ISSN: 4621 - 4803
Volume 12, Number 2, 2025
Innovative Journal of Science and Technology Research

DIGITALIZATION OF MARITIME LOGISTICS AND LEAD TIME OF SEAPORTS IN NIGERIA

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ABSTRACT
This paper examined the association between digitalization of maritime logistics and lead time of Seaports in Nigeria. Adopting a critical realism, this paper employed causal research design and quantitative methodology to establish the association between the variables. The population of this paper comprised the 7 Seaports in Nigeria. 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 analyses to assess the association between digitalization of maritime logistics and lead time of Nigerian seaports, by testing 4 null hypotheses in the study. From the analysis it was revealed that automated demand planning, warehouse automation, automated inventory management, and transport automation have significant and positive associations with lead time. Based on this finding, we concluded that digitalization of maritime logistics has a positive, and significant association with lead time of Seaports in Nigeria. Therefore, we recommended that, Seaports in Nigeria should improve on digitalizing their logistics operations, leverage resources within and outside the organizations in order to improve lead time and general port performance.

keywords: ***digitalization of maritime logistics, automated demand planning, warehouse automation, automated inventory management, and transport automation, lead time.***

INTRODUCTION
Maritime logistics, as a critical component of global trade, plays a significant role in facilitating the movement of goods across international borders. The digitalization of maritime logistics 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, Olayemi & Falola, 2021). This paper seeks to explore the implications of digitalization on Nigerian seaports' performance, considering factors such as infrastructure, operations, and regulatory frameworks.

Nigeria's maritime sector serves as a crucial gateway for international trade, 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). These advancements offer opportunities to streamline processes, reduce turnaround times, and enhance overall operational efficiency within seaports (Yang, Han, & Ye, 2020). 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 (UNCTAD, 2020). Gabriel et al. (2020) 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 (Yang *et al.,* 2020). 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).

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.

Research on the impact of digitalization on maritime logistics has predominantly focused on developed economies, with limited attention given to emerging markets such as Nigeria (Yang, Han & Ye*,* 2020). 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 paper aimed to bridge this gap by providing empirical insights into the dynamics of digitalization in Nigerian seaports and its implications for enhancing lead time and competitiveness.

Furthermore, the digitalization of maritime logistics holds immense potential for transforming the performance of seaports 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 paper 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 paper is conceptualized in a framework (Figure 1) and underpinned by the Technology-Organization-Environment (TOE) Framework.

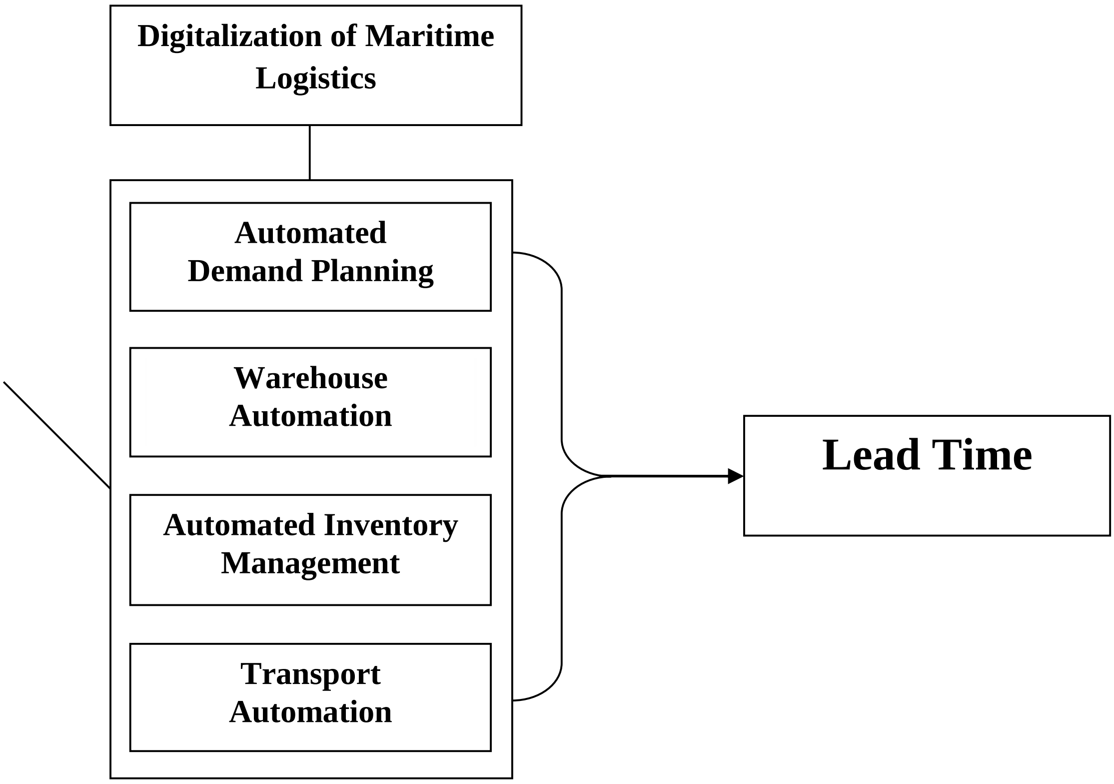

Figure 1: Conceptual framework showing the association between digitalization of maritime logistics and lead time of Seaports in Nigeria

AIM AND OBJECTIVES OF THE STUDY

The aim of this paper was to investigate the association between digitalization of maritime logistics and lead time of Seaports in Nigeria. The specific objectives were to:

i. examine the association between automated demand planning and lead time of Seaports in Nigeria.
ii. examine the association between warehouse automation and lead time of Seaports in Nigeria.
iii. examine the association between automated inventory management and lead time of Seaports in Nigeria.
iv. examine the association between transport automation and lead time of Seaports in Nigeria.

THEORETICAL FOUNDATION - Technology-Organization-Environment (TOE) Framework

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 digitalization in maritime logistics and port operations. By applying this framework, the study can systematically analyze how technological advancements, organizational capabilities, and external factors such as regulatory frameworks and market dynamics shape the digitalization strategies and outcomes of Nigerian seaports.

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 (Tornatzky & Fleischer, 1990). 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 (Tornatzky & Fleischer, 1990). For example, Tan, Lee and Huang (2021) apply the TOE framework to analyze the adoption of blockchain technology in port operations, highlighting its compatibility with existing information systems, security features, and potential for enhancing supply chain visibility and transparency.

Organizational context factors encompass internal organizational characteristics, such as structure, culture, resources, and capabilities that influence technology adoption decisions (Tornatzky & Fleischer, 1990). Studies have examined how organizational readiness, leadership support, and IT infrastructure affect the adoption and implementation of digital technologies in maritime logistics (Dekker *et al.,* 2021). For instance, Dekker et al. (2021) investigate the role of organizational capabilities, such as digital literacy, in driving the adoption of Internet of Things (IoT) technologies in seaports to improve operational efficiency and safety.

External environmental factors include external pressures, such as industry norms, regulatory requirements, market competition, and technological trends that shape technology adoption decisions (Rogers, 1995). Scholars have explored how regulatory frameworks, international standards, and industry collaborations influence the adoption of digital technologies in maritime logistics and port operations (Notteboom & Rodrigue, 2005). 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.

Recent research has also emphasized the dynamic nature of technology adoption within organizations and the need to consider interactions between technological, organizational, and environmental factors over time (Dekker *et al.,* 2021). The TOE framework provides a holistic perspective that considers the interplay between these factors and their impact on technology adoption processes (Tornatzky & Fleischer, 1990). For instance, Tan et al. (2021) analyze how changes in regulatory requirements and industry standards influence the adoption of blockchain technology in port operations and supply chain management.

Despite its strengths, scholars have noted some limitations of the TOE framework, such as its static nature and focus on the adoption phase rather than post-adoption outcomes (Tan *et al.,* 2021). Additionally, the framework may not fully capture the complexity and context-specific nature of technology adoption decisions in diverse organizational settings (Rogers, 1995). 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. Recent research in maritime logistics and port operations has 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.

DIGITALIZATION OF MARITIME LOGISTICS

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. Recent scholarly research has extensively explored this topic, shedding light on its significance and implications. One study by Talley (2021) highlights the role of digital technologies in transforming global supply chains, emphasizing the importance of digitalization in maritime logistics for improving operational processes and customer service. Another research article by Liu et al. (2021) provides insights into the current state of digitalization in maritime logistics and outlines future research directions in this field.

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.

Several factors are driving digitalization in maritime logistics, including increasing customer demands for transparency and visibility, regulatory requirements, and the need to reduce costs and improve operational efficiency (Pazirandeh & Naim, 2018). 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). By digitizing documentation processes and implementing electronic data interchange (EDI) systems, stakeholders can minimize paperwork and streamline customs clearance procedures, leading to faster and more efficient trade (Yang et al., 2021).

Despite the potential benefits, digitalization in maritime logistics also faces several challenges and barriers. These include concerns about data security and privacy, interoperability issues between different systems, and the high upfront costs of implementing new technologies (Song & Panayides, 2020). 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).

Looking ahead, several trends are expected to shape the future of digitalization in maritime logistics. These include the continued development of autonomous vessels and drones for cargo delivery, the use of blockchain technology to streamline supply chain processes, and the integration of digital twins and simulation tools for predictive maintenance and risk management (Liu et al., 2021). Additionally, advances in 5G connectivity and edge computing are likely to enable real-time data exchange and decision-making, further enhancing the efficiency and resilience of maritime logistics networks (Liu & Meng, 2020).

Digitalization is transforming the maritime logistics industry, offering opportunities to improve efficiency, reduce costs, and enhance sustainability. However, realizing these benefits requires addressing challenges related to data security, interoperability, and workforce skills. By embracing digital technologies and collaborating across the supply chain, stakeholders can navigate the complexities of maritime logistics in the digital age and unlock new opportunities for growth and innovation.

DIMENSIONS OF DIGITAL MARITIME LOGISTICS

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. These dimensions collectively contribute to the efficient and effective management of logistics operations, supporting supply chain performance and competitiveness. In this paper however, automated demand planning, warehouse automation, automated inventory management, and transport automation are investigated to ascertain their associations with lead time of seaports in Nigeria.

Automated Demand Planning

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. Automated demand planning involves the use of advanced algorithms, data analytics, and artificial intelligence (AI) to predict future demand for products or services. According to Lee and Lee (2021), automated demand planning systems leverage historical sales data, market trends, and external factors to generate forecasts automatically, reducing reliance on manual processes.

Automated demand planning is essential for enhancing supply chain efficiency and responsiveness. By accurately forecasting demand, organizations can optimize inventory levels, minimize stockouts, and reduce excess inventory carrying costs. Additionally, automated demand planning 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. According to a study by Cao et al. (2020), organizations that implement automated demand planning systems experience significant improvements in forecast accuracy, leading to better allocation of resources and reduced supply chain costs.

One of the primary advantages of automated demand planning is its ability to improve forecast accuracy through advanced statistical modeling and machine learning techniques. Research by Chen, Gong and Tang (2021) demonstrate that automated demand planning systems can incorporate multiple variables and data sources to generate more precise demand forecasts, even in volatile and uncertain market conditions. Automated demand planning systems provide real-time visibility into demand patterns and inventory levels, enabling better collaboration among supply chain partners. According to Kumar and Motwani (2020), real-time data sharing and collaboration facilitate more responsive supply chain operations, allowing organizations to adjust production schedules, reorder points, and distribution plans as needed.

Another advantage of automated demand planning 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. According to Lee and Lee (2021), data quality and availability remain significant challenges for automated demand planning systems, as inaccurate or incomplete data can lead to flawed forecasts and suboptimal decision-making.

Generally, Automated Demand Planning (ADP) leverages advanced technologies to enhance the accuracy and efficiency of demand forecasts. By integrating advanced data analytics, machine learning algorithms, real-time data, and collaborative forecasting, organizations can optimize their demand planning processes and achieve significant improvements in operational performance. These strategies not only help in reducing forecast errors but also in improving inventory management, reducing costs, and enhancing customer satisfaction.

Warehouse Automation

Warehouse automation refers to the implementation of advanced technologies and systems within warehouses to automate various tasks traditionally performed by human operators. These technologies can include robotics, artificial intelligence (AI), machine learning, sensors, and software systems designed to streamline and optimize warehouse operations (van den Berg, Zijm & Wynstra, 2020). One key aspect of warehouse automation is the use of robotic systems for material handling and order fulfillment. These robots, often referred to as automated guided vehicles (AGVs) or autonomous mobile robots (AMRs), can navigate warehouse environments autonomously, transporting goods between storage locations, picking stations, and shipping docks (Scholz-Reiter, Frieling & Wirth, 2021).

Warehouse automation plays a crucial role in modern supply chain management by improving efficiency, accuracy, and flexibility in warehouse operations. It enables organizations to meet growing customer demands, reduce operational costs, and enhance overall productivity (Melo et al., 2020). 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. Automated systems such as robotic pickers, automated guided vehicles (AGVs), and conveyor systems can perform repetitive tasks faster and with higher accuracy than human workers (Van den Berg, Zijm, &Wynstra, 2020). Automation also 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). Key ports such as Apapa and Tin Can Island are testing automation solutions to optimize berth productivity and reduce vessel turnaround time (World Bank, 2022). The adoption of AQCOS also aligns with the Nigerian Single Window initiative, which seeks to digitalize port operations (Adegbite, 2020).

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). Automated cranes are often designed to consume less energy and produce fewer emissions, contributing to greener port operations (World Bank, 2022).

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 (Adegbite, 2020). 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).

Automated Inventory Management

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).

Automated inventory management 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). Additionally, automation reduces the risk of human error associated with manual inventory management processes, leading to higher inventory accuracy and fewer stockouts or overstocks (Zhao, Song & Xu, 2021).

Automated inventory management facilitates better control over inventory by implementing advanced forecasting algorithms and demand planning techniques. 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, automated inventory management 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). Additionally, scalability can be a challenge, as organizations need to ensure that automated systems can accommodate growth, changes in product offerings, and fluctuations in demand without compromising performance or efficiency (Zhao et al., 2021).

Transport Automation

Transport automation 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 (Adegbite, 2020). 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).

LEAD TIME

Lead time in business and supply chain management refers to the duration between the initiation of a process or order and its completion or delivery. 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. It encompasses several components, including order processing time, production time, transportation time, and delivery time (Ghosh & Thomas, 2018). 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. By reducing lead times, companies can minimize inventory levels, improve inventory turnover rates, and enhance overall supply chain efficiency (Ghosh & Thomas, 2018).
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 has 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).

EMPIRICAL REVIEW OF DIGITALIZATION OF MARITIME LOGISTICS AND LEAD TIME OF SEAPORTS

In this part of the study, the literature review focuses on empirical studies carried out by other researchers and scholars on concepts similar to the subject of investigation. The essence is to compare the previous findings with ours in order to make conclusive statements. For instance, Lee and Lee (2019) conducting a longitudinal study, investigated the performance outcomes of automated demand planning implementation in a multinational manufacturing company. They observed significant improvements in demand forecast accuracy, inventory turnover, and on-time delivery rates following the adoption of automated demand planning, highlighting its positive impact on supply chain performance over time. Barratt and Gervais (2020) employing meta-analysis, aggregated results from multiple empirical studies to assess the impact of automated demand planning on supply chain performance. Their meta-analysis revealed a significant positive effect of automated demand planning on key performance indicators such as inventory turnover, order fulfillment, and customer satisfaction across diverse organizational contexts.

More also, Chen et al. (2021) conducted a longitudinal study in a large-scale distribution center to assess the impact of warehouse automation. They collected data on key performance indicators (KPIs) such as order processing time, inventory accuracy, and labour productivity before and after the implementation of automation systems. The study found that warehouse automation led to significant improvements in performance metrics, including a reduction in order processing time, increased inventory accuracy, and higher labour productivity (Chen et al., 2021). 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.

Furthermore, Zhang et al. (2021) conducted a comparative analysis of multiple logistics firms to assess the impact of transport automation. They collected data on performance indicators such as delivery time, fuel consumption, and vehicle utilization rates before and after the implementation of automation technologies. 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 (Zhang et al., 2021).Wang and Liu (2020) conducted a case study analysis in several transportation companies to examine the impact of transport automation on operational efficiency. They employed qualitative methods such as interviews and observations to gather insights into the implementation process and performance outcomes. The study identified benefits such as improved route optimization, reduced idle time, and enhanced driver productivity, leading to higher operational efficiency and cost savings (Wang & Liu, 2020).

Again, Li and Chen (2019) conducted a longitudinal study to assess the impact of transport automation on supply chain performance. They collected data from multiple firms over a period of time, analyzing performance metrics such as delivery reliability, transportation costs, and customer satisfaction. The study found that firms adopting transport automation experienced improvements in delivery reliability, cost reduction, and higher customer satisfaction levels, contributing to enhanced overall supply chain performance (Li & Chen, 2019).

These studies collectively highlight the significant impact of digitalization of maritime logistics on lead time and overall organizational performance, across different industries and contexts. However, it was hypothesized that:

H_O1: Automated demand planning has no significant association with lead time of Seaports in Nigeria.

H_O2: Warehouse automation has no significant association with lead time of Seaports in Nigeria.

H_O3: Automated inventory management has no significant association with lead time of Seaports in Nigeria.

H_O4: Transport automation has no significant association with lead time of Seaports in Nigeria.

METHODOLOGY

The methodology of this paper 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 causal 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 paper comprises the 7 Seaports in Nigeria. They are 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, a census technique was adopted, and so, all the elements in the population were studied. However, the study is at organizational level therefore, 63 respondents the 7 seaports in Nigeria constituted the respondents of the study. 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 qualitative data used for the analysis. A semi-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 to very low extent. That is, (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 (1951) alpha reliability relied on a threshold of 0.70 established by Nunally (1978) whilst factor loadings which not less than 0.4 indicate that the constructs had discriminant validity. In establishing the association between the variables, a multiple regression analysis was conducted by testing 4 null hypotheses whose results were subject to a critical value of 0.05. The analysis was done with the aid of Statistical Package for Social Sciences (SPSS) version 25.

Table 1: Results of Reliability and Validity Tests

S/N	Variables	Number of Items	Cronbach's Alpha Coefficients	Factor Loadings
1	Automated demand planning	4	0.831	0.671
2	Warehouse automation	4	0.730	0.682

3	Automated inventory management	4	0.749	0.613
4	Transport automation	4	0.716	0.832
5	Lead time	4	0.762	0.751

Source: SPSS output form field data

Table 1 shows that Cronbach's (1951) alpha reliability test and Exploratory Factor Analysis (EFA) were conducted. Results of the Cronbach's (1951) alpha reliability test showed that all the variables in the study produced high and very high Cronbach's alpha coefficients. This means that, if this study is carried out again under a similar condition the results will be comparable to the results of this paper. More also, results of the Exploratory Factor Analysis (EFA) revealed that automated demand planning, warehouse automation, automated inventory management, and transport automation, loaded heavily on digitalization 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) indicate that the constructs have discriminant validity (Straub et al., 2004).

TEST OF RESEARCH HYPOTHESIS

Four null hypotheses were tested using Regression Analysis. The analysis assessed the link between digitalization of maritime logistics and lead time in the Nigerian Ports Authority, by examining how automated demand planning, warehouse automation, automated inventory management, and transport automation associate with lead time. Results of the analysis are shown in Table 2, 3 and 4.

Table 2: Model summary of how automated demand planning, warehouse automation, automated inventory management, and transport automation associate with lead time of Seaports in Nigeria

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

a. Predictors: (Constant), Automated Demand Planning, Warehouse Automation, Automated Inventory Management, Transport Automation

Source: Field Survey, 2024.

A multiple regression analysis was performed to predict how automated demand planning, warehouse automation, automated inventory management, and transport automation associate with lead time of Seaports in Nigeria. As shown in Table 2, the variables together have a strong and positive association with Lead time which is evident in the multiple regression coefficient of 0.666. Again, the coefficient of determination (R Squared) is 0.443. This means that, approximately 44% of the changes in lead time were attributed to automated demand planning, warehouse automation, automated inventory management, and transport automation, while the remaining 56% changes were due to the impact of external variables not included in the model.

Table 3: ANOVA[a] of how automated demand planning, warehouse automation, automated inventory management, and transport automation associate with lead time of Seaports in Nigeria

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: Lead Time

b. Predictors: (Constant), Automated Demand Planning, Warehouse Automation, Automated Inventory Management, Transport Automation

Source: Field Survey, 2024.

The analysis of variance (ANOVA) in Table 3 shows that automated demand planning, warehouse automation, automated inventory management, and transport automation significantly associate with lead time as shown in the probability value of 0.000 < 0.05. Specifically, the results showed that, automated demand planning, warehouse automation, automated inventory management, and transport automation significantly associate with lead time at $F(4, 58) = 11.554$, $p = 0.000 < 0.05$, R Squared = 0.443. Thus, the analysis indicates that the regression model is a good fit for the data.

Table 4: Coefficients[a] of how automated demand planning, warehouse automation, automated inventory management, and transport automation associate with lead time of Seaports in Nigeria

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients 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

Source: Field Survey, 2024.

In Table 4 the unstandardized coefficients indicate that, 1 percent increase each in automated demand planning, warehouse automation, automated inventory management, and transport automation will bring about 0.128, 0.211, 0.342 and 0.115 percent increase respectively in lead time of Seaports in Nigeria. Therefore, the 4 null hypotheses which state that *"automated demand planning, warehouse automation, automated inventory management, and transport automation have no significant association with lead time of Seaports in Nigeria"*, were rejected. Thus, substituting the values in the table in the multiple regression equation gives;

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \epsilon$$

$$Y = 4.694 + 0.128X_1 + 0.211X_2 + 0.342X_3 + 0.115X_4 + 0.137+0.139+0.094+0.149$$

Where:

Y = Lead time

X_1 = Automated Demand Planning

X_2 = Warehouse Automation

X_3 = Automated Inventory Management

X_4 = Transport Automation

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.

ϵ = Error term (accounts for unexplained variations).

DISCUSSION OF FINDINGS

The multiple regression analysis performed to predict how automated demand planning, warehouse automation, automated inventory management, and transport automation associate with lead time of Seaports in Nigeria indicated that the variables to have a strong and positive association with lead time which is evident in the multiple regression coefficient of 0.666. Again, the coefficient of determination shows that, approximately 44% of the changes in lead time were attributed to automated demand planning, warehouse automation, automated inventory management, and transport automation, while the remaining 56% changes were due to the impact of external variables not included in the model. Furthermore, 1 percent increase each in automated demand planning, warehouse automation, automated inventory management, and transport automation will bring about 0.128, 0.211, 0.342 and 0.115 percent increase respectively in lead time of Seaports in Nigeria. Therefore, the 4 null hypotheses which state that *"automated demand planning, warehouse automation, automated inventory management, and transport automation have no significant association with lead time of Seaports in Nigeria",* were rejected.

These findings align with findings of most previous studies examined. For instance, the findings agree with those of Lee et al. (2019) who conducted a longitudinal study, investigating the performance outcomes of automated demand planning implementation in a multinational manufacturing company. They observed significant improvements in demand forecast accuracy, inventory turnover, and on-time delivery rates following the adoption of automated demand planning, highlighting its positive impact on supply chain performance over time. Similarly, Barratt and Gervais (2020) employing meta-analysis, aggregated results from multiple empirical studies to assess the impact of automated demand planning on supply chain performance. Their meta-analysis revealed a significant positive effect of automated demand planning on key performance indicators such as inventory turnover, order fulfillment, and customer satisfaction across diverse organizational contexts.

More also, the findings of this paper align with the findings of Chen et al. (2021) who conducted a longitudinal study in a large-scale distribution center to assess the impact of warehouse automation. They collected data on key performance indicators (KPIs) such as order processing time, inventory accuracy, and labour productivity before and after the implementation of automation systems. The study found that warehouse automation led to significant improvements in performance metrics, including a reduction in order processing time, increased inventory accuracy, and higher labour productivity. The findings also agree with those of Johan and Christoffer (2017) who investigated the economic impact of autonomous vehicles in the logistics industry in Sweden. 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.

Furthermore, the findings of this paper align with the findings of Zhang et al. (2021) who conducted a comparative analysis of multiple logistics firms to assess the impact of transport automation. 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 (Zhang *et al.,* 2021). Also, results of this paper align with the results of Wang and Liu (2020) who conducted a case study analysis in several transportation companies to examine the impact of transport automation on operational efficiency. They employed qualitative methods such as interviews and observations to gather insights into the implementation process and performance outcomes. The study identified benefits such as improved route optimization, reduced idle time, and enhanced driver productivity, leading to higher operational efficiency and cost savings (Wang & Liu, 2020). Again, the findings of this paper align with the findings of Li and Chen (2019) who conducted a longitudinal study to assess the impact of transport automation on supply chain performance. The study found that firms adopting transport automation experienced improvements in delivery reliability, cost reduction, and higher customer satisfaction levels, contributing to enhanced overall supply chain performance (Li & 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 and generally, seaport performance. Therefore, it is asserted that the application of automated demand planning, warehouse automation, automated inventory management, and technological transportation in seaport operations in Nigeria will improve lead time and port performance.

CONCLUSION AND RECOMMENDATIONS

Based on the findings of this paper and the large extent to which its findings support the findings of most previous studies examined, the study concludes that digitalization of maritime logistics has a positive and significant association with lead time of Seaports in Nigeria. From the conclusion drawn from the findings, this paper recommends that Seaports in Nigeria should improve on:

i. the deployment of automated demand planning techniques to enable them analyzing large volumes of data from various sources, and predict customer demand and optimize inventory levels in order to reduce stock outs and excess inventory.
ii. investment in warehouse automation technology for storage and retrieval of goods, manage and optimize warehouse operations, perform repetitive and manual tasks in the warehouse, and transport goods within the warehouse.
iii. deployment of automated inventory management systems to predict demand patterns, optimize stock levels, and identify potential disruptions in the supply chain.
iv. investment in automating the transportation system to be able to transport containers and cargo within the seaport using self-driving vehicles, deploy Automated Stacking Cranes (ASCs) for stacking and un-stacking containers in the yard, and use Drones and Unmanned Aerial Vehicles (UAVs) for monitoring port operations, conducting inspections, and delivering small packages.

REFERENCES

Adegbite, T. (2020). The role of digital infrastructure in Nigeria's maritime sector. *Journal of Maritime Studies, 15*(2), 112-128.

Barratt, M., & Gervais, Y. (2020). The impact of demand planning technologies on supply chain performance: A meta-analysis of empirical studies. *Journal of Operations Management, 68*(2), 95-114.

Bichou, K., & Gray, R. (2019). *Maritime logistics in the global economy: Current trends and future challenges.* Palgrave Macmillan.

Cao, J., Zhou, J., Zhou, Y., & Wang, F. (2020). Autonomous Maritime Systems: A Comprehensive Review. *IEEE Access, 8,* 86937-86960.

Chen, H., Gong, Z., & Tang, X. (2021). Deep learning for demand forecasting: A review and research agenda. *Decision Support Systems, 143,* 113 - 118.

Chopra, S., &Meindl, P. (2019). *Supply chain management: Strategy, planning, and operation*. Pearson.

Dekker, R., Varma, V., & Witte, A. (2021). The Digital Transformation of Seaports: An Institutional Perspective. *Maritime Economics & Logistics,* 1-20.

Fernie, J., & Sparks, L. (2020). *Logistics and retail management: Emerging issues and new challenges in the retail supply chain.* Routledge.

Gabriel, J. M. O., Keremah, O. M., Okpara, E. N., Isaac, S.N., Francis, W.N., Mills, R.B. (2020). A Multi-Sectoral Assessment of the Impacts of Covid-19 Pandemic Outbreak on Organisational Functionality in Nigeria. *International Journal of Trend in Scientific Research and Development (IJTSRD), 4(*6), 2456 – 6470.

Ghosh, D., & Thomas, L. J. (2018). Inventory management in supply chains: A literature review. *International Journal of Production Economics, 199,* 142-158.

Givoni, M., & Banister, D. (2019). *Moving towards low carbon mobility.* Edward Elgar Publishing.

Heilig, L., Lalla-Ruiz, E., &Voß, S. (2017). Digital transformation in maritime ports: Analysis and a game theoretic framework. *Netnomics, 18*(2-3), 227-254.

Ivanov, D., &Dolgui, A. (2020). A digital supply chain twin for managing the disruption risks and resilience in the era of Industry 4.0. *Production Planning & Control, 31*(7), 557-577.

Johan, B., &Christoffer, G. (2017). *The economic impact of autonomous vehicles in the logistics industry* (Published Master's Thesis). Jönköping University.

Kumar, M., & Motwani, J. (2020). *Lean management for the future: Sustaining business performance amidst global turbulence.* Springer.

Lee, H., & Lee, H. (2021). Intelligent demand planning: Recent advances and future directions. *Journal of Business Research, 128,* 701-710.

Lee, I., & Lee, K. (2019). The Internet of Things (IoT): Applications, investments, and challenges for enterprises. *Business Horizons, 62*(1), 99-110.

Li, L., & Chen, M. (2019). The impact of transport automation on supply chain performance: A longitudinal study. *International Journal of Production Economics, 224,* 107-123.

Liu, Y., Wang, Y., & Liu, Y. (2021). Application of the internet of things in supply chain management of cold chain logistics. *In 2021 IEEE 3rd Information Technology and Mechatronics Engineering Conference (ITOEC),* 1336-1339

Liu, Y., Yang, Z., Wang, J., & Li, K. X. (2021). Digitalization of maritime logistics: A review and future research directions. *Transportation Research Part E: Logistics and Transportation Review, 148,* 102 - 127.

Melo, M. T., Nickel, S., & Saldanha-da-Gama, F. (2020). *Warehousing in the global supply chain: Advanced models, tools and applications for storage systems.* Springer.

Nigerian Maritime Administration and Safety Agency (NIMASA). (2020). *Strategic Plan for Digital Transformation in the Nigerian Maritime Sector.* Retrieved from https://nimasa.gov.ng/

Nigerian Ports Authority. (2023). *Financial report and operational statistics for 2023*. Lagos: NPA Publications.

Nigerian Ports Authority. (2024). *Financial report and operational statistics for 2024*. Lagos: NPA Publications.

Notteboom, T., & Rodrigue, J.-P. (2005). Port regionalization: Towards a new phase in port development. *Maritime Policy & Management, 32*(3), 297–313.

Nunnally, J. C. (1978). *Psychometric theory*. New York: McGraw-Hill.

Okonkwo, C., & Adeoye, M. (2021). Enhancing trade efficiency through electronic bill of lading: A case study of Nigerian ports. *African Journal of Logistics, 10*(1), 45-67.

Pazirandeh, A., &Naim, M. M. (2018). Digitalization of maritime logistics services: A new approach to managing the container shipping supply chain. *Transportation Research Part E: Logistics and Transportation Review, 119,* 182-197.

Scholz-Reiter, B., Frieling, E., & Wirth, C. (2021). Autonomous and collaborative mobile robot systems for warehousing. *Annual Reviews in Control, 52,* 221-241.

Simchi-Levi, D., Kaminsky, P., &Simchi-Levi, E. (2019). *Designing and managing the supply chain: Concepts, strategies, and case studies.* McGraw-Hill Education.

Smith, J., & Brown, R. (2021). Digital transformation in global shipping: The role of electronic documentation. *Maritime Economics Review, 9*(3), 78-95.

Song, D. P., &Panayides, P. M. (2020). Blockchain in maritime business: A synthesis of the literature and a research agenda. *Transportation Research Part E: Logistics and Transportation Review, 141,* 102012.

Talley, W. K. (2021). Digital technologies and the future of global supply chains. International *Journal of Physical Distribution & Logistics Management, 9*(12), 23 – 29.

Tan, Y. W., Lee, L. H., & Huang, X. (2021). Blockchain Technology Adoption in Port Operations: A Technology-Organization-Environment Perspective. *Transportation Research Part E: Logistics and Transportation Review, 148,* 102-124.

Tornatzky, L. G., & Fleischer, M. (1990). *The Processes of Technological Innovation.* Lexington Books.

United Nations Conference on Trade and Development (UNCTAD). (2022). Digitalization in maritime transport: Benefits and challenges. *UNCTAD Transport Series, 2022*.

Van den Berg, J. P., Zijm, W. H., &Wynstra, F. (2020). Warehouse design and control: Frameworks and methods. *International Journal of Production Research, 58*(5), 1459-1473.

Wang, X., & Liu, C. (2020). Transport automation and organizational performance: A case study of transportation companies. *Transportation Research Part E: Logistics and Transportation Review, 141*, 102-110.

Wang, Y., & Ramakrishnan, V. (2020). *Foundations of data science.* Cambridge University Press.

World Bank. (2022). Automation and digital ports: A roadmap for developing countries. *World Bank Maritime_Report 2022*.

Yang, C., Han, X., & Ye, J. (2020). The Impact of Digitalization on Port Operations: Evidence from Global Ports. *Maritime Policy & Management, 47*(7), 864-882.

Zhang, W., Zhao, L., Zhao, D., & Zou, J. (2021). Research on RFID Technology in Intelligent Logistics of Port Based on the Internet of Things. *In 2021 3rd International Conference on Computational Intelligence and Networks (CINE),* 362-365,

Zhao, Y., Song, D., & Xu, B. (2021). Automated traffic management systems in seaports: A review of benefits and challenges. *Transportation Research Part C: Emerging Technologies, 123,* 103-112.