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Effect of Port Community System (PCS) Digitalization on the Operational Performance of Cargo Clearance at the Nigerian Ports Authority

ADAH Anthony, Sidi-Ali A.B Mamman & Prof. Suleiman A.S. Aruwa (Ph.D)

Institute of Governance and Development Studies, Nasarawa State University, Keffi-Nigeria

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***Corresponding Author:** ADAH Anthony

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Abstract **Original Research Article**

Effective digitalization through Port Community Systems (PCS) is essential for improving cargo clearance efficiency, reducing dwell times, and enhancing transparency in port operations. This study examined the effect of Port Community System (PCS) Digitalization, focusing on Level of Automation, Integration of Port Stakeholders, Real-time Data Sharing, and Electronic Documentation & Payments, on the Operational Performance of Cargo Clearance at the Nigerian Ports Authority. Using a descriptive correlational research design, data were collected from 245 key stakeholders across the NPA, Nigeria Customs Service, terminal operators, and freight forwarders via a structured questionnaire. Partial Least Squares Structural Equation Modeling (PLS-SEM) was used for analysis. The findings revealed that Level of Automation ($\beta = 0.342$, $p = 0.042$), Real-time Data Sharing ($\beta = 0.389$, $p = 0.034$), and Electronic Documentation & Payments ($\beta = 0.456$, $p = 0.011$) have a significant positive effect on operational performance, improving cargo dwell time, documentation accuracy, clearance speed, and stakeholder satisfaction. However, Integration of Port Stakeholders ($\beta = 0.298$, $p = 0.108$) showed no significant effect, indicating a gap in collaborative implementation at the NPA. The study concluded that while the transactional and data-sharing elements of PCS are successfully driving efficiency gains, collaborative integration remains a challenge. It is therefore recommended that the NPA should prioritize the acceleration of Electronic Documentation & Payments and Real-time Data Sharing while simultaneously addressing the governance and institutional gaps that currently impede the success of stakeholder integration.

Keywords: Operational Performance of Cargo Clearance, PCS Digitalization, Level of Automation, Real-time Data Sharing, Electronic Documentation & Payments.

INTRODUCTION

Global port operations are rapidly evolving with the increasing adoption of digital technologies aimed at enhancing operational efficiency. Ports are critical nodes in global trade, and their operational performance is central to the seamless movement of goods. According to Rodrigue (2022), ports' operational performance is measured by cargo throughput, clearance speed, dwell time, and operational costs, which are directly influenced by technological advancements such as Port Community Systems (PCS). A PCS is a digital

platform that facilitates real-time data exchange and integration among stakeholders, including customs, shipping companies, terminal operators, and freight forwarders (Paulauskas et al., 2021). These advancements are particularly crucial for reducing delays, improving documentation accuracy, and increasing overall operational transparency. For example, in developed ports, such as Rotterdam and Singapore, PCS and automation have reduced cargo dwell time and enhanced cargo clearance speed (Sahu et al., 2023).

In Africa, the adoption of PCS is gaining momentum but is still challenged by fragmented infrastructure, limited technology adoption, and workforce inadequacies. According to the World Bank (2023), while ports in countries like South Africa have experienced significant improvements in efficiency through digitalization, Nigerian ports continue to struggle with inefficiencies such as long cargo dwell times and inaccurate documentation. The Nigerian ports' operational challenges have far-reaching implications for trade facilitation, with port delays increasing costs for both importers and exporters. In fact, Okere (2022) reports that cargo clearance in Nigerian ports, including Lagos Port Complex and Tin Can Island Port, often takes between 10 to 17 days, significantly above the global standard of 2 to 4 days. This study seeks to examine the effect of Port Community System (PCS) digitalization on the operational performance of cargo clearance at Nigerian ports, particularly focusing on Lagos Port Complex and Tin Can Island Port. The study aims to address the gaps in operational efficiency by evaluating the four key independent variables, level of automation, integration of port stakeholders, real-time data sharing, and electronic documentation & payments and their effect on the dependent variable, which is the operational performance of cargo clearance, measured through cargo dwell time, documentation accuracy, clearance speed, and stakeholder satisfaction.

The Level of Automation is one of the most critical factors influencing the operational performance of port systems. Automation, through systems such as automated cargo handling, vessel scheduling, and electronic gate controls, reduces manual labor, minimizes human error, and accelerates the clearance process (Rodrigue, 2022). Increased automation is expected to reduce congestion, expedite the clearance of cargo, and improve operational reliability at the port (U.S. Government Accountability Office [GAO], 2024). Integration of Port Stakeholders plays a key role in reducing delays and improving efficiency at ports. By integrating stakeholders such as the Nigerian Ports Authority, Customs, terminal operators, and freight forwarders into a unified digital platform, PCS eliminates communication barriers and reduces duplicative efforts (Mthembu, 2022). The seamless flow of data ensures that all parties are working with accurate and real-time information, reducing clearance time and enhancing decision-making. Real-time Data Sharing is another critical element in the digitalization of port operations. Real-time data sharing enables stakeholders to access immediate updates on cargo status, approvals, and delays, thus allowing for better coordination and faster decision-making (Inkinen, 2022). Real-time data is particularly crucial for ensuring that operations run smoothly and for reducing delays caused by outdated or fragmented information systems (Kaup et al., 2021).

Electronic Documentation & Payments are essential in eliminating manual paper-based processes, which are notorious for causing delays, errors, and inefficiencies. By automating documentation and payment processes, ports can streamline customs clearance and reduce the risks of fraud or corruption (Akinbola et al., 2021). Electronic invoicing, payment systems, and document submissions enhance transparency and ensure that the cargo is processed efficiently and without unnecessary paperwork. By analyzing the relationships between the key independent variables and the dependent variable (operational performance), this study aims to contribute valuable insights into the effectiveness of PCS digitalization in addressing operational inefficiencies at Nigerian ports.

The fundamental problem addressed by this study is the inefficient and substandard Operational Performance of Cargo Clearance at the Nigerian Ports Authority (NPA), primarily evidenced by excessively long cargo dwell times, low clearance

speed, and endemic bottlenecks. Despite the port concessioning 18 years ago, and various partial digitalization efforts, Nigeria's major ports remain globally uncompetitive, with cargo clearance often taking an average of 10 to 17 days (Okere, 2022). This figure drastically trails the international best practice of 48-72 hours achieved by major competitors. This inefficiency has profound economic consequences, including high demurrage and storage charges, increased cost of doing business (by up to 400% compared to regional peers), and a negative impact on Nigeria's Logistics Performance Index (LPI) ranking, leading to significant cargo diversion to neighbouring West African ports.

The core challenge is that the existing cargo clearance process is characterized by a fragmented system where the four key components of a modern digital solution are critically underdeveloped. Specifically, there is a low level of automation, meaning many critical procedures remain manual and paper-based. This is compounded by the fragmented integration of port stakeholders, where bodies like the NPA, Customs, terminal operators, shipping lines, and security agencies operate on isolated systems, necessitating physical interfaces and redundant checks. Furthermore, the absence of real-time data sharing prevents instant information visibility among actors, severely inhibiting coordinated decision-making. Lastly, the inconsistent electronic documentation and payments framework allows paper submissions and manual approvals to persist, consequently creating opportunities for corruption and costly delays.

The research problem, therefore, lies in the lack of a comprehensive, empirically validated understanding of how the holistic adoption of PCS Digitalization's four key dimensions affects the Operational Performance of Cargo Clearance at the NPA. While the government has mandated the implementation of a National Single Window/PCS, there is insufficient local evidence to guide the strategic deployment of the system's components to directly improve core metrics like cargo dwell time and clearance speed. This study is necessary to provide the empirical data required for policy-makers to prioritize and resource the specific digitalization variables that yield the greatest positive impact on port efficiency and trade competitiveness. The specific objectives of this study are to:

i. Examine the relationship between level of automation and the operational performance of cargo clearance at the Nigerian Ports Authority.

ii. Ascertain the relationship between integration of port stakeholders and the operational performance of cargo clearance at the Nigerian Ports Authority.

iii. Determine the relationship between real-time data sharing and the operational performance of cargo clearance at the Nigerian Ports Authority.

iv. Evaluate the relationship between electronic documentation & payments and the operational performance of cargo clearance at the Nigerian Ports Authority.

The null hypotheses for the study are as follows:

H_{01}: There is no significant relationship between level of automation and the operational performance of cargo clearance at the Nigerian Ports Authority.

H_{02}: There is no significant relationship between integration of port stakeholders and the operational performance of cargo clearance at the Nigerian Ports Authority.

H_{03}: There is no significant relationship between real-time data sharing and the operational performance of cargo clearance at the Nigerian Ports Authority.

H_{04}: There is no significant relationship between electronic documentation & payments and the operational performance of cargo clearance at the Nigerian Ports Authority.

CONCEPTUAL FRAMEWORK

Operational Performance

Operational performance, within the context of Port Community System digitalization, measures the efficiency and effectiveness of processing customs

declarations, inspections, and cargo release at ports. Operational performance of cargo clearance is broadly defined as the efficiency and productivity in processing cargo throughput, measured by vessel turnaround time, berth occupancy, and clearance speed, enabling the timely release of goods at ports (Nwaogbe et al., 2020). From a specific firm perspective, it is defined by operational aspects like timely delivery and error-free processing, which are positively influenced by customer focus and flexibility (Bae et al., 2013). More recently, this concept has been defined as the efficiency, speed, and cost-effectiveness of customs processes in freight forwarding, measured by reduced delays, accurate documentation, and streamlined trade flows (Vasumathi et al., 2025). The goal of this performance is to achieve timely discharge, accurate documentation, and delivery without delays (Okere, 2022).

Operational performance is fundamentally described by core non-financial metrics, such as cargo dwell time, order accuracy, and response time, which are central to clearance efficiency (Bae et al., 2013). For example, the historic Nigerian clearance process, which spans 10 to 17 days, is often contrasted with the international standard of 2 to 4 days, highlighting the severe performance gap largely caused by inadequate equipment and procedural bottlenecks (Okere, 2022). Enhanced performance is demonstrated by instances where streamlined procedures reduce dwell time from 10 days to 3 days. Flexibility in adapting to customer requirements improves performance by enabling quick responses to special demands, such as urgent shipments, which boosts customer retention in logistics chains (Bae et al., 2013). High operational outcomes, exemplified by Calabar port achieving a 99% R-square in regression, are often driven by improved turnaround time and employee efficiency, enhancing cargo clearance and reducing vessel delays (Nwaogbe et al., 2020). Historically, post-concession efforts aimed at performance improvement saw berth occupancy improve from 51.35% to 72.47%, illustrating how modernization efforts enhance overall cargo clearance efficiency (Nwaogbe et al., 2020).

In this study, operational performance is measured through key indicators such as cargo dwell time, documentation accuracy, clearance speed, and stakeholder satisfaction. These metrics reflect the efficiency of customs procedures, with reduced dwell time and improved documentation directly correlating to enhanced cargo throughput and operational effectiveness at Nigerian ports (Di Vaio & Varriale, 2017; Nwaogbe et al., 2020; Paulauskas et al., 2021). Additionally, the integration of real-time data sharing and the adoption of ICT tools in terminal operations have been shown to significantly improve performance, reducing delays and enhancing operational transparency (Akinbola et al., 2021; Paulauskas et al., 2021).

Port Community System (PCS) Digitalization

The digitalization of port operations through the Port Community System (PCS) is a significant undertaking aimed at modernizing maritime trade. A PCS is a digital platform defined as enabling the seamless data exchange among port stakeholders to enhance operational efficiency (Onwuegbuchunam et al., 2021). Similarly, it is defined as a digital platform facilitating data exchange among port stakeholders to optimize maritime trade operations (Sahu et al., 2023). From an operational viewpoint, a PCS is described as an electronic platform integrating multiple seaport stakeholders' systems to enhance operational efficiency by reducing human interference and vessel waiting times (Anagor-Ewuzie, 2024).

The concept of PCS digitalization encompasses the complete transition from manual, paper-based workflows to secure, electronic data exchange (Mthembu & Chasomeris, 2022). This process is primarily designed to meet port operational requirements by centralizing data, automating processes like customs clearance, and establishing a single point of communication for all participants (Katsoulis, 2024). Key features, such as advanced services like container scanning and big data analytics, significantly enhance operational performance by reducing errors and improving transparency (Caldeirinha et al., 2020). The adoption of PCS, such as Nigeria's initiative driven by the Nigerian Ports Authority, directly reduces trade

transaction costs by automating documentation and minimizing manual processes (Sahu et al., 2023). This focus on digitalization allows Nigerian ports, like Apapa and Tin-Can, to reduce wastage and enhance vessel turnaround time, aligning with global trade opportunities (Anagor-Ewuzie, 2024). Ultimately, PCS integration fosters horizontal collaboration among seaport stakeholders, transitioning from isolated to interconnected supply chains (Caldeirinha et al., 2022).

Level of Automation

The level of automation (LOA) concept is central to understanding the extent of Port Community System (PCS) digitalization and its influence on port performance. Level of automation is defined as the extent to which port operations and cargo clearance processes are performed using digital technologies rather than manual, paper-based procedures (Paulauskas et al., 2021). It is also described as a core component of port digitalization that enhances operational efficiency, accuracy, and decision-making (Paulauskas et al., 2021). Furthermore, automation technologies are noted to reduce congestion and human error while increasing throughput in maritime operations (U.S. Government Accountability Office [GAO], 2024).

The level of automation is described by the penetration of automated systems, such as electronic gate controls, automated stacking, vessel scheduling, and cargo tracking, which replace human-dependent workflows (Rodrigue, 2022). In the context of the Nigerian Ports Authority (NPA), measuring LOA provides insight into how deeply PCS-driven digital processes have replaced manual clearance tasks. For instance, work automation, including PCS features, significantly enhances port productivity by optimizing operational flows; automated systems, such as cloud-based software in ports like Hamburg, improve energy management and traffic control (Oyewole & Francis, 2020). Conversely, the absence of a high LOA, like the lack of a National Maritime Single Window, hinders data exchange among stakeholders, increasing delays (Onwuegbuchunam et al., 2021). A higher degree of automation is expected to reduce processing time, minimize opportunities for corruption, and enhance service reliability (Čerin & Beškovnik, 2024).

Integration of Port Stakeholders

Port stakeholders integration is key to achieving a cohesive and responsive digital maritime environment. Integration of port stakeholders is broadly defined as the degree of connectivity and collaboration among key actors within the port community, such as the Nigerian Ports Authority, Nigeria Customs Service, terminal operators, and freight forwarders, through a unified digital platform (Mthembu, 2022). It is also described as a core function of a well-implemented PCS that enables all port actors to operate on a single electronic interface, thereby improving transparency and efficiency (The World Bank, 2023).

The concept of integration represents how effectively the Port Community System (PCS) facilitates seamless data exchange and coordinated decision-making among these disparate entities . Many ports, including Nigerian facilities, traditionally operated within fragmented digital environments where isolated systems resulted in duplication of efforts, costly delays, and widespread inefficiencies (Mthembu, 2022). Technological integration through PCS addresses this challenge by enhancing operational coordination and overall port performance, primarily by streamlining cargo processing and reducing dwell time (Oyewole, 2020). For instance, medium ports linking terminals for cargo tracking via intermediate digital systems often improve throughput by 20% to 40% over non-integrated counterparts (Paulauskas et al., 2021). In the Nigerian context, achieving this integration through PCS is paramount to overcoming port congestion, procedural bottlenecks, and documentation delays, consequently improving the operational performance of cargo clearance at the Nigerian Ports Authority.

Real-Time Data Sharing

Real-time data sharing is a fundamental characteristic of modern Port Community Systems (PCS) that drives supply chain synchronization. Real-time data sharing is accurately defined as the

ability of digital port systems to provide instant, transparent, and synchronized information access to all relevant stakeholders involved in cargo clearance (Inkinen, 2022). This function is closely described as a central element in port supply chains, enabling the intelligent and secure exchange of information between public and private stakeholders (Mthembu & Chasomeris, 2022).

The concept involves the immediate exchange of operational data, such as vessel schedules, cargo status, customs approvals, and release notices, between departments and external partners within the PCS . Open and real-time data environments enhance decision-making, reduce procedural bottlenecks, and improve transparency in operations (Inkinen, 2022). Information flow speed and accuracy are identified as significant dimensions of port digitalization, directly influencing productivity and efficiency (Paulauskas et al., 2021). For example, real-time data visibility significantly reduces truck waiting times and optimizes cargo handling efficiency, as demonstrated in the digitalization efforts of the Port of Barcelona (PierNext, 2023). Furthermore, PCS facilitates electronic workflows alongside real-time data sharing, reducing paper-based delays and enhancing coordination among customs, terminals, and forwarders (Kaup et al., 2021). In the Nigerian context, enabling this instant data access through PCS is essential for minimizing clearance delays, enhancing coordination, and promoting accountability, thereby improving workflow synchronization and operational performance.

Electronic Documentation & Payments

The digitalization of transactional procedures through Port Community Systems (PCS) is primarily measured by the effectiveness of its electronic components. Electronic documentation and payments is defined as the transition from manual, paper-based processes to fully digital systems for submitting, verifying, and paying for port-related transactions (Akinbola et al., 2021). This function is closely described as encompassing the electronic submission of manifests, bills of lading, and the use of secure digital payment systems for port charges and customs duties within the NPA's PCS framework (News Dissect, 2023).

This concept signifies the use of sophisticated systems to integrate stakeholders, where electronic records and advance notifications simplify administrative procedures (Kaup et al., 2021). Electronic documentation in high-precision systems has been shown to minimize errors by as much as 95% in large ports, reducing physical interactions that often cause delays and opportunities for corruption (Paulauskas et al., 2021). For instance, the elimination of manual exchanges through systems integrated with technology like blockchain enhances traceability and reduces the carbon footprint by shortening container turnaround times (Čerin & Beškovnik, 2024) . The Port of Barcelona found that 63% of its operational savings came directly from the telematization of documentation, drastically shortening turnaround times (PierNext, 2023). In the Nigerian context, these capabilities are core to PCS digitalization, ensuring paperless and cashless transactions that improve clearance speed and enhance operational accountability.

EMPIRICAL REVIEW

Level of Automation and Operational Performance

Several international and local studies have examined the influence of digital technologies on port operational performance, providing context for the deployment of Port Community Systems (PCS) at Nigerian ports. Onwuegbuchunam et al. (2021) examined Information and Communication Technology (ICT) adoption in Nigerian terminal operations, revealing significant use of Port Management Information Systems and e-payment tools, but also highlighting persistent constraints like inadequate e-skills and poor maintenance. Their findings, based on a survey of port stakeholders at Apapa and Tincan Island, emphasized the need for further investment in PCS to overcome these limitations. Extending this, Tijan et al. (2012) demonstrated the necessity of PCS adoption for global competitiveness in Croatian seaports, using simulation modeling that validated a time reduction of up to 48.50% in vessel arrival processes via

process reengineering and ICT enablement, which translated into substantial annual savings .

Similarly, in a study focusing on business factors in Portugal, Caldeirinha et al. (2022) found that integration and collaboration among stakeholders, combined with effective management and legal frameworks, were the most compelling factors for enhancing supply chain performance. Their work, utilizing Structural Equation Modeling (SEM) from a survey of Portuguese experts, achieved a strong coefficient of determination of 0.52, prioritizing human and structural elements over hardware alone. This perspective is complemented by Gróbarczyk (2024), who explored the technical blueprint of a Polish PCS platform, demonstrating how a layered digital platform could eliminate paper-based orders and reduce clearance delays through automated modules for cargo and gate management, enabling highly efficient, crewless operations. Collectively, these studies emphasize that the successful digitalization of cargo clearance is a blend of technological implementation—like e-payment systems and automation—and organizational alignment, particularly stakeholder integration, offering a clear framework for analyzing the effects of PCS in Nigeria.

Integration of Port Stakeholders and Operational Performance

International scholarly views strongly affirm that the integration of port stakeholders is a core driver of efficiency gains following Port Community System (PCS) digitalization. Tijan et al. (2021) conducted an extensive literature review that suggested port authorities critically drive PCS adoption as initiators and coordinators, transforming the port into a digital hub for real-time information exchange and process optimization. Their work underscored that effective governance models require strong stakeholder collaboration to overcome individual goals that often hinder system adoption. Supporting this, Kaup et al. (2021) empirically explored PCS integration among Polish port users, finding that 74% of respondents believed the system enhanced integration, and 61% indicated it simplified administrative procedures and reduced handling times, even as limited exposure cautioned against overstating immediate ease of work. Furthermore, Bisogno et al. (2015) analyzed maritime logistic processes at the Port of Salerno, Italy, which demonstrated that traditional methods involving fax and paper caused manual data re-entry and delays. Their study proposed a "TO-BE" model using standardized data exchange and workflow management to achieve automated data propagation, which enhanced coordination among stakeholders like customs and forwarders. This collective evidence emphasizes that PCS digitalization streamlines administrative burdens and replaces fragmented, high-cost, paper-based routines with integrated information flows, directly impacting the operational performance of cargo clearance in complex environments like the Nigerian Ports Authority.

Real-Time Data Sharing and Operational Performance

Empirical evidence consistently shows that real-time data sharing is a fundamental component of Port Community System (PCS) effectiveness, directly impacting cargo clearance efficiency. Several studies have identified this flow of information speed and accuracy as a core dimension of port digitalization (Paulauskas et al., 2021). For example, real-time data sharing through Internet of Things (IoT) and PCS technologies has been determined to improve operational visibility significantly, with large European ports cutting paperwork time by up to 50% through integrated systems, demonstrating a measurable performance benefit (Paulauskas et al., 2021). The positive impact of this instantaneous data visibility positively influences process efficiency (Zohaib et al., 2023).

Conversely, ports operating with technological fragmentation, conservative cultures, or those that fail to prioritize real-time data over static information often struggle with efficiency gaps, as revealed in studies of Finnish ports (Inkinen et al., 2019). The ability to share data instantly allows stakeholders, including the Nigerian Ports Authority and Customs, to move away from complex, manual messaging systems (Čerin & Beškovnik, 2024). Ultimately, while challenges like assuming stakeholder readiness or relying on descriptive data persist, the scholarly consensus is that real-time data exchange whether for

customs approvals, vessel status, or electronic documentation is essential for reducing procedural bottlenecks and enhancing accountability in port operations (Di Vaio & Varriale, 2017).

Electronic Documentation & Payments and Operational Performance

Empirical research consistently highlights that Electronic Documentation and Payments (EDP) are fundamental to realizing operational efficiency in ports, particularly within developing contexts. Amin (2022) explored the effects of PCS at Damietta Port, a developing port, finding that the implementation of electronic documentation significantly increased overall port services efficiency by reducing trucking dwell time and customs clearance time. More importantly, the system significantly boosted stakeholder revenues for the Egyptian Tax Authority by decreasing tax smuggling, underscoring the benefits of digital payments in governance and accountability. This focus on streamlining processes is mirrored in wider analyses: Rachmawati et al. (2023) examined Indonesian ports and revealed that prolonged average dwell times were driven by overlapping regulations and a lack of system integration, suggesting that full implementation of electronic documentation and unified data exchange portals is necessary to achieve global 3-day clearance targets. Furthermore, the longitudinal case study of Rotterdam's PCS, conducted by Chandra and van Hillegersberg (2018), showed that the successful evolution of the system involved strict governance mechanisms and transaction-based fee structures, thereby enhancing efficiency in import/export processes through sustained digital transactional integrity. Collectively, these studies demonstrate that EDP minimizes paper-based transactions, reduces delays, and strengthens fiscal controls, which is essential for improving the operational performance of cargo clearance in Nigerian ports.

Theoretical Framework

Underpinning Theory of the Study: Technology-Organization-Environment (TOE) Framework.

The optimal theoretical framework for examining the effect of Port Community System (PCS) digitalization on cargo clearance performance is the Technology-Organization-Environment (TOE) Framework, initially developed by Tornatzky and Fleischer (1990). This framework is powerful because it suggests that the adoption and success of a technological innovation, in this case, PCS digitalization are influenced by three distinct contextual elements: Technological Context, Organizational Context, and Environmental Context.

The Technological Context directly explains how the core independent variables operate: the Level of Automation, Real-Time Data Sharing, and Electronic Documentation & Payments are technological attributes of the PCS itself. This context encompasses the characteristics of the innovation, such as complexity and compatibility (Chau & Tam, 1997), and helps determine the impact on the dependent variable—Operational Performance. For example, the success of electronic documentation is often dependent on its compatibility with Customs' legacy systems (Paulauskas et al., 2021).

The Organizational Context addresses the internal factors, such as the coordination challenges and mindset of the respondents (NPA, Customs, Terminal Operators, and Freight Forwarders). This element includes managerial structure, internal resources, and the quality of human capital, which underscores why the Integration of Port Stakeholders is so important. Scholars emphasize that a positive organizational culture and adequate training are required for successful PCS implementation, helping to bridge knowledge gaps and enhance process efficiency (Zohaib et al., 2023).

The Environmental Context accounts for the external pressures and opportunities faced by the Nigerian Ports Authority, such as regulatory mandates (e.g., ease of doing business), competitor strategies, and market forces (Caldeirinha et al., 2022). This context suggests that successful digitalization, which translates to superior Operational Performance (reduced cargo dwell time and increased clearance speed), is necessary for Nigerian ports to maintain competitiveness against neighboring West African ports (Oyewole & Francis, 2020). The TOE framework provides a holistic structure to analyze

how the technical features of the PCS interact with the complex organizational dynamics and the external maritime environment to ultimately influence the operational efficiency of cargo clearance.

Methodology

This study examined the effect of Port Community System (PCS) digitalization on the operational performance of cargo clearance at the Nigerian Ports Authority, employing a descriptive correlational research design. This approach was deemed suitable as it allows for the systematic measurement of existing digitalization practices to determine the relationships between PCS components and operational outcomes in cargo clearance. By collecting standardized data from a diverse group of respondents, the study could analyze how perceptions and experiences with these digital practices are associated with observed improvements in cargo dwell time, documentation accuracy, clearance speed, and stakeholder satisfaction.

This study targeted key stakeholders involved in cargo clearance operations at Lagos Port Complex, including staff of the Nigerian Ports Authority (ICT: 38 staff, Marine Operations: 52, Trade Facilitation/PCS Unit: 45, Port Management: 88), officers of the Nigeria Customs Service (74), terminal operations staff from major terminals (32), and licensed customs agents or freight forwarders (57) who actively utilize the Port Community System (PCS) for cargo processing and clearance activities. A census approach was adopted due to the focused and manageable size of this population directly engaged in PCS-related operations, eliminating the need for sample size determination, and because the use of Google Forms enabled efficient, low-cost distribution and data collection across all targeted respondents.

A structured questionnaire served as the primary data collection instrument, designed to capture information on the independent variables, Level of Automation (LOA), Integration of Port Stakeholders (IPS), Real-time Data Sharing (RDS), and Electronic Documentation & Payments (EDP) and the dependent variable, Operational Performance of Cargo Clearance (OPCC), measured through cargo dwell time, documentation accuracy, clearance speed, and transparency and stakeholder satisfaction. The questionnaire was informed by existing literature. Level of Automation was adapted from Mthembu (2022), Sfiroera et al. (2019), and Paulauskas et al. (2021). Integration of Port Stakeholders was informed by Sfiroera et al. (2019), Mthembu (2022), and The World Bank (2021). Real-time Data Sharing was adapted from Di Vaio & Varriale (2017). Electronic Documentation & Payments was based on Akinbola et al. (2021). Operational Performance of Cargo Clearance was drawn from Di Vaio & Varriale (2017), Nwaogbe et al. (2020), Paulauskas et al. (2021), and Akinbola et al. (2021). Reliability was evaluated using Cronbach's Alpha, with all constructs exceeding the 0.7 threshold, indicating strong internal consistency:

S/N	Variables	Cronbach's Alpha
1	Level of Automation (LOA)	0.912
2	Integration of Port Stakeholders (IPS)	0.928
3	Real-time Data Sharing (RDS)	0.937
4	Electronic Documentation & Payments (EDP)	0.946
5	Operational Performance of Cargo Clearance (OPCC)	0.952

Source: SMART PLS, Output, 2025.

Data were analyzed using Partial Least Squares Structural Equation Modeling (PLS-SEM) in SmartPLS, selected for its ability to handle complex relationships between multiple constructs and

accommodate smaller sample sizes and non-normal data distributions. The structural model, computed using SmartPLS, is presented to evaluate the relationships among the constructs. Google Form links were sent to 386 stakeholders of the Nigerian Ports Authority (ICT: 38 staff, Marine Operations: 52, Trade Facilitation/PCS Unit: 45, Port Management: 88), Nigeria Customs Service (74 officers), terminal operations staff (32), and licensed customs agents or freight forwarders (57) who are directly engaged in PCS-related cargo clearance operations at Lagos Port Complex, making sure to cover the full population targeted for this study. After allowing sufficient time for responses, a total of 245 valid responses were retrieved and used for the final analysis, representing a response rate of 63.5%.

DATA ANALYSIS AND DISCUSSIONS

Assessment of Measurement Model

In assessing the measurement model, the researcher first evaluated the item outer loadings. Loadings above 0.708 are preferred, as they indicate that the construct explains more than 50% of the indicator's variance, ensuring item reliability (Hair et al., 2019). However, Hair et al. (2019) also suggest that indicators with loadings between 0.50 and 0.708 can still be retained if they contribute meaningfully to construct validity. In this study, all indicators recorded outer loadings above the 0.70 threshold and were retained in the model.

Table 1: Reliability of Study Scale

/N	Variables	Factor Loadings	Cronbach's Alpha	Composite Reliability	AVE	R^2	Q^2
	Level of Automation (LOA)	LOA1 (0.815), LOA2 (0.892), LOA3 (0.837), LOA4 (0.879), LOA5 (0.846)	0.912	0.935	0.745	0.198	0.912
	Integration of Port Stakeholders (IPS)	IPS1 (0.878), IPS2 (0.901), IPS3 (0.865), IPS4 (0.912), IPS5 (0.835)	0.928	0.945	0.780	0.412	
	Real-time Data Sharing (RDS)	RDS1 (0.893), RDS2 (0.917), RDS3 (0.904), RDS4 (0.859), RDS5 (0.881)	0.937	0.951	0.798	0.001	
	Electronic Documentation & Payments (EDP)	EDP1 (0.945), EDP2 (0.862), EDP3 (0.889), EDP4	0.946	0.958	0.821	0	

		(0.931), EDP5 (0.918)			
Operational Performance of Cargo Clearance (OPCC)		OPCC1 (0.958), OPCC2 (0.841), OPCC3 (0.867), OPCC4 (0.935), OPCC5 (0.927)	0.952	0.964	0.839

Source: SmartPLS Output, 2025.

Table 1 presents the reliability results for the study constructs, including Factor Loadings, Cronbach's Alpha, Composite Reliability (CR), and Average Variance Extracted (AVE). The factor loadings for all indicators exceed the recommended 0.70 threshold, confirming that the items are strong indicators of their respective constructs (Hair et al., 2019). Specifically, loadings for Level of Automation range from 0.815 to 0.892, for Operational Performance of Cargo Clearance from 0.841 to 0.958, for Integration of Port Stakeholders from 0.835 to 0.912, for Real-time Data Sharing from 0.859 to 0.917, and for Electronic Documentation & Payments from 0.862 to 0.945.

The Cronbach's Alpha values for all constructs exceed 0.70 (LOA = 0.912; OPCC = 0.952; IPS = 0.928; RDS = 0.937; EDP = 0.946), demonstrating high internal consistency (Nunnally, 1978). Similarly, the Composite Reliability values range from 0.935 (LOA) to 0.964 (OPCC), surpassing the 0.70 threshold, thus further supporting construct reliability (Fornell & Larcker, 1981).

The Average Variance Extracted (AVE) values also exceed the acceptable minimum of 0.50, with LOA (0.745), OPCC (0.839), IPS (0.780), RDS (0.798), and EDP (0.821), indicating adequate convergent validity. Additionally, the model's explanatory power was assessed using R^2 and adjusted R^2 values. The R^2 value for Operational Performance of Cargo Clearance is 0.912, indicating that 91.2% of the variance in Operational Performance of Cargo Clearance is explained by the predictor variables, while the adjusted R^2 is 0.901, demonstrating a substantial level of predictive accuracy (Hair et al., 2019). These findings confirm that the measurement model demonstrates strong reliability and validity and is appropriate for structural model analysis.

Table 2: Heterotrait-Monotrait Ratio (HTMT)

Variables	(LOA)	(OPCC)	(IPS)	(RDS)	(EDP)
Level of Automation (LOA)					
Operational Performance of Cargo Clearance (OPCC)	0.872				

Integration of Port Stakeholders (IPS)	0.845	0.891		
Real-time Data Sharing (RDS)	0.859	0.868	0.879	
Electronic Documentation & Payments (EDP)	0.836	0.853	0.862	0.874

Source: SmartPLS Output, 2025

Table 2 presents the Heterotrait-Monotrait Ratio (HTMT) values for the constructs Level of Automation (LOA), Operational Performance of Cargo Clearance (OPCC), Integration of Port Stakeholders (IPS), Real-time Data Sharing (RDS), and Electronic Documentation & Payments (EDP). The HTMT is used to assess discriminant validity, with values below 0.90 indicating that constructs are distinct from one another (Henseler et al., 2015). The HTMT values in this table range from 0.836 (LOA and EDP) to 0.891 (OPCC and IPS), all below the 0.90 threshold. Specifically, the relationships are as follows: LOA and OPCC (0.872), LOA and RDS (0.859), OPCC and RDS (0.868), OPCC and EDP (0.853), IPS and RDS (0.879), and IPS and EDP (0.862). These results confirmed that the constructs are sufficiently distinct, exhibiting good discriminant validity as they do not share excessive variance. Therefore, the measurement model is valid in terms of both convergent and discriminant validity, aligning with the guidelines established by Henseler et al. (2015) for ensuring the adequacy of model constructs.

Assessing the Structural Model

Having satisfied the measurement model assessment, the next step in evaluating PLS-SEM results is to assess the structural model. Standard assessment criteria, which was considered include the path coefficient, t-values, p-values and coefficient of determination (R2). The bootstrapping procedure was conducted using a resample of 5000.

Table 3: Path Coefficients and Hypothesis Testing Results

Variables	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T Statistics (|O/STDEV|)	P Values	Decision
LOA → OPCC	0.342	0.343	0.168	2.036	0.042	Rejected
IPS → OPCC	0.298	0.295	0.182	1.637	0.108	Accepted
RDS → OPCC	0.389	0.391	0.183	2.126	0.034	Rejected

EDP → OPCC	0.456	0.458	0.179	2.547	0.011	Rejected

Source: SmartPLS Output, 2025

Interpretation of Results

Table 4 presents the path coefficients, T-statistics, and p-values for the relationships between the independent variables (Level of Automation, Integration of Port Stakeholders, Real-time Data Sharing, and Electronic Documentation & Payments) and the dependent variable (Operational Performance of Cargo Clearance, OPCC).

H_{01}: Level of Automation has no significant effect on Operational Performance of Cargo Clearance at the Nigerian Ports Authority.

For the first hypothesis (H_{01}), the analysis of the relationship between Level of Automation (LOA) and Operational Performance of Cargo Clearance (OPCC) at the Nigerian Ports Authority yielded a path coefficient of 0.342, indicating a moderate positive effect. The sample mean of 0.343 and a standard deviation of 0.168 suggest consistency in the data. With a T-statistic of 2.036, surpassing the critical threshold of 1.96, and a p-value of 0.042 (below 0.05), the relationship is statistically significant, leading to the rejection of H_{01}. This result implies that a higher level of automation significantly enhances cargo clearance performance by reducing manual interventions, minimizing errors, and accelerating processes such as gate controls and cargo tracking.

Automated systems within the PCS ensure faster throughput, lower dwell times, and improved efficiency, which are vital for addressing bottlenecks in Nigerian ports. By advancing automation, the Nigerian Ports Authority can reduce delays, enhance reliability, and boost competitiveness in maritime trade. This finding is consistent with Paulauskas et al. (2021), who demonstrated that automation technologies reduce congestion and increase throughput, and with Onwuegbuchunam et al. (2021), who highlighted the role of ICT in overcoming operational constraints in Nigerian terminals.

H_{02}: Integration of Port Stakeholders has no significant effect on Operational Performance of Cargo Clearance at the Nigerian Ports Authority.

The second hypothesis analyzed the relationship between Integration of Port Stakeholders (IPS) and Operational Performance of Cargo Clearance (OPCC). The path coefficient for this relationship is 0.298, with a sample mean of 0.295 and a standard deviation of 0.182. The T-statistic of 1.637 falls below the critical threshold of 1.96, and the p-value of 0.108 exceeds 0.05, confirming the absence of statistical significance. Therefore, the null hypothesis (H_{02}) is accepted. This finding suggests that stakeholder integration does not significantly influence cargo clearance performance, possibly due to challenges like fragmented governance, resistance to collaboration, or incomplete PCS adoption among actors such as customs and terminal operators. While integration aims to foster coordinated workflows, barriers in the Nigerian context may limit its impact on reducing dwell times or improving transparency. This result contrasts with Caldeirinha et al. (2022), who found strong effects from stakeholder collaboration in Portuguese ports, indicating that contextual factors like regulatory alignment may moderate integration's effectiveness at the Nigerian Ports Authority.

H_{03}: Real-time Data Sharing has no significant effect on Operational Performance of Cargo Clearance at the Nigerian Ports Authority.

The third hypothesis (H_{03}) examined the effect of Real-time Data Sharing (RDS) on Operational Performance of Cargo Clearance (OPCC) at the Nigerian Ports Authority. The path coefficient of 0.389, with a sample mean of 0.391 and a standard deviation of 0.183, indicates a moderate positive

relationship. The T-statistic of 2.126 exceeds the critical threshold of 1.96, and a p-value of 0.034 confirms the statistical significance of this relationship, leading to the rejection of H_{03}.

This result implies that real-time data sharing significantly improves clearance efficiency by enabling instant access to vessel status, approvals, and cargo updates, thereby reducing procedural delays and enhancing decision-making. In Nigerian ports, such synchronization minimizes bottlenecks, improves transparency, and supports stakeholder satisfaction. Integrating RDS with other PCS features can further optimize throughput and competitiveness. This finding aligns with Inkinen (2022), who emphasized real-time exchange for supply chain synchronization, and with Paulauskas et al. (2021), who reported reductions in paperwork and delays through digital visibility.

H_{04}: Electronic Documentation & Payments has no significant effect on Operational Performance of Cargo Clearance at the Nigerian Ports Authority.

The fourth hypothesis (H_{04}) analyzed the relationship between Electronic Documentation & Payments (EDP) and Operational Performance of Cargo Clearance (OPCC). The path coefficient is 0.456, with a sample mean of 0.458 and a standard deviation of 0.179. The T-statistic of 2.547 surpasses the critical threshold of 1.96, and the p-value of 0.011 confirms statistical significance, leading to the rejection of H_{04}.

This suggests that electronic processes significantly enhance performance by eliminating paper-based delays, reducing errors in manifests and payments, and accelerating clearance speed. For the Nigerian Ports Authority, adopting digital submissions and payments minimizes corruption risks, improves accuracy, and shortens dwell times, contributing to cost-effectiveness and trade facilitation. This is consistent with Amin (2022), who found efficiency gains in dwell and clearance times at Damietta Port, and with Rachmawati et al. (2023), who advocated electronic systems to meet global clearance targets.

Conclusion

This study examined the effect of Level of Automation (LOA), Integration of Port Stakeholders (IPS), Real-time Data Sharing (RDS), and Electronic Documentation & Payments (EDP) on Operational Performance of Cargo Clearance (OPCC) at the Nigerian Ports Authority. The findings indicate that LOA (path coefficient = 0.342, p = 0.042), RDS (path coefficient = 0.389, p = 0.034), and EDP (path coefficient = 0.456, p = 0.011) significantly enhance OPCC, underscoring their role in reducing dwell times, improving documentation accuracy, accelerating clearance, and boosting transparency and satisfaction. Conversely, IPS showed no significant effect (path coefficient = 0.298, p = 0.108), likely due to governance challenges and fragmented adoption. These results highlight the pivotal role of automation, real-time sharing, and electronic processes in PCS digitalization for minimizing delays and enhancing efficiency, while suggesting barriers limit stakeholder integration's impact.

Recommendations

1. The Nigerian Ports Authority should prioritize advancing the level of automation within PCS, including automated gate systems and cargo tracking, to reduce manual errors and accelerate clearance processes, thereby improving dwell times and operational efficiency.
2. To leverage real-time data sharing, invest in robust PCS infrastructure for instant information exchange among stakeholders, enabling proactive decision-making and reducing procedural bottlenecks.
3. Accelerate the full adoption of electronic documentation and payments to eliminate paper-based workflows, enhance data integrity, and minimize corruption opportunities, supporting faster and more transparent cargo clearance.
4. Address the insignificant impact of stakeholder integration by strengthening governance frameworks, training programs, and collaborative incentives to overcome

resistance and ensure seamless PCS connectivity across all port actors.

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QUESTIONNAIRE

TOPIC: ***The Effect of Port Community System (PCS) Digitalization on the Operational Performance of Cargo Clearance at the Nigerian Ports Authority***

Response Scale: SD = Strongly Disagree | D = Disagree | U = Undecided | A = Agree | SA = Strongly Agree.

S/N	Items	SD	D	U	A	SA
1	**Level of Automation (LOA)**					
LOA1	Automated systems handle most cargo clearance procedures effectively.					
LOA2	Manual paperwork in port clearance has greatly reduced since PCS use.					
LOA3	Cargo release steps are processed automatically through PCS platforms.					
LOA4	Automation has minimized delays and physical interactions at the port.					
LOA5	NPA staff effectively monitor automated cargo processes in real time.					
2	**Integration of Port Stakeholders (IPS)**					
IPS1	PCS links NPA, Customs, and terminals on one shared platform.					
IPS2	Stakeholders exchange cargo information seamlessly through PCS systems.					
IPS3	PCS enhances collaboration among all port clearance participants.					
IPS4	Stakeholder integration reduces duplication and clearance bottlenecks.					
IPS5	Information consistency has improved through multi-stakeholder PCS access.					
3	**Real-Time Data Sharing (RDS)**					
RDS1	Cargo status updates are instantly accessible to all port stakeholders.					
RDS2	PCS enables quick tracking of shipment and clearance progress.					
RDS3	Real-time information improves coordination between NPA and Customs.					
RDS4	PCS reduces information delays in cargo processing and documentation.					
RDS5	Real-time visibility enhances transparency and decision-making efficiency.					
4	**Electronic Documentation & Payments (EDP)**					
EDP1	Cargo documentation is now processed electronically through PCS portals.					
EDP2	E-payment systems have simplified port charges and customs duties.					
EDP3	Electronic records reduce paperwork errors in clearance operations.					
EDP4	PCS ensures secure and traceable electronic transaction processing.					
EDP5	E-documentation has improved transparency in cargo release processes.					
5	**Operational Performance of Cargo Clearance (DV)**					
OPC1	Average cargo dwell time has significantly reduced under PCS use.					

OPC2	Documentation accuracy has improved since PCS implementation.					
OPC3	Clearance speed for cargo has increased with digital port systems.					
OPC4	PCS has enhanced transparency in clearance and release operations.					
OPC5	Stakeholder satisfaction has improved with PCS-driven cargo processes.					