

CORRELATION ANALYSIS BETWEEN DEEP-SEA PORT AND INTERMODALITY: THREAT TO CONGESTION (A STUDY OF LEKKI DEEP-SEA PORT)

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ABSTRACT

This study focused on the congestion and need for intermodal at the Nigerian ports particularly, the Lekki deep-sea port using the Lekki metropolis as a strategic approach. Deep-sea port which have the adequate water depth to accommodate larger vessel (ship draft), modern port operation and improved loading and unloading equipment for large ships poses a threat of congestion to port and shipping practice as a whole. The study analyzed the general infrastructure and statistical operation of the deep-sea port with respect to intermodal and potential for congestion. Using quantitative research through the current state of vessel turnaround, advanced automated cargo handling equipment and the state of intermodal connection as the main tools to analyse the correlation between the deep port and intermodalism. The research adopted a descriptive design with structured questionnaire designed to retrieve information from a sample of 166 respondent gotten from the population of 286 workers of Lekki port in Nigeria. Analysis was done using simple linear regression from spss version 25, while results suggested that all the independent variables statistical significant with congestion with p-value of 0.000, 0.000, 0.000 respectively. The study concluded that there is need for proper intermodal planning for efficient flow of cargo at the port.

Keywords: Deep-sea port, intermodality, port congestion. Inland water way

Introduction

The maritime industry has rapidly shifted towards ultra large container vessels (ULCVs) to achieve economies of scale, requiring deeper water draft (>15m) that traditional ports cannot accommodate. Consequently, the development of deep-sea port has become a global priority with 60-70% of new port project focusing on deep-water capacity, particularly in developing regions. These ports are not just infrastructure but critical strategic hubs that connect regional economies to global supply chain, directly influencing regional competitiveness as in the development of deep-sea port of Lekki in Nigeria to alleviate congestion. Africa is a developing region that suffers from chronic, inherited congestion caused by overstretched shallow and antiquated colonial-era port infrastructure, driven by rising cargo volume and need for competitive hub status. The region is investing in deep-water, automated facilities like Lekki port in Nigeria and Tema port in Ghana with high vessel turnaround times, improve intermodal connectivity, advanced automated and cargo handling equipment as the key driving factor for efficient operation.

Lekki port is a world-class, deep-sea port in Lagos, Nigeria Lekki free trade zone. It stands out for its strategic location, state-of-the-art infrastructure and the capability to accommodate large vessels, making it a key player in facilitating global trade and boosting economic development in the region. The layout of the port, including the layout of the approach channel, turning circle and harbor basins was derived from optimizations based on port operations, construction, costs and possible future extension (Otuokwu, 2023). The analysis of Lekki deep-sea port since inception in terms of container traffic throughput showed a rapid growth from 54,289 TEUs in 2023 to over 500,000 TEUs in 2025 (roughly 50% capacity), driven by 48-hour vessel turnaround and strong regional transshipment, efficient and diverse intermodal connectivity, particularly through barges plays a crucial role in boosting the throughput. Started operation in April, recording 54,289 TEUs, ramping-up-phase in 2024, cargo volume saw a significant increase handling 284,297 TEUs and reaching up to 287,000 TEUs and growth phase by July 2025. 220,000 TEUs were processed with projection reaching 400,000-500,000 TEUs by year ending.

The terminal is operating at approximately 50% capacity. As at Q3 of 2025, Lekki port became a dominant driving 46.8% of total cargo traffic among Nigerian ports. It has successfully facilitated significant regional transshipment of Togo, Ghana and Abidjan. The port handled an estimated \$13.46 trillion in trade value (import/export) in the first three quarters of 2025 (punch 2025). Intermodal connectivity is crucial for maintaining the port's high performance and reducing congestion directly affecting efficiency. The use of barges has emerged as a critical high efficiency evaluation channel, handling approximately 10% of cargo movement. The port boost a 1-hour 25-minute truck turnaround time. The integration of automated systems and effective road/barge evacuation strategies is vital to managing the high volume of imports (268,713 TEUs) and surging exports (69,039 TEUs) as reported in Q3 2025. While the terminal is highly automated (using ship to shore cranes and rubber-tired gantry cranes, 50% capacity utilization brings increased risks of landward evacuation congestion if road network cannot match sea-side speed of cargo output, this because the efficiency of the port heavily relies on seamless uninterrupted cargo evacuation via poorly planned road network capable of creating bottleneck and congestion due to high volume of cargoes thereby reducing the overall turnaround.

To reduce congestion, the port must be supported by robust intermodal infrastructure like modern highways, railways and inland waterways networks for

efficient cargo evacuation Shobayo, P. (2023). The port success is contingent on its connection to efficient hinterland transportation systems by providing viable alternatives like rail, a major contributor to congestion in gateway ports like Apapa. The Lekki deep-sea port is designed to alleviate Lagos's severe urban traffic, particularly the notorious congestion caused by Apapa port. However, experts have long raised concern that without adequate road and good transport infrastructure, the new port of Lekki could simply relocate and intensify traffic problems, especially along the already congested Lekki-Epe corridor, even before the port became fully operational, the Lekki-Epe corridor was known for its constant heavy traffic due to rapid housing development and a booming population Olanipekun, A. S. (2013). The port's truck traffic adds immense pressure to this already strained system.

Statement of the Problem

For decade existing ports in Lagos such as Apapa and tin-can island, have suffered from severe congestion causing delays, higher cost and cargo diversion to neighbouring countries Adewole, O. (2025). However, the Lekki deep-sea port was developed as a modern solution to these issues with the capacity to handle larger vessels and increases output. While it is designed to rival Lome (Togo) and Tema (Ghana), the Lekki deep-sea port currently ranks behind them in terms of TEU volume, this is because the success of 'LDSP' depends on integrating rail and road infrastructure, as over 50% of general logistics constraints in Nigeria port-hinterland logistics stem from inefficient rail system and poor infrastructure. Statistical analysis of intermodality at the Lekki deep-sea port (LDSP) revealed its operational constraint with assessment in mid-2025 that nearly 60% of the port facilities were not fully operational, meaning the full impact of its intermodal systems could not be fully measured.

Moreso, it is a critical, newly established, high capacity hub(16.5m depth,18000TEU capacity) which indicates a high reliance on road haulage rather than rail, resulting in potential congestion the significance concern to the new port is that without adequate intermodal infrastructure- specifically rail and enhanced road network, the Lekki port could undermine its full potential and may even worsen existing congestion problems with the rapid urban and commercial development along the Lekki-Epe corridor with only one major access road. This journal is to investigate the primary concern that the new port, without effective inter-modality, poses a renewed threat of congestion. A correlation analysis would quantify the relationship between port operations and the efficiency of intermodal transport, determining if the new port's capacity is being undermined by a lack of seamless connectivity.

Aim and Objectives of the Study

The main objective of the study is to investigate the correlation between deep-sea port and intermodality along with the possible risk of congestion, while the specific objectives focus on;

1. To access the current state of vessel turn around on intermodal connectivity
2. To analyze and address how advanced automated cargo handling correlate with intermodality
3. To evaluate potential solution and mitigating strategies to alleviate congestion at the port

Research Questions

The research question focus on

1. What is the current state of vessel turn around and intermodal connectivity?
2. What is the correlation between advanced automated cargo handling and intermodal transport and congestion at Lekki port?

3. What are the potential solution and mitigating strategies to overcome congestion

Literature Review

Deep-sea port

A deep-sea port is a modern , large-scale port designed to handle very large and heavily loaded ships that require significant water depth, often at least 18meter(60 feet). These ports are crucial for global trade, serving as major hubs for loading and unloading cargo and often handle large volumes of containers, oil and natural gas. Their infrastructure is built to support larger and more economical vessels which in turn support the economic growth through increased trade and logistics. It requires specialized infrastructure including powerful mobile cranes capable of reaching very large ships to load and unload cargo efficiently. They serve as critical nodes in global supply chains, connecting sea and transport networks. Deep-sea port development can lead to significant economic benefits, such as increased employment, lower shipping costs and infrastructural development in surrounding areas through improved rail and highway links.. they are strategically located to serve as transshipment point , where smaller vessels can distribute cargo to other ports in the region.

Intermodality and Deep-sea port in Nigeria

Inter modality is crucial for deep-sea port efficiency because it facilitate the smooth, cost-effective and low-emission movement of goods inland by linking sea transport and trucks. It involves transferring goods between transport modes without handling the cargo itself, using the same container unit, which reduces congestion and cost and also enhances overall supply chain integration. Efficient Intermodal operation require integrated infrastructure, seamless operations and clear institutional policies to coordinate various logistics. Thus, intermodal transport system refers to loading unit transfers that carry goods from one mode of transportation to another without handling the commodity during transportation. Efficient intermodal terminal operation is vital in sea transport particularly deep-sea port that require planning for optimal performance. Other hand, inefficient intermodal system for sea port operation will drastically militate against fast cargo flow to their destinations which can lead to ship dwell time at the port brought about congestion and higher cost of shipment Historically , inadequate and congested road network have posed a major hindrance to the Lekki deep-sea port, threatening to replicate the gridlock issues seen at older ports. The port was linked to the rest of the city by only the narrow Lekki-Epe expressway which is also the main artery for numerous residential and commercial development, this single road could become a choke- point, trapping the port in perpetual traffic congestion and delaying cargo movement. As of mid-2025, the Lekki port was operating significantly below its projected capacity, a situation that has been linked to unresolved logistics issues, while economic challenges were a factor, delay in completing access roads also hindered the port's ability to maximize its output. Port operations play a significant role in holding the power to impact supply chain efficiency because of their increasing complexity and extensiveness (Lam and Gu 2013). This is why port are critically looking to expand their connectivity with the hinterland to facilitate cargo flow from the inland areas. Lack of coordination and integration among the port operation, shipping lines and inland logistics providers generate institutional constraint and differences in characteristic between port and hinterland transport. These can be trace to challenges in optimizing empty container management, exemplified by the need for coordination between dry ports and seaports, a problem that can lead to inefficiencies as discussed.

Rail link is an important mode of transport to alleviate congestion at the Lekki deep-sea port by providing alternative to road transport for both passengers and cargo.

The primary function of the rail link is to provide a way to move large quantities of cargo from the port to the hinterland at a reduced cost without overwhelming the road network (Behdani, Wiegman, Roso & Haralambides, 2020). Without a rail connectivity, the port will be limited to single-mode transport leading to traffic gridlock and hindering its ability to achieve its full economic potential for cargo evacuation and movement. The rail link provides an alternative to roads for moving large volumes of cargo inland as is standard in modern ports globally. Rail link is an important mode to Lekki deep-sea port, because it enables efficient cargo evacuation to the hinterland, prevents congestion and allows the port to operate at full potential, without it, the port's economic benefits would be limited, as goods would have to rely on less efficient road transport which could be a significant issue for a new modern facility lacking hinterland connectivity from the outset. A rail connection would allow for faster processing and movement of goods, reducing reliance on road transport and mitigating the kind of congestion experienced at the Apapa and Tin Can Island ports.

An adequate rail connection transforms a deep-sea port into a highly efficient multimodal logistics hub, strengthening the entire chain from origin to destination. It offers reliable transit times and is less affected by weather conditions and road traffic jams than trucking. It is also a safer mode of transport, reducing the incidence of accidents associated with busy road transport in port areas. Rail connections are vital for extending a deep-sea port's hinterland- the inland area it serves to distant regions and industrial zones. This expanded reach attracts more cargo volume and enhances the port's competitiveness against other ports. Therefore, the economy of a port depends largely on its rail connection (Abu-Aisha, Audy & Ouhimmou, 2024). Massimo Deandreis, an Italian researcher, pointed out that the efficiency of a port is not just a matter of loading and unloading services. It is important that goods (as well as passengers) can move quickly once off the quayside and interconnect with other transport systems. Intermodality, the connection with the rail and its efficiency, the ability to transform the area behind the port into a center of innovation and investment attraction, the attention paid to technology and sustainability are the elements that make a port truly competitive today. The hindrance associated with connecting deep-sea ports and rail systems are significant and multi-facets which are

1. Inadequate infrastructure: most deep-sea ports, especially newer ones like the Lekki deep-sea port in its initial phases, lack direct rail links making them overly dependent on road transport and leading to severe port congestion and delays.
2. Geographical constraints: existing urban land use and the need to acquire property rights creating urban barriers, splitting communities and impacting local mobility of not properly planned.
3. Institutional and policy barriers: lack of integrated planning in new port developments often lack a master plan that includes integrated rail connectivity from the outset, requiring retrofitting later. Conflicts of vision and low coordination levels between different government agencies and private entities can cause delay in project implementation.
4. Economic and financial issues: rail infrastructure requires massive investment for track, rolling stock and maintenance. Securing the right financing schemes and attracting investment can be a major hurdle, especially for projects with long return periods.
5. Environmental and safety concerns: increases in freight flows raise concerns about safety (e.g. level crossings) noise pollution and environmental regulations and mitigation measures.

An inland waterway is a navigable stretch of water such as canal or lake that is not part of the sea and is used for transport. These waterways are either natural or artificial may be connected in a system and are often used for moving large volumes of heavy or bulk goods efficiently and with lower environmental impact compared to other transport modes. Inland waterway are relevant to deep-sea port because they act as a logistic link, extending the ports reach into the hinterland by transporting goods more cheaply and efficiently (Shitu, 2021). Port performance and crude oil export logistics system distribution in Nigeria. They reduce congestion at coastal ports by shifting cargo to smaller inland ports or dry port and connecting integrated transport corridors. This multimodal transport system lowers costs, provides a more sustainable alternatives to road and rail transport and increases overall economic activity. Inland waterways are key component of integrated multimodal logistics chains. It allows for seamless transfers between ships, barges, train and trucks at 'dry ports ' or inland terminals creating a more robust and flexible supply chain. By diverting cargo from the immediate coastal port to inland facilities via waterways, it helps decongest the main port, reduce delays and improves overall efficiency.

Urban Mobility Crises and Lekki Deep-sea port

The Lekki deep-sea port while significant achievement could worsen Lagos urban mobility crisis if not properly managed as it is expected to increase heavy truck traffic. The port's infrastructure including its access road is crucial but requires a more comprehensive transportation master plan to address the potential for congestion, especially for the movement of workers and residents and to ensure public transport options are prioritized. While the port itself has impressive infrastructure, there are concerns that mobility for workers and residents particularly those without private vehicles is not adequately addressed. The port is surrounded by circumstances that may cause a traffic crisis despite its economic potential. The port represent a major investment in Nigeria's trade capacity, but its integration into the existing urban fabric must be carefully planned to prevent it from increasing the current urban mobility crisis in Lagos (the Guardians 2022)

Port Congestion

Port congestion occurs when a port's cargo volume or traffic exceeds its capacity to handle shipments efficiently, creating bottlenecks. This can be due to various factors including high cargo volumes, limited infrastructure, labor shortages or inefficient operations, all of which slow down the free flow of goods Researchers emphasize that congestion is not limited to ships waiting at berth, but is a system-wide problem. It cascades through the entire shipping and logistic system affecting inland transport, storage areas and overall supply chain efficiency. Port congestion is the overcrowding of a port with cargo ships exceeding its handling capacity, leading to delays, extended wait times and operational efficiencies (Ojadi & Maiyaki, 2025). Congestion occurs when the volume of cargo exceeds a port's ability to process it efficiently, ships must wait in a queue often for extended periods to dock and unload their cargo. Congestion creates a domino effect impacting the entire supply chain and causing a cascade of problems for business and consumers.

Impact of Port Congestion

Higher Cost: businesses face increased logistics costs including expensive fees for ships waiting at port

Supply chain disruption: the delays disrupt production schedules and can cause a ripple effect throughout the global supply chain

Longer delivery time: consumers experience delays in receiving their goods and may face higher prices as businesses pass on extra costs

Economic consequences: congestion can hinder economic growth and trade agreements

Theoretical Framework: System Dynamics Modeling

The theory was developed by Jay W. Forrester in the 1950s at MIT, he applied engineering principles to social systems, creating a way to model complex systems and understand their behaviour over time. This model theory can be used to analyze the correlation between deep-sea ports and inter modality while considering the threat of congestion. It allows for the simulation of complex interactions, such as the flow of cargo, container management and infrastructure capacity, to understand how increases in port traffic affect inland transportation networks that can lead to bottlenecks and delays. It uses casual loop diagrams and computer simulations to represent feedback loops, delay and interdependence within a system. It is ideal for studying the relationship between a deep sea and its intermodal hinterland because it can capture the dynamic interplay among port throughput, intermodal transfer and congestion through assessing the effecting of expanding capacity with optimizing current operation, focusing on congestion risk and test interventions. It models vessel arrival, berth availability and cargo flow.

Methodology

The study adopted a descriptive research design in order to analyze the correlation within the research phenomenon using the sub variables such as vessel turn around time, advanced automated cargo handling and state of intermodality (road, rail and inland) to analysis between intermodal and congestion and strategies to alleviate congestion. The population of the study consist of 286 employees limited to the stakeholders of Lekki deep-sea port (Nigeria port authority, shipping liner, terminal operator and freight forwarders), this because the study try to analyse and focus on the potential of threat of congestion at the Lekki port area. Using Taro Yamane formulae, a sample size of 166 respondents was purposively selected of which 149 were retrieved based on structured questionnaire on a four-point likert scale of strongly agreed to strongly disagreed was used to retrieved data from the respondents. The data was analyzed using descriptive and inferential statistics while the hypothesis was tested using simple linear regression method from SPSS version 25.

Results

Table 1: Correlations

		Intermodality	VT	AA	CH
Pearson Correlation	Intermodality	1.000	.891	.871	.782
	VT	.891	1.000	.714	.806
	AA	.871	.714	1.000	.695
	CH	.782	.806	.695	1.000
Sig. (1-tailed)	Intermodality	.	.000	.000	.000
	VT	.000	.	.000	.000
	AA	.000	.000	.	.000
	CH	.000	.000	.000	.
N	Intermodality	149	149	149	149
	VT	149	149	149	149
	AA	149	149	149	149
	CH	149	149	149	149

Source: Extracted from SPSS, Version 25

All the variables revealed had a positive correlation. Vessel turnaround correlate with intermodality at .891, (i.e, there is a strong correlation between these variables). Advanced automated correlated with intermodality at .871 (i.e, there is a strong positive correlation between the two variable). Cargo handling correlate with intermodality at .782 (i.e, there is a strong positive correlation between the two variable).

Table 2: Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.952 ^a	.907	.905	.62216

a. Predictors: (Constant), CH, AA, VT

Source: Extracted from SPSS, Version 25.

The table above shows the R square with the value of .90 which indicates that 90% variation in intermodality was caused by the explanatory variables which include vessel turnaround, Advanced automated and cargo handling. Also, the adjusted R square indicates that after adjusting the degree of freedom, the explanatory variables can still explain 90% variation in intermodality.

Table 3: ANOVA^a

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	547.135	3	182.378	471.163	.000 ^b
	Residual	56.127	145	.387		
	Total	603.262	148			

a. Dependent Variable: Intermodality

b. Predictors: (Constant), CH, AA, VT

Source: Extracted from SPSS, Version 25.

The F statistic table reveals the overall significance of the model, the probability value of 0.000 which is below the level of significance indicate that there is a correlation analysis between deep-sea port and intermodality.

Table 4: Coefficients^a

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-1.097	.541		-2.029	.044
	VT	.484	.041	.537	11.697	.000
	AA	.573	.046	.475	12.568	.000
	CH	.018	.043	.019	.416	.678

a. Dependent Variable: Intermodality

Source: Extracted from SPSS, Version 25

The coefficient table reveals the relationship between the variables which shows that vessel turnaround, Advanced automated and cargo handling have a positive relationship with intermodality with 0.484, 0.573 and 0.018 respectively. The table further reveals the significance of the explanatory variables which was however used to test the hypotheses of the study. However, the T statistic rules states that once the probability value of the variable is greater than 0.05 which is the level of significance,

we therefore accept null hypothesis and if otherwise, we reject null hypothesis and accept alternate hypothesis.

Conclusion

The study objective was to examine the strategies adopted by deep-sea port in analyzing the correlation between deep-sea port and intermodality with possible risk of congestion at Lekki port. The first, second, and third objective analyses the state of intermodality on vessel turn around, advanced automated and cargo equipment and strategies to mitigate congestion at the deep-sea port with a p-value of 0.000, 0.000 and 0.000 respectively. The study concluded that there is statistical significance and strong relationship between the sub-variable and independent variable. The study focus on the analysis of deep-sea port and the potential for congestion within the port metropolis. The research work highlights the possible measures to mitigate the potential threats looming at the port. The general conclusion on the deep-sea port and intermodalism is that developing intermodal transport systems is a critical solution for mitigating port congestion which is primarily caused by infrastructure limitation and operational inefficiencies. The research concluded that an integrated intermodal transport system (combining sea, road and rail) can significantly enhance the flow of trade of goods to and from the port's hinterland thereby reducing cargo accumulation at the terminals. The development of dry port in particular is noted as a potential solution for alleviating congestion in urban ports by moving logistics activities. Furthermore, congestion often stems from an imbalance between growing cargo demand (driven by larger vessels and global trade growth) and inadequate ageing physical infrastructure. In conclusion, achieving efficiency in deep-sea port requires a holistic approach that goes beyond the port perimeter, emphasizing integrated and technologically advanced intermodal solution to manage the increasing volume and complexity of global trade and effectively mitigate congestion threats.

Recommendations

In line with the findings, the following were recommended:

1. Implementing multi-modal transport strategies that integrates port operations with other forms of transport like rail and road to create a seamless and efficient logistics chain
2. Invest in other deep(sea port development and their infrastructure across Nigeria to create a network and prevent the over- reliance and congestion of a single major hub.
3. Develop an effective integrated transport operation I.e. improve the road and rail infrastructure connecting the port to the rest of the country to ensure efficient and timely delivery of goods
4. Optimizing internal operation system for handling cargo including container management and equipment availability is crucial for maintaining flow of cargo

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