and analyzed with SmartPLS 4.1. The results demonstrate that both TOS Upgrade Implementation and VMT Usage have a positive and significant effect on Container Data Accuracy. Furthermore, Container Data Accuracy is found to influence Operational Performance significantly and serves as a vital mediator in the relationship between VMT Usage and overall operational outcomes. These findings suggest that integrating hardware and software systems minimizes manual errors and streamlines workflow. Managerial implications recommend that port authorities prioritize sustained investment in TOS-VMT integration and workforce digital literacy to maintain a competitive advantage. Ultimately, enhancing digital infrastructure is essential for optimizing data integrity and accelerating container throughput in modern port logistics.
Keywords: TOS Upgrade, Vehicle Mounted Terminal (VMT), Container Data Accuracy, Operational Performance.

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INTRODUCTION

In the contemporary era of Global Value Chains (GVC), the port industry serves as the backbone of international trade, facilitating the movement of over 80% of global goods. The rapid acceleration of digitalization, coupled with intensifying global competition, has compelled port authorities and terminal operators to transition from traditional labor-intensive models to high-technology driven operations. Innovation is no longer a peripheral strategy but a fundamental necessity to enhance operational efficiency, speed, and precision. Among the most critical technological advancements in this sector is the implementation of integrated systems such as the Terminal Operating System (TOS) and Vehicle Mounted Terminal (VMT). These dual technologies are widely recognized for their ability to significantly improve container data accuracy, which ultimately plays a pivotal role in the effectiveness of loading and unloading processes and in optimizing overall terminal operational performance (Carissa, 2023).

The transformation toward a high-technology-based ecosystem is a strategic response to the complexities of modern logistics. Modern ports are increasingly adopting an "Industry 4.0" framework, characterized by the integration of the Internet of Things (IoT), blockchain, and advanced data analytics. IoT enables real-time tracking of assets, providing visibility into every container's movement within the yard. Blockchain ensures the security and transparency of logistics transactions, while data analytics provides the empirical foundation for terminal operators to make measurable, information-based decisions. The systematic application of these technologies has been empirically shown to accelerate information flow, reduce operational costs, and increase the overall productivity of the port system (Septian, 2024). However, the success of these high-cost investments is highly contingent upon how well the hardware (VMT) and software (TOS) are integrated with the actual flow of physical goods.

PT Belawan New Container Terminal (BNCT), as one of the primary maritime hubs in Western Indonesia, has recognized this urgency by adopting a TOS Upgrade and implementing VMT at Terminal B. This initiative represents a strategic leap in the company's digital transformation roadmap. The TOS Upgrade is specifically engineered to extend automation features, enhance system integration, and provide a more robust database architecture. Complementing this, the VMT serves as the critical hardware interface, allowing machine operators such as those handling Rubber Tired Gantry (RTG) cranes and Head Trucks to access real-time work instructions and update container status directly from the field (Jamal, 2022). Despite the substantial capital expenditure involved in these upgrades, the expected improvements in operational performance have not yet been fully realized. Observations indicate technical and operational constraints that hinder synergy between the digital system and physical operations.

The digitalization of container terminals through a TOS Upgrade is theoretically a crucial step toward modernization because it minimizes human intervention in data processing, thereby reducing input delays and improving the synchronization between operational equipment (Gozali, 2024). Nevertheless, the current phenomenon at BNCT's Terminal B reveals a persistent "data-reality gap." Inconsistencies frequently occur between the digital inventory in the system and the actual physical conditions in the yard. These discrepancies manifest as container location errors, misidentification of units, and significant delays in loading and unloading cycles due to inaccurate data. Such inaccuracies create a ripple effect, leading to congestion in the terminal, increased dwell times, and ultimately, a decline in customer satisfaction and terminal competitiveness.

To further investigate these issues, a pre-survey was conducted involving 30 operational respondents at Terminal B. The findings were revealing: while the TOS Upgrade was perceived as relatively user-friendly, with an average score of 3.87, the actual perception of data accuracy was lower, at 3.15. Technical issues such as system glitches, slow input response times, and the lack of reliable real-time reporting were categorized in the "medium" performance range. This suggests that while the software exists, its implementation has not been optimized to support the high-pressure environment of port operations. Similarly, the use of VMT is acknowledged as a vital component for real-time operations, providing the necessary link for status updates and work instructions (Tasya, 2024). However, the pre-survey indicated that operator skill levels, network latency, and integration friction hamper VMT effectiveness. Despite a positive perception of VMT utility (3.80), specific metrics regarding data transmission speed (3.40), input precision (3.20), and the adequacy of technical training (3.30) showed significant room for improvement.

The criticality of container data accuracy cannot be overstated. In the context of a high-throughput terminal, data is the "digital twin" of the physical container; if the data is flawed, the physical operation stalls. Discrepancies lead to "ghost containers" (containers present in the system but not in the yard) or "misplaced containers," both of which force terminal tractors to wait and cranes to remain idle. The pre-survey on data accuracy confirmed this struggle: while the general suitability of container locations was rated at 3.60, the frequency of input errors (3.25), delays in status updates (3.45), and the lack of seamless VMT–TOS synchronization (3.30) remain the primary bottlenecks. These errors necessitate manual verification by supervisors, a process that is not only time-consuming but also prone to further human error, thereby degrading overall terminal efficiency. Consequently, while heavy equipment productivity scored 3.70, other performance indicators, such as vehicle movement speed (3.30) and the number of containers processed per shift (3.45), lagged. The lowest customer satisfaction score, at 3.25, clearly indicates that internal inefficiencies are affecting the port's clients.

These findings suggest that the return on technological investment is not automatic. Operational performance remains heavily dependent on the integrity of the data flowing through the system. Therefore, the success of the TOS Upgrade and VMT usage is determined not only by the sophistication of the technology itself but also by the quality of the data that serves as the bridge between the digital system and field conditions. From a theoretical perspective, there is a clear gap in the existing literature. Previous research by Pranata and Wijaya (2020) demonstrated that TOS can improve loading and unloading efficiency and reduce data errors; however, their study focused on basic TOS implementations and did not examine the specific nuances of a TOS Upgrade. Furthermore, earlier studies conducted by other researchers have not specifically tested the mediating role of container data accuracy. At the same time, separate investigations have yet to integrate TOS and VMT as simultaneous drivers of operational performance. Most existing research tends to treat technology as a direct driver of performance, ignoring the intervening variables that can either facilitate or block that impact in a real-world terminal environment.

Research that integrates TOS Upgrade, VMT usage, container data accuracy, and operational performance in the specific context of Indonesian container terminals, especially those undergoing rapid expansion, such as BNCT, remains extremely limited. This study, therefore, possesses both academic and practical urgency. Academically, it seeks to build a more nuanced model of how digital tools impact performance through data integrity. Practically, it aims to provide PT BNCT management with actionable insights on aligning their technological assets with human and environmental factors to achieve peak operational output.

Based on the aforementioned conditions, this research is titled: "Analysis of the Implementation of TOS Upgrade and the Use of VMT on Operational Performance with Container Data Accuracy as an Intervening Variable in Terminal B of PT Belawan New Container Terminal (BNCT) Medan City." By focusing on these interconnected variables, this study aims to analyze the effects of TOS Upgrade and VMT usage on operational performance, with container data accuracy mediating the relationship between them. It is expected that the findings will not only validate the importance of digital infrastructure but also highlight the "human-and-system" synergy required to maintain data integrity, reduce operational bottlenecks, and ultimately enhance PT BNCT's competitive positioning in the global logistics market.

Literature Review

This research is anchored in a multi-layered theoretical framework that explains the complex dynamics of port digitalization. At the grand theory level, General Systems Theory, as proposed by Bertalanffy, posits that container terminals operate as open systems consisting of mutually interacting subsystems. In this context, the TOS Upgrade and VMT function as critical technological subsystems that drive overall operational efficiency. Furthermore, Oliver's

Satisfaction Theory (1980) remains highly relevant, as optimizing these operational systems directly contributes to heightened stakeholder and customer satisfaction. Moving to middle-range theories, the Technology Acceptance Model (TAM), developed by Davis (1989), underscores that the successful adoption of these tools depends heavily on users' perceptions of ease of use and perceived usefulness. This is further supported by Barney's (1991) Resource-Based View, which argues that operational excellence is a sustainable competitive advantage achieved through the strategic use of high-quality data and advanced technology. At the application level, the Data Quality Dimensions by Wang and Strong (1996) provide the necessary metrics to evaluate container data accuracy as a pivotal intervening variable.

Operational performance represents the capacity of an organization to synchronize its processes, human resources, and technological assets to maximize productivity. In container terminal environments, this performance is quantified through indicators such as vessel turnaround time, crane productivity, container throughput, and service reliability. The integration of digital infrastructures such as TOS and VMT is instrumental in improving these metrics. The implementation of a TOS Upgrade is a core element of digital transformation aimed at refining data integrity and system interoperability. According to the DeLone and McLean (2003) model, the success of such a system is contingent upon the quality of the information and services provided. Empirical evidence suggests that modernizing these systems reduces human error and fosters operational transparency.

The use of VMT enables real-time data logging and improves visibility into container movements across the yard. Its effectiveness is influenced by organizational support and infrastructure stability, as suggested by the Unified Theory of Acceptance and Use of Technology (UTAUT; Venkatesh et al., 2003). Ultimately, the accuracy of container data serves as the bedrock for operational reliability. This accuracy dictates the success of system integration and directly impacts the quality of managerial decisions.

Critical gaps remain in the current academic landscape regarding these specific technological integrations. Previous research by Pranata and Wijaya (2020) demonstrated the general benefits of TOS in reducing errors but did not investigate the mediating role of data accuracy. Similarly, separate studies by other researchers have examined terminal performance without integrating TOS and VMT as simultaneous technological drivers. This research addresses these voids by examining how data integrity serves as the essential bridge between hardware-software implementation and terminal productivity.

RESEARCH METHOD

A hypothesis serves as a preliminary proposition that requires empirical validation through rigorous scientific inquiry (Sugiyono, 2020). In this study, the hypotheses guide the analytical direction to test the influence of information technology on port operations. The first hypothesis (H1) posits that implementing a TOS Upgrade significantly affects the accuracy of container data. Enhanced features and improved validation protocols within an upgraded system are expected to reduce logging discrepancies. The second hypothesis (H2) posits that VMT usage positively affects data accuracy. By enabling field operators to record data at the point of activity, VMT minimizes manual input delays and errors.

Furthermore, the third hypothesis (H3) argues that container data accuracy is a primary determinant of operational performance. Precise and real-time data are essential for the effective planning of loading and unloading cycles. Inaccuracies often lead to equipment idle time and logistical bottlenecks, which diminish productivity. The fourth and fifth hypotheses (H4 and H5) propose that both TOS Upgrade and VMT usage have direct and indirect effects on performance. Specifically, these technologies optimize the synchronization between personnel and machinery.

This study uniquely positions container data accuracy as an intervening variable bridging the gap between technological inputs and operational outputs. Drawing from the DeLone and McLean (2003) framework, the value of an information system is realized through the quality of the information it generates. Therefore, a TOS Upgrade and VMT utilization will only achieve optimal operational results if they produce valid, real-time data. In summary, this research analyzes the influence of TOS Upgrade and VMT on operational performance via the mediating role of container data accuracy.

METHOD

This research employs a causal-associative design to identify and analyze the cause-and-effect relationships among the established variables. Specifically, the study examines how the Implementation of TOS Upgrade (X1) and VMT Usage (X2) influences Operational Performance (Y), with Container Data Accuracy (Z) serving as the intervening variable mediating these relationships. This design facilitates the analysis of both direct and indirect effects within the structural model. Data collection was conducted at Terminal B of PT Belawan New Container Terminal (BNCT) in Medan over a period of eight months. The research used primary data collected through structured questionnaires distributed between August 1st and September 30th, 2025. To ensure a robust response rate, the instruments were administered to 80 potential participants, yielding 63 completed and valid responses (78.7% response rate). Sampling was conducted using a simple random sampling technique, with the sample size determined by the Slovin formula to allow for a 10% margin of error. A sample of 63 is considered highly adequate for Partial Least Square (PLS) analysis, as it exceeds the common "ten times rule" for the number of structural paths or indicators in the model.

Operational Definition of Variables

The variables in this study are operationally defined to ensure precise measurement using five-point Likert-scale indicators ranging from "Strongly Disagree" to "Strongly Agree."

Variable	Definition	Indicators	Scale
TOS Upgrade Implementation (X1)	The process of updating the Terminal Operating System to enhance automation and system integration.	1. System automation level 2. Integration with other units 3. Information validation features 4. Ease of system use	Likert
VMT Usage (X2)	The utilization of hardware terminals in field vehicles for real-time data logging and instruction.	1. Real-time logging frequency 2. Network stability 3. Accuracy of field input 4. Hardware reliability	Likert
Container Data Accuracy (Z)	The degree to which digital records match the actual physical status of containers in the field.	1. Location suitability 2. Status update speed 3. Minimization of input errors 4. Synchronization between systems	Likert
Operational Performance (Y)	The measurable output and efficiency of port operations, including speed and productivity.	1. Loading/unloading speed 2. Equipment productivity 3. Vehicle turnaround time 4. Customer satisfaction levels	Likert

Sumber: Data processed by author, 2025

Data Analysis Technique

The data analysis is conducted using Structural Equation Modeling (SEM) with the Partial Least Squares (PLS) approach, facilitated by SmartPLS 4 software. This analytical process is systematically divided into two primary stages: first, the evaluation of the measurement model (outer model), followed by the assessment of the structural model (inner model).In the outer model evaluation, the study assesses convergent validity by ensuring that all factor loadings exceed 0.70 and the Average Variance Extracted (AVE) values exceed 0.50. Furthermore, discriminant validity is assessed using the Fornell-Larcker criterion and the Heterotrait-Monotrait Ratio

(HTMT) values, with values below 0.90 indicating discriminant validity. At the same time, construct reliability is confirmed by achieving Cronbach's Alpha and Composite Reliability scores above 0.70.

Once the measurement model is validated, the inner model evaluation is performed to determine the strength and predictive power of the structural relationships. This assessment involves calculating the coefficient of determination (R2) to explain the variance in endogenous variables, assessing predictive relevance (Q2), and ensuring model fit with a Standardized Root Mean Square Residual (SRMR) value below 0.10. The final stage involves testing the research hypotheses through a bootstrapping procedure. The significance of both direct and indirect (mediating) effects is determined by comparing results against statistical thresholds, specifically seeking T-statistics greater than 1.96 and P-values less than 0.05 to support the proposed relationships within the research framework.

RESULTS AND DISCUSSION

Result

Respondent Description

Table 1. Characteristics of Respondents

Respondent Characteristics	Category	Number (People)	Percentage (%)
Gender	Man	47	74,6
	Woman	16	25,4
Age	26–35 years old	23	36,5
	36–45 years old	21	33,3
	46–55 years old	12	19,0
	>55 years old	7	11,1
Final Education	High School/Equivalent	18	28,6
	Diploma	20	31,7
	Bachelor (S1)	22	34,9
	Magister (S2)	3	4,8
Tenure	<5 years old	9	14,3
	5–10 years	22	34,9
	10–15 years	19	30,2
	>15 years old	13	20,6
Position/Title	Field Operator (VMT)	20	31,7
	TOS Administration/Planning Officer	18	28,6
	Supervisor/Coordinator	12	19,0

Source: Data processed by author, 2025

Based on the questionnaire responses, an overview of the respondents' gender was obtained, as shown in Table 2. The majority of respondents were male, namely 47 people (74.6%), while female respondents numbered 16 (25.4%). These findings show that employees at Terminal B of PT Belawan New Container Terminal (BNCT) are predominantly male and generally engaged in field activities and port operations requiring physical strength and endurance.

The questionnaire results also provide information on respondents' age ranges, as shown in Table 2. Most respondents were in the 26–35 age group, with 23 people (36.5%), followed by the 36–45 age group, with 21 people (33.3%). This condition shows that the majority of employees are at a relatively mature productive age, so they are considered to have good physical abilities and sufficient work experience to support operational activities at BNCT.

Based on the results of the questionnaire summarized in Table 2, most respondents had a Bachelor's (S1) level of education, with 22 people (34.9%). This number was followed by 20 Diploma graduates (31.7%) and 18 high school/equivalent graduates (28.6%). Only 3 respondents

(4.8%) have a Master's (S2) education. This data indicates that BNCT employees generally have a sufficient educational background and are well-suited to support technical and administrative competencies in modern port operations.

The respondents' working period data, as shown in Table 2, indicate that the majority of employees have a working period of between 5 and 10 years, totaling 22 people (34.9%). Furthermore, 19 people (30.2%) have worked for 10-15 years. These findings indicate that most respondents have adequate work experience and a deep understanding of BNCT's operational system, which is an important factor in the effective implementation of digital systems such as TOS and VMT.

Based on the position or operational position in Table 2, the majority of respondents work as Field Operators (VMT), at 20 people (31.7%). This position was followed by 18 TOS Administrative Officers/Planning Officers (28.6%). This shows that most respondents are employees directly involved in the terminal's core operational activities, both in the field and in managing digital systems such as the Terminal Operating System (TOS) and Vehicle Mounted Terminal (VMT). The dominance of the operational position strengthens the validity of the research data because the respondent is directly involved with the system under study.

Analysis Results

Measurement Model

The Outer Model, or measurement model, was evaluated to assess the relationship between the indicator (manifest variable) and the latent construct in this study. The main objective of the external model evaluation is to ensure that each indicator is valid and reliable for measuring its corresponding latent variable. The assessment of the outer model is conducted across three main aspects: convergent validity, discriminant validity, and reliability.

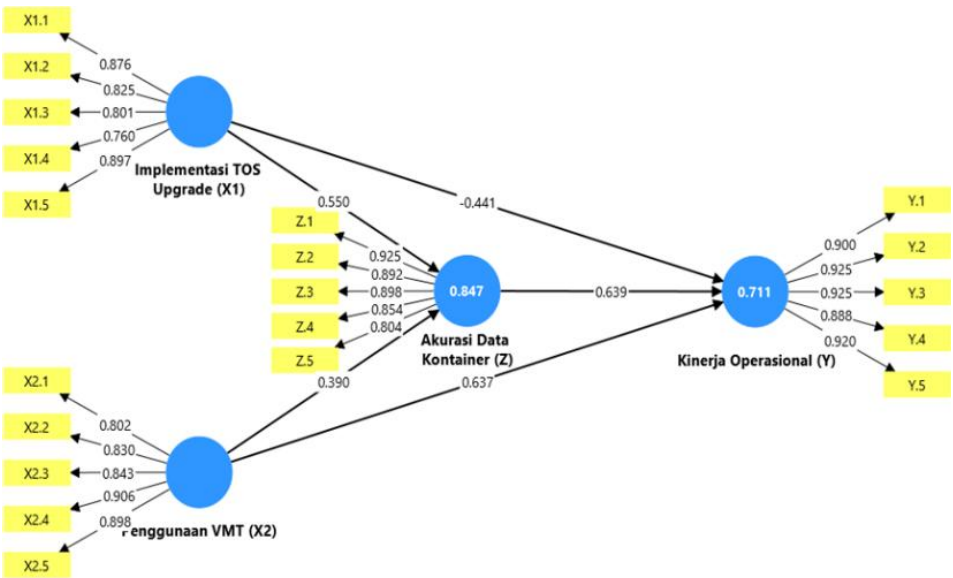

Figure 1. Factor Loading Test
Source: SmartPLS 4.1.1.4 Output Results (2025)

a. Convergent Validity

Convergent validity assesses the extent to which the indicators of a construct correlate highly with that construct. Evaluation was carried out through outer loading and Average Variance Extracted (AVE) values. An outer loading value above 0.70 indicates a valid indicator. Based on the results of data processing using SmartPLS 4.1.1.4, all indicators for TOS Upgrade Implementation (X1), VMT Usage (X2), Operational Performance (Y), and Container Data Accuracy (Z) have values > 0.70, indicating they are valid. The AVE test is used to assess the proportion of variance in indicators explained by latent constructs. The results showed that all variables had AVE values> 0.50, namely Z (0.766), X1 (0.694), X2 (0.734), and Y (0.831), indicating that convergent validity was met.

b. Discriminant Validity

Discriminant validity ensures that each construct is empirically different from the other constructs in the model. Evaluation was carried out through cross-loading, Fornell–Larcker Criterion, and Heterotrait–Monotrait Ratio (HTMT). The results of the cross-loading test showed that each indicator had the highest loading on its own variable compared to other variables, meeting the criteria of discriminant validity. The Fornell–Larcker analysis corroborates this finding, with the root AVE of each construct exceeding the highest correlation between constructs, namely Z (0.875), X1 (0.833), X2 (0.857), and Y (0.912). The HTMT method yields values < 0.90 for all construct pairs, confirming that discriminant validity is met.

c. Reliability

Reliability is used to assess the internal consistency of indicators in their representation of latent constructs. The evaluation was conducted using Cronbach's alpha and composite reliability, with a minimum threshold of 0.70. All variables in this study showed Cronbach's alpha and composite reliability values > 0.70: Z (0.923), X1 (0.889), X2 (0.909), and Y (0.949), so that they were total.

Based on the evaluation of the outer model, all research indicators are valid and reliable, with respect to both convergent and discriminant validity. This suggests that the measurement model is suitable for further analysis, including testing the influence of independent variables on dependent variables and assessing the accuracy of container data in improving operational performance. These findings also support the reliability of the data for implementing digital systems in modern container terminals, particularly for the variables TOS Upgrade and VMT, which are the focus of research aimed at improving operational effectiveness.

Structural Model

After the validity and reliability of the indicators in the outer model are established, the research proceeds to evaluate the inner model to assess the causal relationship between latent variables. This evaluation is important for testing the hypothesis and determining the model's predictive ability for the dependent variables.

1. Coefficient of Determination (R^2 Value)

R^2 measures how much an independent variable explains the variability in a dependent variable. Based on the results of SmartPLS 4.1.1.4 processing, the R^2 value for Container Data Accuracy (Z) is 0.847, indicating that 84.7% of the variation in Z is explained by the Implementation of TOS Upgrade (X1) and the Use of VMT (X2). Other factors outside the study influenced the remaining 15.3%. The R^2 value of Operational Performance (Y) is 0.711, meaning that X1, X2, and Z can explain 71.1% of Y variations, while external variables influence 28.9%. This value shows that the model's predictive ability is relatively strong.

Table 2. R Square and R Square Adjusted Values

Variabel	R-square	R-square adjusted
Container Data Accuracy (Z)	0,847	0,842
Operational Performance (Y)	0,711	0,696

Source: SmartPLS 4.1.1.4 Output Results (2025)

2. Model Fit

The model suitability evaluation was conducted using the Standardized Root Mean Square Residual (SRMR), with an SRMR criterion of < 0.10 indicating a fit model. The results showed an SRMR of 0.081, indicating that the structural model met the criteria and was suitable for hypothesis testing.

Table 3. Model Fit Test Results

Variabel	Saturated model	Estimated model
SRMR	0,081	0,081

Source: SmartPLS 4.1.1.4 Output Results (2025)

3. Predictive Relevance (Q^2)

The Q^2 test measures the model's predictive relevance. A Q^2 value > 0 indicates that the model has good predictive ability. The results show Q^2 Z = 0.837 and Q^2 Y = 0.625, so the model has adequate predictive relevance for both dependent variables.

Table 4. Q2 Predict Results

Variabel	Q^2predict
Container Data Accuracy (Z)	0,837
Operational Performance (Y)	0,625

Source: SmartPLS 4.1.1.4 Output Results (2025)

The demographic profile of respondents is presented to provide a contextual understanding of generational composition and the distribution of work experience. A total of 110 employees participated in this study, representing various age groups and tenure levels within the organization.

Hypothesis Testing

Hypothesis testing was conducted to determine the direct and indirect effects of the variables.

Table 5. Direct Influence Hypothesis Test Results

Variabel	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistics (|O/STDEV|)	P values
Container Data Accuracy (Z) -> Operational Performance (Y)	0,639	0,626	0,222	2,870	0,004
Implementation of TOS *Upgrade* (X1) -> Container Data Accuracy (Z)	0,550	0,558	0,132	4,160	0,000
Usage of VMT (X2) -> Container Data Accuracy (Z)	0,390	0,383	0,134	2,901	0,004

Source: SmartPLS 4.1.1.4 Output Results (2025)

1. Direct Influence

a. Container Data Accuracy → Operational Performance: Coefficient 0.639, T-statistic 2.870 > 1.96, P = 0.004 < 0.05; have a positive and significant effect.
b. Implementation of TOS Upgrade → Container Data Accuracy: Coefficient 0.550, T-statistic 4.160 > 1.96, P = 0.000 < 0.05; positive and significant.
c. Use of VMT → Container Data Accuracy: Coefficient 0.390, T-statistic 2.901 > 1.96, P = 0.004 < 0.05; positive and significant.

2. Indirect Influence (Mediation)

a. Implementation of TOS Upgrade → Container Data Accuracy → Operational Performance: Coefficient 0.352, T-statistic 2.264 > 1.96, P = 0.024 < 0.05, showing a significant mediating effect.

b. Use of VMT → Container Data Accuracy → Operational Performance: Coefficient 0.249, T-statistic 2.063 > 1.96, P = 0.039 < 0.05, indicating significant mediation.

These results confirm that Container Data Accuracy mediates the influence of the use of digital technology (TOS Upgrade and VMT) on terminal operational performance. In other words, improving the effectiveness of digital systems improves data accuracy. Evaluation of the inner model shows that the structural model has strong predictive capabilities and is statistically fit. The hypothesis test confirmed that all direct and indirect influences were significant, supporting the Technology Acceptance Model (TAM) and the Theory of Performance (ToP) in the context of the application of digital systems in modern container terminals. These findings have practical implications: optimizing TOS Upgrades and using VMT consistently will improve the accuracy of operational data and overall organizational performance.

Discussion

The findings of this study demonstrate that the Implementation of TOS Upgrade, the Utilization of VMT, and Container Data Accuracy exert a significant positive influence on Operational Performance at Terminal B of PT Belawan New Container Terminal (BNCT). These results reinforce the postulation that digital infrastructure is the primary catalyst for operational excellence in the maritime logistics sector.

The transition to an upgraded Terminal Operating System (TOS) significantly enhances data integrity by fundamentally restructuring the data entry workflow. By reducing the necessity for manual intervention, the TOS Upgrade minimizes the probability of human error and facilitates seamless real-time synchronization between administrative planning and field execution. This automation ensures that every container movement is logged instantaneously, creating a transparent and accountable digital trail. Furthermore, the integration of VMT allows operators to verify and update data directly from the cabin of heavy equipment, bridging the communication gap between the yard and the control center. Consequently, the reduction in decision latency and the elimination of data disparities ensure that yard planning is executed with high precision.

A comparative analysis shows that these findings are highly consistent with Nguyen et al. (2021), who argued that integrated digital systems are essential for improving service speed and data reliability in high-throughput terminals. However, this study presents a nuanced departure from Wang & Song (2020); while their research suggested that VMT usage directly dictates performance, our results indicate that the hardware alone is insufficient without high-level data accuracy as a prerequisite. Additionally, this study aligns with Choi (2022) on the necessity of real-time logging. However, it offers a more comprehensive view by positioning data accuracy as the critical link in the equipment dispatch logic, where accurate positioning prevents "dry runs" or idle equipment time.

The Mediating Role of Container Data Accuracy

Operationally, container data accuracy is a vital mediator in the terminal workflow, as it dictates the efficiency of yard planning and equipment dispatch. In a terminal environment, inaccurate data can lead to "lost" containers or misaligned stacking, forcing yard cranes and head trucks into unproductive movements. By ensuring high data integrity, the TOS-VMT integration optimizes the equipment dispatch logic, ensuring that the nearest machine is assigned to the correct task without delay. This reduction in operational friction directly accelerates container throughput and improves the overall reliability of the loading and unloading process.

Theoretical Contributions

This research provides a significant contribution to the existing literature by extending the Technology Acceptance Model (TAM). While traditional TAM frameworks emphasize that perceived usefulness and ease of use lead directly to improved performance, this study proves that in complex industrial environments, technological usefulness does not impact performance in a vacuum. Instead, it operates through the mediating lens of Information Quality. This finding suggests that the "use" of technology (TOS and VMT) translates into "performance" (Efficiency and Productivity) only when the output container data achieves a high level of accuracy. This refines the Theory of Performance (ToP) by highlighting that the "context" and "knowledge" required for performance are fundamentally data-driven in the digital port era.

Practical Implications

For PT BNCT management, these findings offer concrete strategic directions. It is recommended that the company allocate a dedicated annual budget for the periodic maintenance of TOS software to prevent system glitches that could compromise data flow. Furthermore, a structured technical training program for VMT operators is essential, since the system's accuracy is heavily dependent on field input; improving operator digital literacy will reduce accidental data entry errors. Management should also implement a "Data Audit" protocol where system data is periodically reconciled with physical yard conditions to maintain the highest standards of data integrity.

Limitations and Future Research

Despite the rigorous methodology employed, this study is subject to certain limitations. The scope of the research is restricted to a single terminal (Terminal B of BNCT), which may limit the generalizability of the findings to different geographical or organizational contexts. Future research should consider a multi-site comparison involving various container terminals across Indonesia to validate these relationships on a broader scale. Additionally, incorporating qualitative insights from field supervisors could provide a deeper understanding of the behavioral barriers to VMT adoption and data accuracy.

CONCLUSION

The results of this study indicate that the implementation of the TOS Upgrade had a positive and significant impact on Container Data Accuracy, indicating that the more optimal the operational system's features and functions, the higher the precision of the resulting data. The use of VMT was also shown to significantly improve data accuracy, indicating that real-time digital recording via this device can minimize manual input errors in the field. Furthermore, Container Data Accuracy was shown to be a key driver of Operational Performance, as high data integrity directly facilitates more efficient loading and unloading, precise yard planning, and stronger monitoring of terminal activity. These findings also confirmed that data accuracy significantly mediated the effect of VMT use on operational performance. This relationship emphasizes that increased terminal productivity is achieved through improving the quality of information generated by the digital system. Overall, these results support the Technology Acceptance Model (TAM) and the Theory of Performance (ToP), which assert that technology perceived as useful and easy to use will increase organizational effectiveness if it provides an accurate data foundation.

In terms of scientific contribution, this study contributes to the TAM literature by demonstrating the mediating role of information quality and showing that the accuracy of the resulting data facilitates the transition from technology adoption to performance. From a management perspective, port authorities should prioritize data accuracy as a key Key Performance Indicator (KPI) alongside traditional operational speed, given that data integrity serves as a buffer against costly logistical bottlenecks. While the analytical framework employed is rigorous, this study has several limitations, including a single-case study design focusing solely on Terminal B of PT BNCT, which limits the generalizability of the results to other port environments with different operational cultures. Furthermore, the use of a cross-sectional design means the data reflect only a single point in time. In contrast, the long-term impact of digital transformation may be better captured through a longitudinal approach. Future research is expected to expand the scope to various container terminals in Indonesia and incorporate qualitative methods.

Suggestion

The results of this study lead to several strategic and scientific recommendations aimed at enhancing the digital integration within port environments. For PT BNCT management, it is highly advisable to maintain the technical superiority of the TOS Upgrade through periodic software maintenance, rigorous system audits, and the achievement of full interoperability between the central operating system and field equipment. Furthermore, the utilization of VMT must be optimized by strengthening localized network connectivity, ensuring the excellent physical condition of hardware devices, and systematically improving operator competence to ensure that the data recording process remains precise and free from manual errors. To maintain the integrity of Container Data Accuracy, management should implement an automated data verification mechanism that periodically reconciles system records with physical yard conditions, thereby reducing mismatches that cause operational delays.

To improve overall Operational Performance, there is a critical need to strengthen inter-unit coordination and develop a workforce highly adaptive to emerging maritime technologies, ensuring that digital systems are viewed as primary tools for productivity. Regarding future academic inquiries, this research contributes significantly to the TAM literature by empirically proving the mediating role of information quality in the relationship between technology usage and organizational outcomes. While this study provides a foundational understanding, it is limited by its single-case study focus on Terminal B and its cross-sectional design, which captures only a specific moment in time. Therefore, future researchers are encouraged to employ a longitudinal design to capture the evolution of performance metrics before and after the implementation of a TOS Upgrade, while also considering additional variables, such as employee motivation and technological innovation, to provide a more comprehensive perspective on the digital transformation of the port sector.

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