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Digital Maritime Logistics and Lead Time performance: Empirical Evidence from Nigerian Seaport Industry

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ABSTRACT
This study provides a deep understanding of the significance impact of digital maritime logistics on lead time performance in Nigerian Seaports and actionable insights for policymakers, port operators, and other stakeholders to enhance lead time and port performance in the globalized world. The aim of the study was to evaluate the impact of digital maritime logistics on lead time performance in Nigerian seaport industry. The study comprises the 7 Seaports with the sample size of 63 respondents from the seaports provided quantitative data for the study through a semi-structured questionnaire designed in Likert 5-point scale. The data were analyzed using inferential statistics particularly regression. The analysis of the study on digital maritime logistics and lead time performance in Nigerian Seaports industry indicated that there is a strong positive correlation between digital maritime logistics and lead time performance inferring that the adoption of digital maritime logistics will enhance lead time performance in Nigerian Seaports industry. The study showed evidence that DPA, WA, AID, and ATS enhance forecast accuracy on lead time performance, improve order fulfillment on lead time performance, enhance real-time inventory tracking on lead time performance and improve delivery times on lead time performance in Nigeria seaport industry. It forms that the impact is very significant to a moderate extent given at 46.9%, while a percentage improvement on DPA, WA, AID, and ATS would result to 12.8%, 2.11%, 3.42% and 11.5% on fostering forecast accuracy, enhance order fulfillment, enhance real-time inventory tracking, and improve delivery times on lead time performance in Nigeria seaport industry respectively.

keywords: *digitalization, maritime logistics, automation, lead time.*

1. INTRODUCTION

Digital maritime logistics plays a crucial role in enhancing lead time performance in seaport industry by leveraging technologies like artificial intelligence, blockchain technologies, Internet of Things IoT, and Automations (Zeeshan et al., 2023; Wang, & Hsu, 2025; Mohamed et al., 2024). Maritime logistics as a critical component of global trade, plays a significant role in facilitating the movement of goods across international borders (Emanuele et al., 2023; Delfin-Ortega, 2025).

The digitalization of maritime logistics operations has emerged as a transformative force, reshaping traditional practices and enhancing efficiency in port operations (UNCTAD, 2020). In Nigeria, a country with extensive maritime trade connections, the impact of digitalization on the performance of seaports is of particular interest due to its potential to improve competitiveness and streamline processes (Adelaja, et al., 2021). This study seeks to evaluate the impacts of digital maritime logistics on lead time performance, considering factors such as Demand Planning Automation, Warehouse Automation, Automated Inventory Management, Automated Transport System. In addition, (Hlali et al., 2026) examined the strategic potential of blockchain technology and smart contracts in maritime supply chains, and identified key legal, technological, and governance challenges while outlining how digital ledger technologies can enhance transparency, traceability, and coordination among maritime stakeholders.

Nigeria's maritime sector serves as a crucial gateway for international trade (Guedidi, et al., 2024; Ayoola, 2024), handling a significant portion of the country's imports and exports (NPA, 2020). However, challenges such as inefficiencies in port operations, congestion, and bureaucratic processes have long plagued the sector, hindering its potential for growth (Adelaja *et al.,* 2021). Against this backdrop, the adoption of digital technologies holds promise for addressing these challenges and driving improvements in port performance. Digitalization in maritime logistics encompasses various technologies and innovations, including electronic documentation systems, automated cargo handling, real-time tracking solutions (UNCTAD, 2020), automatic identification system (AIS), and radio frequency identification system (RFID). For Nigerian ports, embracing digitalization presents a pathway to modernization and improved competitiveness in the global maritime landscape.

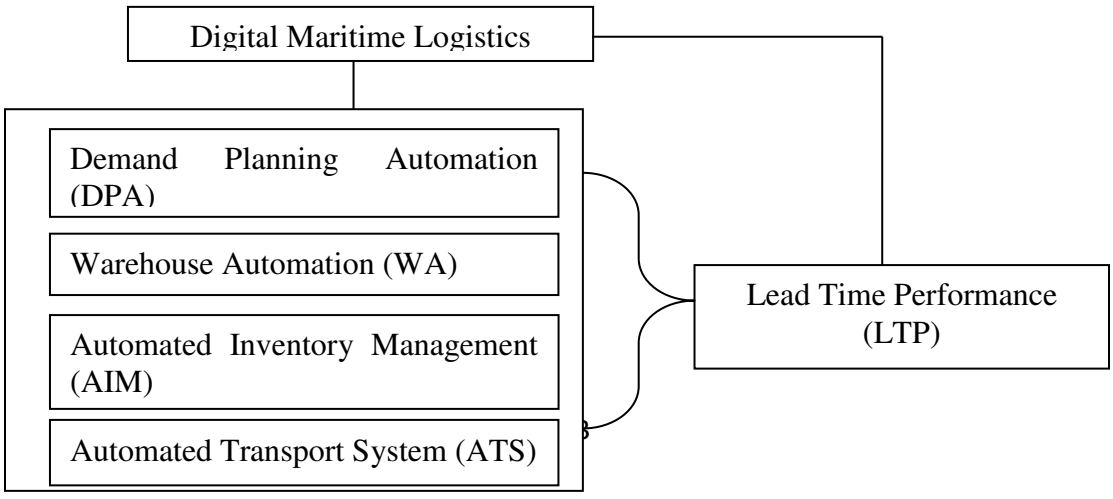
In recent years, the Nigerian government has shown a growing commitment to modernizing the maritime sector and promoting digitalization initiatives (NIMASA, 2020). Policies aimed at improving port infrastructure, enhancing customs processes, and encouraging investment in digital technologies reflect this shift towards a more technology-driven approach (Adelaja *et al.,* 2021). However, the effective implementation of these policies requires collaboration between government agencies, port operators, and private sector stakeholders to ensure alignment with industry needs and best practices. The COVID-19 pandemic has further underscored the importance of digitalization in maritime logistics, as lockdown measures and supply chain disruptions highlighted the vulnerabilities of traditional port operations (Jiaguo et al., 2023; UNCTAD, 2020). Gabriel et al. (2020) and Moosavi et al., (2022) among others observed that the COVID-19 pandemic had adverse effects and damage on organizations however the approach and strategic response of organizations are very important in determining the level of their losses, and their capacity for resilience and stability in the situation. In response, ports worldwide accelerated their adoption of digital solutions to mitigate risks and maintain business continuity (Claran et al., 2025). In Nigeria, the pandemic served as a catalyst for digital transformation efforts, prompting stakeholders to explore innovative technologies for remote operations, contactless transactions, and risk management strategies (NIMASA, 2020, Deepjyoti & Aditya 2025).

Recent research has increasingly highlighted the role of digital technologies in enhancing efficiency and sustainability within transport and supply chain systems. For instance, Nwoloziri, Nze, and Hlali (2026) provide empirical evidence from Nigerian container terminals demonstrating how operational delays in container vessel handling significantly affect trade performance and terminal efficiency, emphasizing the need for structural and technological improvements in port operations.

Despite the potential benefits of digitalization, challenges exist in implementing and integrating these technologies effectively within the Nigerian maritime context. Limited infrastructure, inadequate digital literacy, and cybersecurity concerns pose barriers to widespread adoption (Adelaja *et al.,* 2021). Additionally, resistance to change and entrenched bureaucratic processes may impede the pace of digital transformation within port operations (UNCTAD, 2020). Addressing these challenges requires a holistic approach that considers not only technological solutions but also organizational readiness, capacity building, and stakeholder engagement strategies (Deepjyoti & Aditya 2025). Consequently, there is a gap in understanding how digital technologies influence port performance within the Nigerian context and the specific challenges and opportunities they present (Adelaja *et al.,* 2021). This study aimed to bridge this gap by providing empirical insights into the dynamics of digital maritime logistics in Nigerian seaports and its implications for enhancing lead time perfomance and effectiveness in port supply chain management.

Furthermore, the digitalization of maritime logistics holds immense potential for transforming the performance of seaports logistics system in Nigeria, offering opportunities to enhance efficiency, reduce costs, and improve competitiveness in global trade. However, realizing these benefits requires overcoming various challenges related to infrastructure, governance, and organizational dynamics. Through empirical research and theoretical analysis, this study aims to contribute to a deeper understanding of the complex dynamics surrounding digitalization in Nigerian seaports and provide actionable insights for policymakers, port operators, and other stakeholders to navigate this transformative process effectively. This study is conceptualized in a framework (Figure 1) and underpinned by the Technology-Organization-Environment (TOE) Framework. Therefore, the study aimed to analyse the impact of digital maritime logistics on lead time performance, a case of Nigeria industry, with the following specific objectives including to evaluate the extent to which demand planning automation improves forecast accuracy on lead time performance; examine the extent to which warehouse automation improves order fulfillment on lead time performance; examine the extent to which automated inventory management enhances real-time inventory tracking on lead time performance; and to determine the extent to which automated transport system enhances delivery times on lead time performance in Nigeria industry. Therefore, study hypothesized that demand planning automation, warehouse automation, automated inventory management, and automated transport system have no significant impact on lead time performance in Nigeria seaport industry.

Figure 1: Conceptual framework showing the impact of digital maritime logistics on lead time performance



Source: authors elaboration

2. Literature Review

The study adopted Technology-Organization-Environment (TOE) Framework, a theoretical model used to study the adoption of technological innovations within organizations (Chandra, 2025). The TOE framework provides a structured approach to examining the interplay between technological factors, organizational characteristics, and environmental influences on the adoption and implementation of digital maritime logistics and shipping operations. By applying this framework, the study can systematically analyze how technological innovations, organizational capabilities, and external factors such as regulatory frameworks and market dynamics shape the operational strategies and outcomes of shipping industries. The Technology-Organization-Environment (TOE) framework is a widely-used theoretical framework in the field of information systems and organizational studies, aiming to explain the factors influencing the adoption and implementation of technology within organizations (Tran, et al., 2022). The TOE framework posits that technology adoption decisions are influenced by three main sets of factors: technological characteristics, organizational context, and external environmental factors (Rogers, 1995). Recent research has applied the TOE framework to various contexts, including the adoption of digital technologies in maritime logistics and port operations.

In the context of maritime logistics, technological characteristics refers to the features and attributes of digital technologies, such as their compatibility with existing systems, complexity, and perceived benefits (Amoin & Zhan, 2024). Study have examined how organizational readiness, leadership support, and IT infrastructure affect the adoption and implementation of digital technologies in maritime logistics (*Guangming, et al., 2025*). External environmental factors include external pressures, such as industry norms, regulatory requirements, market competition, and technological trends that shape technology adoption decisions (Tadesse, & Debela, 2024). Scholars have explored how regulatory frameworks, international standards, and industry collaborations influence the adoption of digital technologies in maritime logistics and port operations (Latip, et al., 2022). For example, Notteboom and Rodrigue (2005) examine how global maritime governance regimes, such as the International Maritime Organization (IMO) and World Customs Organization (WCO), promote the adoption of electronic documentation systems and cargo tracking platforms to enhance port security and efficiency.

The TOE framework provides a holistic perspective that considers the interplay between these factors and their impact on technology adoption processes (Tadesse, & Debela, 2024). Additionally, the framework may not fully capture the complexity and context-specific nature of technology adoption decisions in diverse organizational settings (Latip, et al., 2022). Nonetheless, the TOE framework remains a valuable tool for understanding the multifaceted factors influencing technology adoption within organizations and guiding empirical research and practical interventions in the field of information systems and organizational studies. Thus, the Technology-Organization-Environment (TOE) framework provides a comprehensive and systematic approach to understanding the adoption and implementation of technology within organizations. Empirical studies in maritime logistics and port operations have applied the TOE framework to analyze the factors influencing the adoption of digital technologies, such as blockchain, Internet of Things (IoT), and electronic documentation systems, highlighting the importance of technological,

organizational, and environmental factors in shaping technology adoption decisions (Moosavi et al., 2022; Wang, & Hsu 2025; Claran, et al., 2025).

Digitalization of maritime logistics involves the integration of digital technologies and data-driven solutions into various aspects of the maritime supply chain to enhance efficiency, transparency, and competitiveness. Maritime logistics plays a crucial role in global trade, facilitating the movement of goods across continents. In recent years, there has been a significant shift towards digitalization in the maritime sector, driven by technological advancements and the need for efficiency and competitiveness. This critical background provides an overview of the key factors driving digitalization in maritime logistics, the challenges faced, and the implications for stakeholders.

Additionally, the COVID-19 pandemic has accelerated the adoption of digital technologies in the maritime sector, as companies seek to mitigate disruptions and adapt to remote working conditions (UNCTAD, 2020). The digitalization of maritime logistics offers numerous benefits, including reduced transit times, lower inventory holding costs, and improved safety and security (Bichou & Gray, 2019). Despite the potential benefits, digitalization in maritime logistics also faces several challenges and barriers. Additionally, resistance to change from traditional stakeholders and a lack of digital skills among the workforce pose significant obstacles to the adoption of digital solutions (Rodrigue et al., 2019).

Logistics encompasses various dimensions that are crucial for the effective management and movement of goods throughout the supply chain. Scholars have identified and discussed these dimensions in recent literature, shedding light on their significance and interconnections. Some of the key dimensions of logistics according to recent scholarly research are (i) transportation management (ii) inventory management (iii) warehousing and distribution (iv) information technology (v) customer service and (vi) sustainability (Franca et al., 2024; slam, et al., 2023). These dimensions collectively contribute to the efficient and effective management of logistics operations, supporting supply chain performance and competitiveness. In this study however, demand planning automation (DPA), warehouse automation (WA), automated inventory management (AIM), and automated transport system (ATS) are investigated to ascertain the impacts on lead time performance in Nigeria shipping industry.

ADP - Automated demand planning is a critical aspect of supply chain management, enabling organizations to forecast demand accurately, optimize inventory levels, and improve customer service. This scholarly discussion provides insights into automated demand planning, its benefits, challenges, and recent advancements, supported by recent literature in the field. ADP involves the use of advanced algorithms, data analytics, and artificial intelligence (AI) to predict future demand for products or services. Additionally, ADP enables faster decision-making and proactive adjustments to changing market conditions. Several benefits are associated with automated demand planning, including improved forecast accuracy, enhanced inventory management, and increased customer satisfaction.

Another advantage of ADP is its scalability and adaptability to changing business requirements. As organizations grow and diversify their product offerings, automated demand planning systems can accommodate new products, markets, and demand patterns without significant manual intervention (Chopra & Meind, 2019). Despite its benefits, automated demand planning also presents challenges, such as data integration issues, algorithm complexity, and reliance on historical data.

WA - Warehouse Automation refers to the implementation of advanced technologies and systems within warehouses to automate various tasks traditionally performed by human operators. WA plays a crucial role in modern supply chain management by improving efficiency, accuracy, and flexibility in warehouse operations. Automation also addresses labor shortages and the need for faster order fulfillment in today's e-commerce-driven market (Kamble & Gunasekaran, 2021). One of the primary benefits of warehouse automation is increased operational efficiency. Automation reduces errors in order picking, packing, and shipping, leading to improved customer satisfaction and retention (Ivanov & Rozhkov, 2020). The Nigerian Ports Authority (NPA) and terminal operators have begun integrating automated quay cranes into major seaports to improve cargo-handling speed and reliability (NPA, 2023). The implementation process involves deploying advanced control systems, sensors, and artificial intelligence to enhance crane operations (Okonkwo & Adeoye, 2021). Apapa and Tin Can Island have adopted automation solutions to optimize berth productivity and reduce vessel turnaround time. The adoption of AQCOS also aligns with the Nigerian Single Window initiative, which seeks to digitalize port operations. Automated quay cranes significantly reduce loading and unloading times, improving overall port throughput (Smith & Brown, 2021). Automation minimizes workplace accidents and operational risks by reducing direct human involvement in crane operations (UNCTAD, 2022). Long-term operational costs are lowered due to reduced labor dependency and improved fuel efficiency of automated cranes (Okonkwo & Adeoye, 2021).

The challenges of Implementing AQCOS in Nigerian Seaports include the capital expenditure required for acquiring and installing automated quay cranes is significant, posing financial constraints. Inconsistent power supply, inadequate digital infrastructure, and unreliable internet connectivity hinder seamless automation (NPA, 2023). The transition to automation requires extensive workforce training and possible job displacement, leading to resistance from port labor unions (Smith & Brown, 2021). The future of AQCOS in Nigerian seaports hinges on sustained investment, policy support, and capacity-building initiatives. The integration of artificial intelligence and IoT-enabled monitoring systems will further enhance automation efficiency. Collaborative efforts between the government and private stakeholders will be instrumental in overcoming adoption barriers (UNCTAD, 2022).

AID- Automated inventory management refers to the use of advanced technologies and systems to streamline and optimize the processes involved in tracking, monitoring, and controlling inventory levels within a warehouse or supply chain environment. This approach involves the deployment of automated solutions such as barcode scanners, RFID (Radio Frequency Identification) systems, and inventory management software to automate tasks traditionally performed manually, such as inventory tracking, stock replenishment, and order fulfillment (Kamble & Gunasekaran, 2021). AID has become increasingly prevalent in modern supply chain operations, driven by advancements in technology and the need for enhanced efficiency and accuracy in inventory control. This discussion explores the significance, benefits, challenges, and recent trends in automated inventory management. Automated inventory management plays a critical role in optimizing inventory levels, reducing carrying costs, and improving order fulfillment accuracy. By leveraging technology such as barcode scanners, RFID tags, and inventory management software, organizations can automate various inventory-related tasks, including tracking stock levels, generating replenishment orders, and conducting cycle counts (Wang & Ramakrishnan, 2020).

One of the primary benefits of automated inventory management is improved accuracy and visibility. Automated systems provide real-time insights into inventory levels, locations, and movements, enabling organizations to make informed decisions and respond quickly to changes in demand (Ivanov & Sokolov, 2020). By analyzing historical sales data, market trends, and other relevant factors, automated systems can generate more accurate demand forecasts and optimize inventory replenishment schedules (Wu et al., 2021). This enables organizations to minimize excess inventory holding costs while ensuring adequate stock availability to meet customer demand. Despite its benefits, AIM poses challenges related to technology integration, data accuracy, and system complexity. Integrating automated inventory management systems with existing enterprise systems, such as ERP and WMS platforms, can be complex and time-consuming (Kamble & Gunasekaran, 2021). Ensuring the accuracy and reliability of data inputs is also crucial for the effectiveness of automated inventory management, as inaccurate data can lead to suboptimal decision-making and inventory discrepancies (Wang & Ramakrishnan, 2020). Implementing and maintaining automated inventory management systems requires specialized expertise and resources, particularly for small and medium-sized enterprises (SMEs) with limited IT infrastructure and budgets (Ivanov & Sokolov, 2020).

ATS - Automated Transport System in seaport operations involves the utilization of automated systems and technologies to enhance the efficiency, safety, and reliability of the transportation and handling of goods within and between seaport facilities. This includes the deployment of Automated Guided Vehicles (AGVs), Automated Stacking Cranes (ASCs), and automated mooring systems to streamline logistics and reduce the need for manual labor (Vis, 2006). Transport automation in seaport operations refers to the implementation of advanced technological solutions such as Internet of Things (IoT) devices, robotic process automation (RPA), and blockchain technology to optimize the management and movement of cargo. These technologies improve operational efficiency by providing real-time data, enhancing visibility, and automating repetitive tasks (Heilig, Lalla-Ruiz & Voß, 2017). Transportation is a significant driver of economic activity, enabling trade, commerce, and the movement of goods across supply chains. Efficient transportation networks reduce transaction costs, facilitate market access, and support the growth of industries and businesses (Banister, 2019). Despite its benefits, transportation also contributes to environmental challenges such as air pollution, greenhouse gas emissions, and habitat destruction. Efforts to mitigate these impacts include promoting sustainable transport modes, improving fuel efficiency, and investing in alternative fuels and renewable energy sources (Givoni & Banister, 2019). Recent advancements in technology, including electric vehicles, autonomous transportation systems, and intelligent transportation systems, are reshaping the transport landscape. These innovations offer opportunities to improve efficiency, safety, and environmental performance while addressing emerging challenges such as urban congestion and climate change (Levinson, 2019). Transportation plays a central role in facilitating globalization and international trade by connecting markets, enabling the movement of goods and services, and supporting global supply chains. Efficient transportation systems are essential for maintaining competitiveness and economic growth in an increasingly interconnected world (Givoni & Banister, 2019). Traffic management is crucial for ensuring maritime safety, optimizing port operations, and enhancing trade facilitation. The Vessel Traffic Management System (VTMS) is a critical technology designed to monitor, manage, and regulate ship movements within port and coastal areas. Nigerian seaports, being key hubs for international trade, have begun adopting VTMS to improve operational efficiency, reduce congestion, and enhance maritime security (UNCTAD,

2022). This paper explores the implementation, benefits, challenges, and future outlook of VTMS in Nigerian seaports.

The Nigerian Ports Authority (NPA) and the Nigerian Maritime Administration and Safety Agency (NIMASA) have undertaken initiatives to deploy VTMS across major seaports, including Apapa, Tin Can Island, and Onne (NPA, 2023). The system comprises radar, Automatic Identification Systems (AIS), closed-circuit television (CCTV) surveillance, and real-time data analytics for vessel tracking and coordination (Okonkwo & Adeoye, 2021). The implementation of VTMS in Nigeria involves integrating smart technologies with existing port infrastructure to ensure seamless communication between port control centers, shipping lines, and regulatory agencies. Additionally, efforts are being made to align VTMS operations with international maritime safety conventions (World Bank, 2022). VTMS improves navigational safety by providing real-time monitoring of vessel movements, thereby reducing the risks of collisions and unauthorized access (Smith & Brown, 2021). By optimizing vessel scheduling and traffic flow, VTMS minimizes delays, improves berth allocation, and enhances overall port efficiency (UNCTAD, 2022). Effective traffic management reduces emissions and pollution by enabling better route planning and minimizing vessel idling times (World Bank, 2022). VTMS supports compliance with international maritime regulations by ensuring accurate documentation, reporting, and monitoring of vessel activities (Okonkwo & Adeoye, 2021). Challenges of Implementing VTMS in Nigerian Seaports include the initial capital investment required for VTMS infrastructure, coupled with maintenance expenses, poses a financial challenge for port authorities. Inconsistent power supply, outdated port infrastructure, and limited digital connectivity hinder the full-scale deployment of VTMS (NPA, 2023). A lack of technical expertise and skilled personnel to manage and operate VTMS effectively presents a major hurdle to its successful implementation (Smith & Brown, 2021). The future of VTMS in Nigerian seaports depends on continued investment in smart port technologies, policy enhancements, and capacity-building initiatives. Integrating artificial intelligence, satellite-based tracking, and predictive analytics will further enhance VTMS capabilities. Collaboration between government agencies, private stakeholders, and international maritime bodies will be critical in ensuring sustainable adoption and operation of VTMS in Nigeria (UNCTAD, 2022).

LTP - Lead Time Performance in seaport supply chain management refers to the duration between the initiation of a process or order and its completion or delivery. It involves the coordination and management of activities that deliver finished products to end users or customers through ports. It encompasses the time required for activities such as order processing, production, transportation, and delivery to fulfill customer demand (Chopra & Meind, 2021). Lead time plays a critical role in determining the responsiveness and efficiency of supply chain operations, as shorter lead times enable faster order fulfillment and improved customer satisfaction. Effective management of lead time is essential for optimizing inventory levels, reducing stockouts, and enhancing overall supply chain performance (Fernie & Sparks, 2020). Chopra and Meind (2021) discuss the importance of lead time management in supply chain operations, emphasizing the impact of lead time variability on inventory management and customer service levels. Fernie and Sparks (2020) examine the relationship between lead time reduction strategies and supply chain performance, highlighting the benefits of shorter lead times in improving responsiveness and competitiveness. Lead time is a critical concept in logistics and supply chain management, referring to the time it takes for a product or service to move through various stages of the supply chain, from order placement to delivery to the customer. Lead time plays a crucial role in determining the responsiveness, efficiency, and competitiveness of supply chain operations. Shorter lead times enable companies

to fulfill customer orders quickly, reduce inventory holding costs, and adapt to changing market demands more effectively (Chopra & Meind, 2021). Lead time directly impacts inventory management practices, as longer lead times require companies to maintain higher levels of safety stock to meet customer demand and avoid stockouts. Lead time significantly influences customer satisfaction levels, as shorter lead times lead to faster order fulfillment and delivery. Timely delivery of products or services enhances customer experience, fosters loyalty, and strengthens relationships with customers (Fernie & Sparks, 2020). Effective management of lead time is essential for optimizing supply chain performance and achieving strategic objectives such as cost reduction, revenue growth, and market expansion. Companies that effectively minimize lead times can gain a competitive advantage by offering faster delivery times and superior service levels (Simchi-Levi *et al.,* 2019). In Nigerian Seaports, information technology is adopted to improve service delivery. The Authority adopts information technology resources to maintain an unrivalled edge in the maritime subsector. The aim is to enhance customer services, follow a low-cost product to reduce costs through increased productivity and reduced need for employee overhead. Redundant tasks have been centralized at one location and high-cost functions have also been migrated into an online environment. Rapid communications have helped to increase productivity allowing for better business decision-making. Streamlined work flow systems and collaborative work spaces have also increased efficiency and allowed employees to process a greater level of work in a shorter period of time (NPA, 2024).

Many literature reviews focusing on empirical studies carried out by other researchers and scholars on concepts similar to the subject of investigation are of essence to compare the previous findings with ours in order to make conclusive statements. Johan and Christoffer (2017) investigated the economic impact of Autonomous Vehicles in the logistics industry in Sweden. Data were collected from document studies, literature studies and interviews. These were carried out simultaneously in an iterative process. The data were compared with existing theory by pattern matching and analyzed with thematic approach, in order to ensure the level of trustworthiness. The findings of the study revealed that autonomous vehicles will heavily impact the logistics industry. By gradually implementing autonomous vehicles, the Swedish logistics sector can save upwards of 13.4 billion SEK between 2020 and 2030.

Zhang et al. (2021) conducted a comparative analysis of multiple logistics firms to assess the impact of transport automation, data was collected on performance indicators such as delivery time, fuel consumption, and vehicle utilization rates before and after the implementation of automation technologies and the study found that transport automation led to significant improvements in performance metrics, including reduced delivery times, lower fuel consumption, and increased vehicle utilization rates. Li and Chen (2019) assess the impact of transport automation on supply chain performance with data from multiple firms over a period of time, analysing performance metrics such as delivery reliability, transportation costs, and customer satisfaction, the result infers that firms adopting transport automation experienced improvements in delivery reliability, cost reduction, and higher customer satisfaction levels, contributing to enhanced overall supply chain performance.

3. Materials and Methods

The methodology of this study is founded on the positivist research paradigm which relies on deductive logic, formulation and testing of hypotheses, offering operational definitions and mathematical equations, calculations, extrapolations and expressions to derive conclusions. Thus,

a quasi-experimental research design was employed by the researchers to establish the association between digitalization of maritime logistics and lead time of Seaports in Nigeria. The population of this study comprises the Nigerian ports including Lagos Port, Tincan Island Port, Rivers Port, Onne Port, Delta Port, Calabar Port, and Lekki Deep Sea Port. Considering the manageable size of the population of 150, a census technique was adopted, and all the elements in the population were studied. However, the study is at organizational level therefore, 135 respondents constituting 90% of the study population were adopted using Taro Yamane. The respondents were (i) Tariff and Billing Managers (ii) Traffic Managers (iii) Logistics Managers (iv) Port Managers (v) Operations Managers (vi) IT Managers (vii) Safety Managers (viii) Warehouse Managers (ix) Financial Managers and (x) Divisional Managers. However, only 63 respondents provided the quantitative data useful for the analysis. A well-structured questionnaire consisting of 20 items was used to collect primary data from the respondents. The instrument was designed in Likert 5–point scale of very high extent 5; high extent 4; moderate extent 3; low extent 2; very low extent 1.

Furthermore, Cronbach's alpha reliability analysis, and Exploratory Factor Analysis (EFA) were conducted to determine the reliability and construct validity of the research instrument. The Cronbach's alpha reliability relied on a threshold of 0.70 established by Nunally whilst factor loadings which was not less than 0.4 indicate that the constructs had discriminant validity. In establishing the impacts on the dependent variable, a multiple regression analysis was conducted by testing the research hypothesis whose result was subject to a critical value of 0.05 (95% confidence). The analysis was done with the aid of Statistical Package for Social Sciences (SPSS) version 25. The regression model expression is thus stated:

$Y_{LTP} = \beta_0 + \beta_1 X_{DPA} + \beta_2 X_{WA} + \beta_3 X_{AID} + \beta_4 X_{ATS}$
Where:
Y_{LTP} = Lead Time Performance
X_{DPA} = Demand Planning Automation
X_{WA} = Warehouse Automation
X_{AID} = Automated Inventory Management
X_{ATS} = Automated Transport System
β_0 = Intercept (constant term).
$\beta_1, \beta_2, \beta_3, \beta_4$ = Regression coefficients representing the effect of each independent variable on lead time performance.

4. Results

Table 1. Results of Reliability and Validity Tests

S/N	Variables	Number of Items	Cronbach's Alpha Coefficients	Factor Loadings
1	demand planning automation	4	0.831	0.671
2	Warehouse automation	4	0.730	0.682
3	Automated inventory management	4	0.749	0.613
4	Automated Transport system	4	0.716	0.832
5	Lead time performance	4	0.762	0.751

Table 1 shows the results of the Cronbach's alpha reliability test on all the variables in the study, showing high Cronbach's alpha coefficients. This means that, if this study was to be carried out again under a similar condition the results would be comparable to the results of this study. More also, results of the Exploratory Factor Analysis (EFA) revealed that DPA, WA, AID, and ATS, loaded heavily on digital of maritime logistics whilst all questionnaire items related to lead time loaded heavily on the variable, and these loadings (no factor loading is less than 0.4) indicating that the constructs have discriminant validity (Straub et al., 2004).

Table 2. Model summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.666[a]	.443	.405	1.837

a. Predictors: (Constant), DPA, WA, AID, and ATS

As shown on Table 2, the multiple regression coefficient (R value) is given as 0.666 showing that there is a positive correlation at 66.6% between dependent and independent variables. The coefficient of determination (R Squared) is 0.443, that is, approximately 44% informing that the changes in LTP were attributed to DPA, WA, AID, and ATS, while the remaining 56% changes were due to the impact of other external variables not included in the model.

Table 3. ANOVA[a]

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	155.974	4	38.994	11.554	.000[b]
	Residual	195.740	58	3.375		
	Total	351.714	62			

a. Dependent Variable: LTP

b. Predictors: (Constant), DPA, WA, AID, and ATS

The analysis of variance (ANOVA) in Table 3 shows that DPA, WA, AID, and ATS have significantly impact on LTP as shown in the probability value of 0.000 < 0.05 at 95% confidence. Specifically, the results showed that, DPA, WA, AID, and ATS significantly improves LTP at F (4, 58) given as 11.554, at p-value 0.000<0.05, R Squared 44.3%. Thus, the analysis indicates that the regression model is a good fit for the data.

Table 4. Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	4.694	2.737		1.715	.092
	Automated Demand Planning	.128	.137	.122	.938	.042
	Warehouse Automation	.211	.139	.204	1.524	.033

Automated Inventory Management	.342	.094	.409	3.639	.001
Transport Automation	.115	.149	.109	.771	.044

a. Dependent Variable: Lead Time

In Table 4, the unstandardized coefficients show the extent to which demand planning automation improves forecast accuracy on lead time performance; the extent to which warehouse automation improves order fulfillment on lead time performance; the extent to which automated inventory management enhances real-time inventory tracking on lead time performance; and the extent to which automated transport system enhances delivery times on lead time performance in Nigeria seaport industry. The impacts of the independent variables on dependent variables were demonstrated using the regression model equation below:

$$Y_{LTP} = 4.694 + 0.128X_{DPA} + 0.211X_{WA} + 0.342X_{AID} + 0.115X_{ATS}$$

The study infers that generally, the implementation of digital maritime logistics in Nigerian seaport industry has about 46.9% impact on lead time performance, hence, one percent improvement on DPA, WA, AID, and ATS would contribute about 12.8%, 2.11%, 3.42% and 11.5% in fostering forecast accuracy on lead time performance, improve order fulfillment on lead time performance, enhance real-time inventory tracking on lead time performance and improve delivery times on lead time performance in Nigeria seaport industry respectively. Therefore, the study rejected the null hypothesis and that, demand planning automation, warehouse automation, automated inventory management, and automated transport system have significant impact on lead time performance in Nigeria seaport industry.

5. Discussion of Findings

The analysis of the study on digital maritime logistics and lead time performance in Nigerian Seaports industry indicated that there is a strong positive correlation between digital maritime logistics and lead time performance inferring that the adoption of digital maritime logistics will enhance lead time performance in Nigerian Seaports industry. The study showed evidence that DPA, WA, AID, and ATS enhance forecast accuracy on lead time performance, improve order fulfillment on lead time performance, enhance real-time inventory tracking on lead time performance and improve delivery times on lead time performance in Nigeria seaport industry. It forms that the impact is very significant to a moderate extent given at 46.9%, while a percentage improvement on DPA, WA, AID, and ATS would result to 12.8%, 2.11%, 3.42% and 11.5% on fostering forecast accuracy, enhance order fulfillment, enhance real-time inventory tracking, and improve delivery times on lead time performance in Nigeria seaport industry respectively.

The findings agree with those of Johan and Christoffer (2017), and Li and Chen (2019). These studies collectively highlight the extent to which automated demand planning, warehouse automation, automated inventory management, and technological transportation associate with lead time performance in seaports. Therefore, it is asserted that the adoption of digital maritime logistics and implementation of demand planning automation, warehouse automation, automated inventory management, and automated transport system will improve forecast accuracy, enhance order fulfillment, enhance real-time inventory tracking, and improve delivery times on lead time performance in seaport industry.

6. Conclusion and Recommendations

Based on the findings of this study and the large extent to which its findings align with most authors, the study concludes that digitalization of maritime logistics operations has a positive and significant impact on lead time performance of Seaports in Nigeria. Therefore, it recommends the need to deployment digital maritime logistics systems that enhance lead time performance such as

i. Automated Gate System that automate the entry and exit processes of cargo, reducing waiting times and increase efficiency.
ii. Real-Time Tracking System to provide continuous visibility of vessel locations, cargo status and route progress, enabling informed decision and improve customer satisfaction.
iii. Bloch-chain Technology to enhance transparency, security and efficiency in supply chain operations and automating customer clearance.
iv. MSC's Digital Documentation Platform (eBL)- a digital bill of lading process that streamlines logistics, safeguards transaction and improves customer satisfaction by reducing error and processing times.
v. CMA CGM's Amart Containers- an automated system for tracking containers using smart technologies, improving tracking accuracy and reducing time delays which enables operational reliability and customer satisfaction.
vi. IoT-based Container Monitoring- a real time tracking of containers using IoT sensors, improving of cargo safety and enabling proactive response to transit issue, leading to higher reliability and customer trust.

Furthermore, the study emphasizes that digital transformation in maritime logistics should not be viewed merely as a technological upgrade but as a strategic imperative for enhancing port competitiveness in an increasingly dynamic global trade environment. Policymakers and port authorities should prioritize investments in digital infrastructure, cybersecurity frameworks, and capacity-building initiatives to ensure the effective adoption and integration of these technologies. In addition, regulatory support and institutional collaboration among port operators, shipping lines, customs authorities, and logistics service providers are essential to maximize the benefits of digitalization. By fostering a digitally integrated maritime ecosystem, Nigerian seaports can significantly improve lead time performance, strengthen supply chain resilience, and position themselves more competitively within regional and global trade networks.

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