



**DIGITAL TRANSFORMATION AND PORT OPERATIONS: A PANACEA TO
NIGERIAN PORT DECONGESTION.**

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Abstract

The unending problem of port congestion in Nigeria has seriously reduced the effectiveness of trade, increased operating expenses, and resulted in longer cargo dwell periods. This study sort to examine the effect of digital transformation on the Nigerian ports' operation as a way out to the continuous congestion. Other specific objectives of the study were to determine the effects of automation of port operations (APO), adoption of blockchain technology for trade documentation (BTDD) and implementation of Internet of Things (IoT) and smart port systems on the Nigerian ports operation. A descriptive research design was adopted and close-ended questionnaires was used to collect data from 127 management-level employees of four port operating companies in Lagos Nigeria, through a purposive random sampling technique. The data was analyzed using a multiple regression method and the findings revealed that APO and BTDD have a positive correlation with ports operation (0.001, 0.000), while IoT has a not statistically significant with a p-value of (1.07). The study further concluded that the adoption of digital transformation will go a long way to decongest the ports and its environment as well as aid a complete overhauling and simplification of ports activities.

Keywords: Digital Transformation, Automation, Blockchain Technology, Trade Documentation, Internet of Things, Ports Operation.

Introduction

The fast growth of digital technologies is rapidly transforming all sectors, and the maritime sector is no exception. In Nigeria, the continuous issue of port congestion has greatly hampered trade efficiency, increased operational costs, and prolonged cargo dwell times. Digital transformation has emerged as the most viable method of improving ports' operational efficiency, improving logistic flows, and decongesting Nigerian ports (Edih, Faghawari and Agboro, 2023). With the use of digital solutions, such as automation, block-chain, artificial intelligence (AI), and Internet of Things (IoT), ports can improve the cargo handling processes, reduce documentation bottlenecks, and improve port operations through better monitoring in real-time. Port operations involve a process of connected activities to facilitate and move goods through maritime gateways (Notteboom, Pallis and Rodrigue, 2021). Activities include vessel scheduling and berth assignment; cargo handling; storage and warehousing; customs and documentation; and inter-modal transfers. Inefficiencies in any of the above, too often lead to port congestion, leading to delays, increased operational costs and supply chain disruptions (Almeida, 2023). These inefficiencies may be from human dependency on manual processes, subordinate infrastructure, coupled with a lack of true coordination between stakeholders.

The introduction of digital technologies can provide clients solutions that will enhance port activities and promote operational efficiency. Automation of port operations can speed cargo handling and diminish labor costs. The use of the Internet of Things (IoT) can through real-time information tracking of cargo and equipment, improves management (Kotari et. al., 2025) Data analytic tools can enhance vessel scheduling, berth assignments, and predictive maintenance, while blockchain technologies enhance transparency and framework speed to documentation processes. All of these digital transformation tools, can reduce ports congestion, increase throughput, and enhance service to the global supply chain (Kassou et.al., 2021). The only mitigating factors are high cost, challenges involved with integration, and opposing energy from labor unions, that all limits users from realizing the full benefits of digitization (Almeida, 2023).

This has impacted upon the ports of Nigeria, which retain considerable importance to her trade and economic development, as the main avenues of imports and exports. Nevertheless, with continuous congestion, the ports have lost efficiency, betting high operational costs for extensive cargo dwell times, and disruption of the national distribution chain (Eddrgash, 2022). Port congestion would appear from infrastructural unpreparedness, bureaucracy, manual documentation processes, and cargo handling inefficiencies. Businesses and stakeholders are adversely impacted by delays, demurrage, and trade inefficiencies operating in Nigeria.

Although other countries have made vast strides in digital transformations, Nigeria ports still have tunnel vision, and still make use of old systems of port management, which are inadequate to keep up citizen expectations with growing trade. The ports are further hindered by manual documentation processing, as Nigeria is unable to automate cargo clearance documentation; it is noteworthy that other countries are using blockchain for trade documentation, Automation of Port Operations, and Cybersecurity and Digital Infrastructure; still, Nigeria has not worked to ditch the old ways of antiquated port operations.

This study, therefore, seeks to examine how digital transformation can serve as a panacea for port decongestion in Nigeria. It will explore the extent to which digital technologies can enhance operational efficiency, streamline customs clearance, and improve cargo handling processes. By identifying key digital transformation indicators and measuring their impact on port operations, this research aims to provide actionable recommendations for policymakers and industry stakeholders to adopt digital innovations for sustainable port management and economic growth.

Literature Review

Digital Transformation: Digital transformation describes the way that organizations accept and use digital technology to develop new products, services, and processes or to modify existing products, services, and processes to create digital versions of their business processes (He, Hu, Li and Hu, 2023). The main goals of digital transformation are to add value to the business through innovation, enrich and improve customer experience, and improve efficiency through operation (Kassou et.al., 2021).

Digital transformation are necessary for organizations to stay current and competitive in today's fast-moving technological world. By implementing automation and related digital, its helps organizations to transform their processes and reduce human interaction with increased efficiency and fewer errors (Dalaklis et.al., 2022) It provides opportunities for the use of data analytics and real time information for better and quicker decision making. Digital applications facilitate custom and seamless transactions with customers, leading to enriching the customer experiences Suvadashini and Dandapat, 2023). And finally, it affords organizations the potential to create, develop and innovate new products and services.

Digital transformation can clearly improve the efficiency and competitiveness of the port domain by incorporating sophisticated technologies within its processes (Behdani, 2023). Importantly, automation that uses robotic cranes and guided vehicles benefits the port by expediting cargo movements and operational costs associated with labor. Advanced networks, such as 5G offers assurance of close and effective communication between port systems (Cavalli et.al. 2021); for example, the Port of Valencia has initiated its own private 5G network as it continues to advance its own digital transformation efforts to facilitate its adoption as a smart port (Clemente, Cabral, Rosa-Santos and Taveira-Pinto, 2023).

Automating Port Processes” Automating port processes involves the use of technology to perform tasks that were traditionally completed by humans (e.g. data processing, moving cargo, and operating equipment) Lehmacher, 2021). Automated processes can include cranes to move cargo and guided vehicles to navigate a specific route; the purpose of automated processes is to add efficiency, reduce human error, and reduce costs. Automation of port processes can benefit from advanced technologies such as Artificial Intelligence (AI), Internet of Things (IoT), and robotics (Henríquez, De-Osés and Marín, 2022). For example, the delivery of cargo can be optimized through AI scheduling; IoT devices and applications to track and monitor the location of cargo in real time, and Robotics use similar processing to achieve movement that avoids repetitive tasks in detail or precision.

Block-chain Technology for Trade Documentation: To develop and use blockchain Technology is to develop and use a digitized form of a decentralized ledger that is distributed across a network of computers to record transactions (Yuen, Li, Lai & Yang, 2021). For example, blockchain technology can be used in port logistics for trade documentation; thereby establishing a single source of truth that gives transparency of ownership and removes fraud from a process. It can also cut down on paperwork and administrative delays to the barest minimal (Sarker, Henningsson, Jensen and Hedman, 2021). To illustrate the digital change in port logistics, the Port of Valencia has implemented blockchain technology to improve its operations. Additionally, in an effort to improve ship fueling procedures' efficiency and transparency, Singapore intends to require digital bunker notes beginning in April 2025. unfortunately, the worry of paying significant implementation and ongoing maintenance costs has remained a barrier to the adoption of these tactics in Nigeria.

Cyber-security and Digital Infrastructure: Cyber-security is concerned with guarding against cyber threats, while digital infrastructure consists of all the hardware and software that provide support for digital functions. In ports, it is important to establish strong cyber-security and digital infrastructure as a means to support data protection, operational continuity, and stakeholder confidence (Progoulakis et.al., 2023). Coordination with private companies and vendors to update your digital infrastructure to include secure fast networks like 5G, can support the adoption of Internet of Things (IoT) devices and real-time data analytics, among other things (Attaran, 2023). For instance, the Port of Valencia is implementing its own 5G network, and is initiating the process of becoming a smart port or model of a smart port. Also, adopting advanced cyber-security measures, such as secure communications and intrusion detection systems are also key to managing risks related to cyber threats, and can be used to ensure the integrity and availability of port operations (Dalaklis et.al., 2022).

Port Operations: Port operations, in general, refers to the entirety of activities, events and management in a port to assist in the movement of goods and ships (Edih, Faghawari and Agboro, 2023). These actions include services that pertain to the handling of freight, vessel traffic services, warehousing, port customs, maintenance of equipment and facilities, etc. Port operatives, such as public authorities and/or privately held port authorities and related companies are responsible for ensuring that port operations are conducted safely, efficiently, and in accordance with appropriate regulations Lehmacher, 2021). The application of digital technologies for ports, often referred to as the concept for creating "smart ports", adds to operational activities, and can create better efficiency, security and sustainability of the environment through actions such as;

Automation: This involves the use of automated systems, robotic cranes and/or automated vehicles, which can lessen the cost (labour) associated with freight handling, and improve the speed to which freight is handled using robotics. Several ports in the U.S. have been investigating how automation can help handle considerable increases in import volumes and resolve capacity issues, while some cities fighting congestion are advocating for private companies investigating automation entirely (Gerrero-Molina et.al., 2024).

Internet of Things (IoT): The implementation of IoT devices will allow ports to monitor their equipment and freight in real-time to complete maintenance more proactively and better utilize assets (Cil, Abdulrahman and Cil, 2022).

Blockchain Technology: With blockchain, port authorities can streamline trade documents with blockchain to demonstrate transparency and security through contracting (Sarker et.al., 2021). For example, South Asia Gateway Terminals in Sri Lanka adopted the blockchain initiative focusing on digitizing supply chains (UNCTAD, 2021) to create a transportation system that improves efficiency through reliability.

5G Connectivity: Providing dedicated 5G networks for the ports, can enhance the reliability of high-speed communication between the systems/devices of the port and multiple systems (Clemente et. al., 2023). The Port of Valencia has implemented their own 5G service in order to advance their digital transformation and in order to become the model that a smart port can present.

Theoretical Review

Dynamic Capabilities Theory: The notion of dynamic capabilities was introduced by David Teece, Gary Pisano, and Amy Shuen in their 1997 working paper, "Dynamic Capabilities and Strategic Management." They define dynamic capabilities as the firm's ability to integrate, build, and reconfigure internal and external competences to address rapidly changing environments. The theory is concerned with an organizational ability to purposefully adapt its resource base to address rapidly changing environments. Dynamic capability theory emphasizes the firm's ability to integrate, build, and reconfigure internal and external competences to remain competitive.

Dynamic capabilities theory is key to port operations in order to adapt to innovations in technology coupled with changing market needs. The theory emphasizes the integration of new technologies such as automation of cargo and digital tracking systems to increase efficiency and enhance competitiveness. By developing dynamic capabilities in port operations, ports can reconfigure their operational processes quickly to adapt to increases and decreases in the global trading market and the number of cargo containers that ports must handle. Ports will benefit from collaboration with stakeholders, such as shipping companies and regulatory organizations, to monitor and respond to regulation changes in some circumstances, and industry standards in others. The port operations can only integrate a digital solution by collaborating with stakeholders, building a global network, and being willing to achieve agreement on the common goal of transforming port operations.

Queuing Theory: Queuing theory is the mathematical study of waiting in lines (or queues) that is concerned with what queues will look like (i.e., queue length and waiting time). It is a subset of operations research. Queuing theory has applications in telecommunications, traffic engineering, computing, and industrial engineering. Queuing theory was first introduced by Danish engineer Agner Krarup Erlang (1909). He worked for the Copenhagen Telephone Exchange, where he established models to describe the arrival of telephone calls using a Poisson process. He evaluated systems with one server (M/D/1) and with multiple servers (M/D/k).

Queuing theory is important for port operations since it helps analyze and manage the flow of vessels and cargo in order to achieve a more efficient flow and fewer delays. By using queuing models for the arrival and service times of ships, ports will be able to develop appropriate berthing schedules which decreases wait times for vessels and maximizes the use of berth space; such models may also be used to determine the inevitable delays that can be expected in the process. This addresses the Berth Allocation Problem, which is a crucial aspect of operational efficiency for every port; namely, assigning docking or berthing space to ships efficiently.

Queuing theory is also helpful for analyzing the flow of cargo, in general, as it goes through and loading/unloading stations; this includes analyzing the arrangement of resources required in the loading/unloading stations to minimize

delays. Similarly, applying queuing models should also be used in customs and inspection processes to better manage queues and through-put in the customs and inspection processes. By using these types of analytical tools, ports can analyze different elements of its operations to improve the efficiency of operations and reduce costs.

Empirical Review

Emelogu (2023), investigated the effect of Transforming Nigerian Maritime Business Operations through Digital Strategy Inclusion. This article conducts a semi-structured interview with leaders and managers of maritime enterprises in Lagos, Nigeria, through content analysis, to explore how incorporating digital strategy into the business processes of Nigerian maritime enterprises can change the industry to obtain more value. The result showed inclusive values of digital strategy inclusion in transforming Nigeria's maritime business operation through integrating technology-based solutions—both soft and hardware and other digital implements. The study further recommended the continuous integration of technology-based solutions, workforce digital upskilling, strict intervention and support by the government and other stakeholders directed at diminishing the impediments to digital strategy inclusion in Nigerian Maritime businesses, drive compliance, and influence change in process and management of the maritime business operation in Nigeria.

Akpo, Udofia and Edemidiong (2021), examined the impact of modern technology on port administration in Nigeria. This study examined the prospects which the deployment of modern technology for the management of Ports can bring to the growth and development economic activities of Nigeria. The objectives of this study were to assess the impact of port equipment and infrastructure on turnaround time in Onne Port and to suggest measures for the enhancement of effective and efficient Port administration. The survey design was adopted to enable the researcher elicit information from a sub-set of the population. This method required the use of both primary and secondary sources to generate data. Findings from the data analysis revealed that Port equipment and infrastructures had a significant positive impact on the turnaround time. That the availability of consistent reform policies has a positive impact on cargo throughput in Onne port. Based on the above findings, the study recommended, among others, that the government should minimise its undue intervention and give independence to the concessionaire to operate in an atmosphere of freedom from all forms of interference from politicians.

Methodology

The study adopted a descriptive research design in order to describe and expand the knowledge of the research phenomenon. The population of the study covered 278 management level employees of four shipping companies namely; Orine Shipping Company, African Ports Terminal, Dado Maritime Services and Sifax Group Nig Ltd. These companies were chosen because they receive more of foreign vessels and most of their employees are indigenes of Nigeria. Using the Taro Yamane formula, a sample size of 109 respondents were purposively selected and a structured questionnaire on a 4-point Likert scale of strongly agree to strongly disagree was used to collect data from them. The data was analyzed using descriptive and inferential statistics while the hypothesis was tested using simple linear regression method from SPSS version 26.

Result and Discussion

TABLE 1: Reliability Statistics		
Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.859	.858	20

Source: Field Survey, 2025.

In table 1, a value of 0.859 suggests a high level of internal consistency among the items in the scale. Therefore, an alpha of 0.859 indicates that the items are reliably measuring the same underlying construct.

Table 2: Total Variance Explained						
Comp	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of	Cumulat	Total	% of	Cumulativ

Component	Mean	Variance	Percentage	Mean	Variance	Percentage
1	6.171	30.854	30.854	6.171	30.854	30.854
2	4.685	23.423	54.277	4.685	23.423	54.277
3	3.534	17.671	71.948	3.534	17.671	71.948
4	2.471	12.353	84.300	2.471	12.353	84.300
5	1.517	7.584	91.884	1.517	7.584	91.884
6	.614	3.070	94.954			

Source: Field Survey, 2025

Five components account for a significant amount of the total variance (91.884%). This suggests that the data can be effectively summarized by these five components, providing a good dimensionality reduction. This analysis provides a reliable and comprehensive understanding of the dataset's structure and the consistency of the measured constructs.

Table : Descriptive Statistics			
	Mean	Std. Deviation	N
DT	52.2086	5.50021	109
PO	17.3957	2.02018	109

Source: Field Survey, 2025

The average value of DT is 52.2086 with a standard deviation of 5.50021, indicating variability around the mean while the average value of PO is 17.3957 with a standard deviation of 2.02018, showing less variability compared to DT.

Table : Correlations			
		DT	PO
Pearson Correlation	DT	1.000	.857
	PO	.857	1.000
Sig. (1-tailed)	DT	.	.000
	PO	.000	.
N	DT	109	109
	PO	109	109

Source: Field Survey, 2025

The Pearson correlation coefficient between DT and PO is 0.857, indicating a very strong positive linear relationship. The significance value (p-value) is 0.000, which is less than 0.05, indicating that the correlation is statistically significant.

Table : Model Summary							
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	Change Statistics	
1	.857 ^a	.735	.734	2.83555	.735	766.231	1

a. Predictors: (Constant), PO

Source: Field Survey, 2025

This table provides an overview of the regression model where DT is used to predict PO. The correlation coefficient (R) of 0.857 indicates a strong positive relationship between DT and PO while the R Square value of 0.735 means that approximately 73.5% of the variance in DT can be explained by PO.

Table : ANOVA ^a						
Model		Sum of Squares	Df	Mean Square	F	Sig.
1.	Regression	6160.762	1	6160.762	766.231	.000 ^b
	Residual	2219.137	276	8.040		
	Total	8379.899	277			

a. Dependent Variable: PO

b. Predictors: (Constant), DT

Source: Field Survey, 2025

The F-statistic (766.231) is very high, and the significance level is 0.000, indicating that the model is statistically significant and that PO is a significant predictor of DT

Table 4: Coefficients

		Unstandardized Coefficients		Standardized Coefficients		
Model		B	Std. Error	Beta	T	Sig.
1	(Constant)	4.023	.513		7.839	.000
1	APO	.835	.058	.667	9.856	.000
1	BTDD	.744	.037	.699	9.066	.001
1	IoT	.858	.067	.780	7.835	.000

- **Dependent Variable: PO**

For every unit change in the independent variable (BD), the following are the actual projected changes in the dependent variable: For PO, the DT coefficient is 4.023; for APO, it is 0.835; for BTDD, it is 0.744; and for IoT, it is 0.858. The coefficient's standard errors are APO (0.058), BTDD (0.037), and IoT (0.067). The relevance of each predictor was shown by the t-statistics and p-values for the coefficient. The P-value = 0.000 indicates that all predictors are highly significant.

Conclusion

The study explored digital transformation and port operations as a panacea to Nigerian ports decongestion. The results shows that digital transformation has a statistically strong positive correlation with ports operation and the overall p-value of 0.000 is an indication that the adoption of digital transformation in the ports operation will go a long way in aiding the decongestion of the ports, improve efficiency and reduce recurrent maintenance cost.

Recommendations

To reduce congestion and optimize the processes for users of the Nigeria Port Authorities and users, it is important to acknowledge the effects of digital transformation and accept changes. Hence the study recommends thus;

The introduction of automation through the advancements of technology, such as automated cranes, autonomous guided vehicles (AGVs), and so on, will expedite container transfers which will allow ports to complete tasks much more quickly, lower costs related to labor, etc.

The data produced through Internet of Things (IoT) devices can assist with managing, locating, tracking, and piloting cargo in real time, and also allow the users of the port, such as shipping lines/brokers/agents to be more organized with the resources they already have through a network of stakeholders operating in maritime transport.

There are also new logistical networks being developed around communications technology 5G allowing more reliable, and secure communications with cloud-based systems functioning through systems within ports.

With the implementation of automated services that utilize reliable delivery and communications processes, ports will be able to alleviate congestion, reduce operating costs for users within the port system, while continuing to facilitate the competitiveness of Nigeria in the global maritime arena.

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