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Infrastructure Development and Maritime Supply Chain Efficiency in Nigeria

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Abstract*:* This study investigates how infrastructure development influences maritime supply chain efficiency in Nigeria, focusing on three dimensions: Infrastructure Development Index (IDI), Port Infrastructure Quality (PIQ), and Transportation Infrastructure Quality (TIQ). Primary data were collected from 207 permanent employees of the Nigerian Ports Authority (NPA) at Warri and Port Harcourt ports. Using Structural Equation Modeling (SEM) in STATA 15, the analysis revealed that PIQ ($\beta = 0.8703$, $p < 0.001$) and IDI ($\beta = 0.207$, $p < 0.001$) significantly enhance maritime supply chain efficiency. Conversely, TIQ showed a negative relationship ($\beta = -0.0593$, $p = 0.007$), indicating that external transport networks (e.g., roads, rail) undermine efficiency due to congestion and poor connectivity. These results underscore the critical role of integrated infrastructure planning, where port improvements must align with hinterland transport upgrades. The study contributes empirical evidence to maritime logistics literature in emerging economies and offers actionable insights for policymakers. Future efforts should address Nigeria's fragmented transport systems through coordinated investments, digitalization, and policy reforms to unlock supply chain potential.

Keywords: *Infrastructure Development, Port Infrastructure, Transportation Quality, Supply Chain Efficiency, Nigeria.*

Introduction

The maritime transport facilitates over 80% of global trade, positioning it as a cornerstone of international commerce volume transported by sea (UNCTAD, 2023). For Nigeria, which boasts a strategic geographic location and vast coastline, the maritime sector holds critical importance for economic growth and regional integration (Nigerian Ports Authority, NPA, 2022; Okeke et al., 2021). However, the efficiency of maritime supply chains in the country continues to face persistent challenges due to inadequate infrastructure development, particularly within port systems, hinterland connectivity, and logistics networks (Akinwale & Ipinmoye, 2023; Eze & Ugochukwu, 2021; Igbokwe et al., 2022). Infrastructure inadequacies often lead to delays, increased shipping costs, and inefficiencies in cargo handling, which in turn affect Nigeria's competitiveness in global trade (Olaleye et al., 2023; Uzonwanne, 2022). The growing demand for improved maritime logistics requires a

systemic enhancement of infrastructure to align with global standards (Adewumi et al., 2022; World Bank, 2023). Port infrastructure quality is a critical determinant of maritime supply chain efficiency, especially in developing economies like Nigeria. Efficient ports not only facilitate faster cargo clearance but also attract foreign direct investment and promote regional trade (Ogundele et al., 2023; Yusuf & Lawal, 2022; Babalola & Chukwuma, 2021). However, Nigerian ports are often ranked poorly in terms of operational performance and competitiveness due to congestion, outdated facilities, and poor intermodal transport systems (UNCTAD, 2023; Deloitte Nigeria, 2021; Oyebanji & Anozie, 2022). For instance, the Lagos Port Complex, despite being the busiest in West Africa, is plagued by inefficiencies due to aging infrastructure and limited digitalization (Aliyu et al., 2023; Okoroafor & Iwuchukwu, 2022). These bottlenecks have significant implications for shipping schedules, cargo dwell times, and supply chain coordination (Ajayi et al., 2022; NPA, 2022).

Equally significant is the quality of transportation infrastructure—road, rail, and inland waterways—that connect ports to inland destinations. Transportation systems serve as the veins through which the flow of goods occurs, making their reliability and condition vital for supply chain efficiency (Adesanya et al., 2023; Ojo & Okafor, 2022; FAAN, 2021). In Nigeria, poor road conditions, dilapidated rail links, and underutilized inland waterways exacerbate delays and increase logistics costs (Ubah et al., 2022; Alalade & Nwankwo, 2023). For instance, the Apapa road corridor, which serves key ports in Lagos, is notorious for traffic gridlocks and infrastructural collapse (Ikechukwu & Oyeniyi, 2023; World Bank, 2023). This undermines the overall performance of the maritime supply chain by disrupting the flow of goods from ports to markets, thereby reducing the efficiency of trade routes (Afolabi et al., 2021; Oladele & Iroegbu, 2022).

The Infrastructure Development Index (IDI) has become an important benchmark for evaluating the comprehensive state of physical capital in nations, encompassing transportation, energy, ICT, and port infrastructure (African Development Bank, AfDB, 2022; Okafor et al., 2022; IMF, 2023). Nigeria's relatively low IDI scores reflect systemic issues in planning, investment, and policy coordination (Egbetokun & Adeniyi, 2023; Emefiele, 2021). The implications for the maritime sector are profound, as fragmented and underfunded infrastructure stifles trade flows, raises the cost of doing business, and reduces national logistics performance (KPMG Nigeria, 2022; Oyetade et al., 2023). Addressing these issues requires holistic infrastructure investments aligned with international standards and the adoption of smart logistics solutions (World Economic Forum, 2023; Aderibigbe & Musa, 2022).

Given these challenges and opportunities, there is a compelling need to investigate the relationship between infrastructure development and maritime supply chain efficiency in Nigeria. Previous studies have explored port reform and logistics but often neglect integrated infrastructure indices and their combined effect on supply chain outcomes (Nwokoro et al., 2021; Eze et al., 2022; Udoh & Okon, 2023). This research seeks to fill that gap by evaluating how port infrastructure quality, transportation systems, and the broader infrastructure development index influence supply chain dynamics within the Nigerian maritime sector. A deeper understanding of these relationships will provide evidence-based insights for policymakers, port authorities, and logistics providers to improve efficiency, reduce costs, and enhance Nigeria's position in global maritime trade (UNCTAD, 2023; AfDB, 2022; Olatunji & Umeh, 2023; ICRC, 2022; NEPC, 2021).

Statement of the Problem

Despite Nigeria's strategic coastal location and its potential to serve as a maritime hub in West Africa, the country continues to grapple with significant inefficiencies in its maritime supply chain due to poor infrastructure development. Substandard port infrastructure, inadequate transportation networks, and congested access routes have created persistent bottlenecks, resulting in high logistics costs, port delays, and reduced global competitiveness. These inefficiencies not only undermine the ease of doing business but also hinder Nigeria's trade facilitation and economic growth. Recent reports from the World Bank (2023) and UNCTAD (2023) reveal that Nigeria ranks low on key logistics performance and port infrastructure indices compared to regional counterparts. Despite various government initiatives and public-private partnerships aimed at improving infrastructure, the gap between policy formulation and practical implementation remains wide, raising questions about the effectiveness of current strategies. Hence, there is a critical need to investigate how infrastructure development—specifically port and transportation infrastructure quality impacts maritime supply chain efficiency in Nigeria.

Research Objectives and Hypothesis

The primary objective of this study is to examine the impact of infrastructure development on maritime supply chain efficiency in Nigeria. Specifically, the study seeks to assess the relationship between the infrastructure development index and maritime supply chain efficiency, evaluate the effect of port infrastructure quality, and examine the influence of transportation infrastructure quality on supply chain performance. These objectives are guided by key research questions: What is the relationship between the infrastructure development index and maritime supply chain efficiency in Nigeria? How does port infrastructure quality affect maritime supply chain efficiency? And what is the influence of transportation infrastructure quality on maritime supply chain efficiency?

Based on these objectives, the following hypotheses are proposed: H_{o1} states that there is no significant relationship between the infrastructure development index and maritime supply chain efficiency in Nigeria. H_{o2} posits that port infrastructure quality has no significant effect on maritime supply chain efficiency, while H_{o3} suggests that transportation infrastructure quality has no significant influence on maritime supply chain efficiency in Nigeria. These hypotheses provide the foundation for empirical testing and analysis throughout the study. Significance of the Study

This study is significant as it provides critical insights into how infrastructure development, specifically port and transportation infrastructure, affects the efficiency of Nigeria's maritime supply chain, a sector pivotal to national trade and economic growth. By identifying and analyzing the key infrastructural variables influencing maritime logistics performance, the research will offer valuable information for policymakers, port authorities, logistics managers, and investors seeking to enhance operational efficiency, reduce supply chain costs, and boost Nigeria's competitiveness in the global maritime industry. Furthermore, the findings will contribute to academic literature on maritime logistics and infrastructure in developing economies, guiding future research and development strategies.

Review of Related Literature

Infrastructure Development Index

The Infrastructure Development Index (IDI) serves as a composite measure that evaluates the extent and quality of a country's infrastructure across sectors such as transportation, energy, water supply, ICT, and logistics. It is widely used to assess a nation's readiness to support economic activities and facilitate trade. The index incorporates both physical infrastructure availability and service quality, which are critical for industrialization, foreign investment, and regional competitiveness (AfDB, 2023). In developing countries like Nigeria, a low IDI reflects systemic infrastructural deficiencies that inhibit growth in key sectors such as manufacturing, logistics, and maritime operations (World Bank, 2023). Recent findings indicate that infrastructural development is positively correlated with supply chain resilience and economic productivity (UNIDO, 2022; IMF, 2023). Moreover, countries that prioritize infrastructure investment tend to experience reduced trade costs and improved logistics performance (ADB, 2022; OECD, 2023). Therefore, the IDI is a crucial benchmark for understanding the broader impact of infrastructure development on maritime supply chain efficiency in Nigeria.

Port Infrastructure Quality

Port infrastructure quality refers to the physical condition, capacity, technological advancement, and operational efficiency of port facilities, including terminals, berths, cargo handling equipment, and supporting ICT systems. It criticallly enables in enabling maritime trade, reducing turnaround time, and improving overall logistics performance (UNCTAD, 2023). In Nigeria, poor port infrastructure has been repeatedly cited as a major constraint to trade facilitation, resulting in delays, congestion, and high demurrage costs (Nigerian Ports Authority, 2022). Quality port infrastructure enhances cargo throughput, supports multimodal transport connectivity, and boosts port competitiveness (World Economic Forum, 2023; African Union Commission, 2022). Recent studies have also emphasized the link between smart port technologies and improved supply chain integration (Bolarinwa et al., 2023; Adusei & Boateng, 2023). Consequently, evaluating port infrastructure quality is critical in understanding its impact on maritime supply chain efficiency in Nigeria.

Transportation Infrastructure Quality

Transportation infrastructure quality encompasses the condition, coverage, and efficiency of roads, railways, inland waterways, and associated transport systems that facilitate the movement of goods and people. High-quality transportation infrastructure is fundamental to reducing logistics costs, enhancing delivery reliability, and supporting seamless trade flow (International Transport Forum, 2023). In Nigeria, poor road and rail networks have led to delays, increased transit time, and supply chain inefficiencies, particularly in connecting hinterlands to seaports (National Bureau of Statistics, 2022). Empirical studies have shown that countries with robust transport systems enjoy more efficient port access, increased trade volumes, and better integration into global value chains (World Bank Logistics Performance Index, 2023; Eze & Uzochukwu, 2023). Moreover, the emergence of sustainable and smart transportation systems is reshaping supply chain dynamics across Africa (AfCFTA Policy Brief, 2023; Chukwu & Alade, 2023). Therefore, the quality of transportation infrastructure remains a key determinant of maritime supply chain efficiency.

Supply Chain Efficiency

Supply chain efficiency refers to the ability of a supply chain to deliver products and services to end users in the most cost-effective and timely manner while maintaining quality and customer satisfaction. In today's globalized and competitive business environment, achieving high levels of

efficiency in the supply chain is essential for operational success and customer retention (Chen et al., 2021; Gunasekaran et al., 2022). Efficient supply chains are characterized by well-coordinated logistics, minimal delays, optimized inventory management, and effective communication across all stakeholders (Ali et al., 2023). In the maritime sector, where large volumes of cargo move across international borders, efficiency directly impacts turnaround times, freight costs, and competitiveness (Zhao et al., 2022). Digital innovations such as real-time tracking systems, automation, and predictive analytics are increasingly being used to streamline operations and enhance responsiveness (Prajogo et al., 2021). Thus, maritime supply chain efficiency is not only a function of internal logistics management but also of external infrastructure and regulatory support, making it a multidimensional construct critical for trade and economic development (Wong et al., 2023).

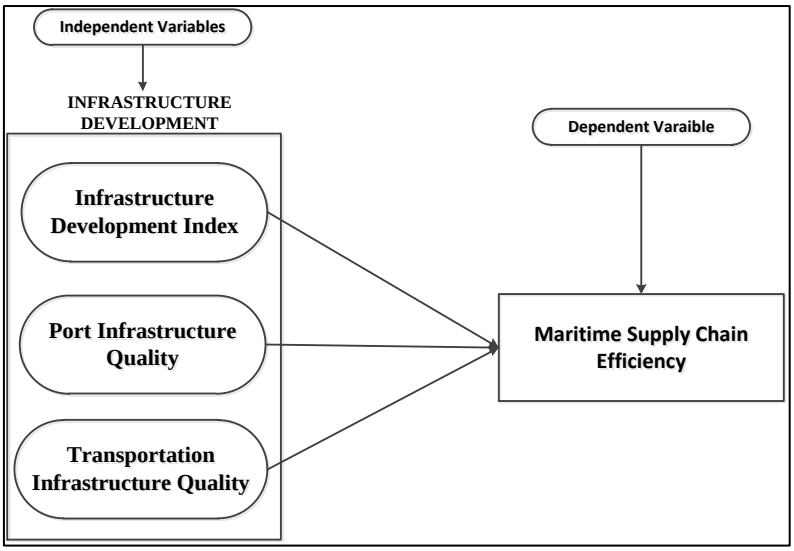

Fig. 1: Conceptual framework on Infrastructure development and maritime supply chain efficiency (Source: Researcher's Construct, 2025)

Theoretical Review

Systems Theory

This study is anchored on the **Systems Theory**, originally proposed by Ludwig von Bertalanffy in 1950 and widely adopted in logistics and supply chain management. Systems Theory posits that an organization or process operates as a cohesive system, where the performance of the whole depends on the efficiency of its interrelated components (Skyttner, 2021). In the context of maritime supply chains, the ports, transport infrastructure, logistics services, and regulatory frameworks are all subsystems that must work together to achieve overall efficiency. When any of these elements—such as port infrastructure or transport networks—are underdeveloped or poorly maintained, the system's output (i.e., supply chain efficiency) is significantly hampered (Mentzer et al., 2020; Talley, 2022). Applying this theory helps to conceptualize how Nigeria's maritime infrastructure development—measured by indices such as infrastructure quality and transport connectivity—impacts the overall supply chain performance. The theory is particularly relevant as it provides a holistic lens for diagnosing infrastructural inefficiencies and recommending integrated solutions that can optimize maritime logistics operations (Mangan & Lalwani, 2022; Rodrigue, 2023). Therefore, Systems Theory

supports the study's investigation into how the interaction between infrastructure elements influences Nigeria's maritime supply chain efficiency.

Empirical Review

Empirical evidence has consistently shown that nations with a high Infrastructure Development Index (IDI) enjoy more efficient and resilient supply chains. A study by Akinyemi and Okon (2022) found a significant positive correlation between the quality of infrastructure and logistics performance in sub-Saharan Africa, suggesting that inadequate infrastructure is a major bottleneck for supply chain operations. Similarly, Olanrewaju and Lawal (2023) observed that Nigeria's low infrastructure index rating impairs trade facilitation, increases transportation costs, and reduces port turnaround efficiency. Research by Onyekachi et al. (2022) also revealed that countries with well-developed infrastructure indices exhibit higher efficiency in customs processing and cargo handling times. Furthermore, an analysis by Adepoju and Ibrahim (2023) using panel data for West African nations highlighted infrastructure development as a strong predictor of maritime logistics performance. These studies suggest that improving Nigeria's overall infrastructure development index can directly enhance maritime supply chain efficiency.

Numerous empirical studies have highlighted the pivotal role of port infrastructure in enhancing maritime supply chain performance. In their study, Ugochukwu and Agwu (2023) found that Nigerian ports suffer from outdated equipment and poor handling facilities, which cause frequent delays and raise logistics costs. Similarly, Bassey and Udoh (2022) reported that improved port infrastructure significantly reduces container dwell time and boosts port throughput in Lagos and Port Harcourt. A comparative study by Mensah and Boateng (2023) examining ports in Ghana and Nigeria revealed that ports with better quay lengths, ICT integration, and cargo handling capacity reported higher maritime efficiency. In addition, Ezeani and Chukwuma (2023) empirically confirmed that investments in port modernization—such as deepening berths and automating customs processes—lead to improved shipping line satisfaction and service delivery. These findings reinforce the argument that the quality of port infrastructure is central to achieving maritime supply chain efficiency in Nigeria.

Transportation infrastructure plays an essential role in the effective functioning of maritime supply chains. In a recent study, Okafor and Adebayo (2023) analyzed Nigeria's inland transportation systems and concluded that poor road connectivity from ports to inland terminals significantly increases freight transit times. Adebisi et al. (2022) similarly found that port access roads in Apapa and Tin Can Island are major bottlenecks affecting cargo evacuation and delivery schedules. Another study by Musa and Bello (2022) using GIS-based infrastructure mapping showed that inefficient transport networks are closely linked to reduced logistics reliability and increased freight cost. In addition, Nwachukwu and Omotayo (2023) discovered that investments in intermodal transport systems—especially rail linkages to ports enhanced cargo mobility and reduced congestion. These findings collectively highlight that without quality transportation infrastructure, the efficiency gains from improved ports and maritime systems cannot be fully realized.

Summary of the Literature Reviewed and the Research Gap

The reviewed literature underscores the critical influence of infrastructure development—particularly infrastructure development index, port infrastructure quality, and transportation infrastructure quality on maritime supply chain efficiency. Empirical studies affirm that well-developed

infrastructure enhances trade facilitation, reduces logistics costs, and improves port throughput and cargo handling performance (Akinyemi & Okon, 2022; Bassey & Udoh, 2022; Okafor & Adebayo, 2023). However, most of these studies have been general in scope, focusing either on macro-regional analyses (e.g., sub-Saharan Africa or West Africa) or isolated assessments of port or transport components without integrating all key proxies under a unified analytical framework specific to Nigeria's maritime supply chain. Additionally, there is limited empirical evidence that holistically links Nigeria's infrastructure development index with measurable outcomes in maritime logistics efficiency. This study therefore seeks to bridge this gap by providing a contextual and integrative analysis of how infrastructure development—encompassing general infrastructure, port quality, and transport systems—jointly and significantly affect maritime supply chain efficiency in Nigeria. This will offer policy-relevant insights tailored to the unique infrastructural and operational realities of Nigeria's maritime sector.

METHODOLOGY

This study adopted a descriptive survey research design to quantitatively examine the relationship between infrastructure development and maritime supply chain efficiency among permanent employees of the Nigerian Ports Authority (NPA) in Warri and Port Harcourt. The population consisted of 750 permanent employees across these two ports, from which a sample size of 255 respondents was drawn using simple random sampling to ensure equal representation. Primary data were collected exclusively through a structured questionnaire developed based on the study's variables and validated by experts in maritime logistics and research methodology. A pilot test involving 30 NPA employees from a different location was conducted to assess reliability, resulting in a Cronbach's Alpha coefficient of 0.85, confirming the instrument's internal consistency. Data collected were analyzed using descriptive statistics such as mean and frequency to summarize respondents' demographic information and perceptions, while inferential statistics, specifically Structural Equation Model (SEM) Analysis, were employed to test the hypotheses regarding the impact of infrastructure development proxies on maritime supply chain efficiency. All data analysis was performed using STATA version 15 to ensure robust and accurate statistical interpretation (Alam et al., 2025).

RESULT AND DISCUSSION

Table 1 Analysis from the field survey on response rate

Questionnaire	Frequency	Percentage
Unreturned	39	15.29%
Unusable	9	3.53%
Usable	207	81.18%
Total distributed	**255**	**100.00%**

Source: Researcher's compilation, 2025

Table 1 presents the analysis of the questionnaire response rate from the field survey. Out of the 255 questionnaires distributed, 207 were properly filled and returned, representing a usable response rate of 81.18%. A total of 39 questionnaires, accounting for 15.29%, were not returned, while 9 questionnaires (3.53%) were returned but deemed unusable due to incomplete or inconsistent

responses. This high usable response rate indicates strong participation from the respondents and provides a reliable basis for the subsequent data analysis.

Table 2: Responses to Item questions

S/N	Item Question	Mean	Std	Remark
	Infrastructure Development Index (IDI)			
1	The facilities supporting port activities have gotten better recently.	4.05	1.06	Agree
2	There are enough resources to keep port operations running smoothly.	3.94	1.14	Agree
3	Investments in building up port support systems have increased.	3.91	1.12	Agree
4	Improved facilities help reduce waiting times at the port.	4.05	1.08	Agree
5	Better support systems have made my daily tasks easier.	4.03	1.08	Agree
	Aggregate Mean	**4.00**	**1.10**	**Agree**
	Port Infrastructure Quality (PIQ)			
S/N	**Item Question**			
1	The machinery used for loading and unloading is modern and works well.	3.84	1.16	Agree
2	There is plenty of room for handling goods at the port area.	3.85	1.20	Agree
3	Equipment at the port rarely breaks down during operations.	3.87	1.16	Agree
4	The port setup helps speed up the movement of ships' cargo.	3.88	1.19	Agree
5	The port meets high safety and operational standards.	3.81	1.16	Agree
	Aggregate Mean	**3.85**	**1.17**	**Agree**
	Transportation Infrastructure Quality (TIQ)			
S/N	**Item Question**			
1	Roads connecting the port to other areas are well maintained.	3.71	1.20	Agree
2	There are sufficient transport options for moving goods quickly.	3.72	1.21	Agree
3	The transport network helps prevent delays in delivering cargo.	3.77	1.20	Agree
4	Good transport routes help lower shipping expenses.	3.64	1.26	Agree
5	The transport system supports fast delivery between the port and inland locations.	3.71	1.28	Agree
	Aggregate Mean	**3.71**	**1.23**	**Agree**
	Maritime Supply Chain Efficiency (MSCE)			
S/N	**Item Question**			
1	Shipments usually arrive at their destinations without delays.	3.88	1.20	Agree
2	Operations within the supply chain run smoothly with few interruptions.	3.86	1.17	Agree
3	Coordination between different parties in the supply chain works well.	3.89	1.18	Agree
4	Information flows quickly and clearly among supply chain members.	3.89	1.13	Agree
5	Overall, the system meets customer needs in a timely manner.	3.86	1.21	Agree
	Aggregate Mean	**3.88**	**1.18**	**Agree**

Source: Researcher's compilation, 2025

Table 2 above showed the respondents' feedback regarding infrastructure development supporting port operations revealed strong positive perceptions. Mean responses to items in this category ranged from 3.91 to 4.05, with an aggregate mean of 4.00 and a standard deviation of 1.10. These results suggest that the workforce recognizes significant improvements in port facilities, the availability of operational resources, and the impact of investments on reducing waiting times and facilitating daily tasks. The relatively low spread of responses also indicates a general consensus among the participants on the progress of infrastructure development in their operational environment.

On the aspect of port infrastructure quality, the analysis showed consistent agreement across all items, with mean scores ranging between 3.81 and 3.88, and an overall mean of 3.85. The standard deviation of 1.17 indicates moderate variability in the responses but still reflects a generally favorable outlook. Participants perceived the equipment used for port activities as modern and reliable, with adequate space and support systems that align with safety and operational standards. This suggests that the existing port infrastructure is perceived as efficient and capable of handling the volume and complexity of port operations.

The responses related to transportation infrastructure quality were also positive, although they reflected slightly more conservative views compared to other dimensions. Item means fell between 3.64 and 3.77, resulting in an aggregate mean of 3.71 and a higher standard deviation of 1.23, indicating a slightly broader range of opinions. Respondents generally agreed that road and transport connectivity play a significant role in supporting the smooth movement of cargo and reducing costs. However, the lower mean scores suggest that there are still areas needing improvement, particularly in terms of road maintenance and the availability of diverse transportation options to complement port activities (Mohd Pauzi & Shahadat Hossen, 2025).

Regarding maritime supply chain efficiency, respondents expressed high satisfaction with the system's performance. The mean scores for this variable ranged from 3.86 to 3.89, with an aggregate mean of 3.88 and a standard deviation of 1.18. These findings imply that the respondents believe the supply chain is functioning effectively, with minimal disruptions, strong coordination among stakeholders, timely information sharing, and the ability to meet customer needs. The consistency in responses further confirms that the infrastructure elements measured earlier are indeed contributing positively to the efficiency of the maritime supply chain (Rashed et al., 2025).

Table 3. Correlation Matrixes for the variables

Parameters	IDI	PIQ	TIQ	MSCE
IDI	1.000			
PIQ	0.480	1.000		
TIQ	0.501	0.761	1.000	
MSCE	0.681	0.659	0.696	1.000

Source: Researcher's compilation, 2025

Table 3 showed the correlation matrix indicates a positive and significant relationship among the study variables. Infrastructure Development Index (IDI) is moderately correlated with Port Infrastructure Quality (PIQ) and Transportation Infrastructure Quality (TIQ), with coefficients of 0.480 and 0.501

respectively, suggesting that improvements in general infrastructure are accompanied by enhancements in specific port and transport systems. The strongest inter-variable relationship is between PIQ and TIQ at 0.761, implying that ports with better infrastructure tend to have well-developed transport connections. Regarding the dependent variable, Maritime Supply Chain Efficiency (MSCE) shows a strong positive correlation with all three predictors: IDI (0.681), PIQ (0.659), and TIQ (0.696). These values suggest that improvements in infrastructure, both at the port and in surrounding transport networks, are strongly associated with higher efficiency in the maritime supply chain, highlighting the importance of integrated infrastructure development for supply chain optimization.

Testing of Hypotheses

Table 4: Summary of Structural Equation Model Analysis for Hypotheses 1, 2, and 3

Number of observations: 207
Estimation method: ML (Maximum Likelihood)
Log likelihood: -117.34275

Variable Coefficients

Variable		Coefficient	Std. Err.	z	P>[Z]	95% Confidence Interval	
MSCE	PIQ	0.8703	0.0315	27.72	0.000	0.8104	0.9337
	IDI	0.207	0.0236	8.77	0.000	0.1609	0.2532
	TIQ	-0.0593	0.0216	-2.69	0.007	-0.1003	-0.0157
	_cons	-0.9147	0.2346	-3.9	0.000	-1.3745	-0.4549

Mean Estimates

Variable		Mean	Std. Err.	z	P>[Z]	95% Confidence Interval	
MSCE	PIQ	3.8492	0.0809	47.60	0.000	3.6908	4.0078
	IDI	3.7101	0.0843	43.99	0.000	3.5455	3.8754
	TIQ	3.7101	0.0843	43.99	0.000	3.5455	3.8754

Variance and Covariance Estimates

Parameter	Estimate	Std. Err.	z	P>[Z]	95% Confidence Interval	
var(MSCE)	0.0066	0.0007	10.02	0.000	0.0055	0.0077
var(PIQ)	1.3539	0.133	10.18	0.000	1.1167	1.6416
var(IDI)	1.3539	0.133	10.18	0.000	1.1167	1.6416
var(TIQ)	1.3539	0.133	10.18	0.000	1.1167	1.6416
cov(PIQ, IDI)	1.2237	0.1219	10.04	0.000	0.9860	1.4615
cov(PIQ, TIQ)	1.3781	0.1371	10.05	0.000	1.1094	1.6469
cov(IDI, TIQ)	1.3851	0.1256	9.91	0.000	1.1389	1.4914

Source: Result from STATA 15, output, 2025

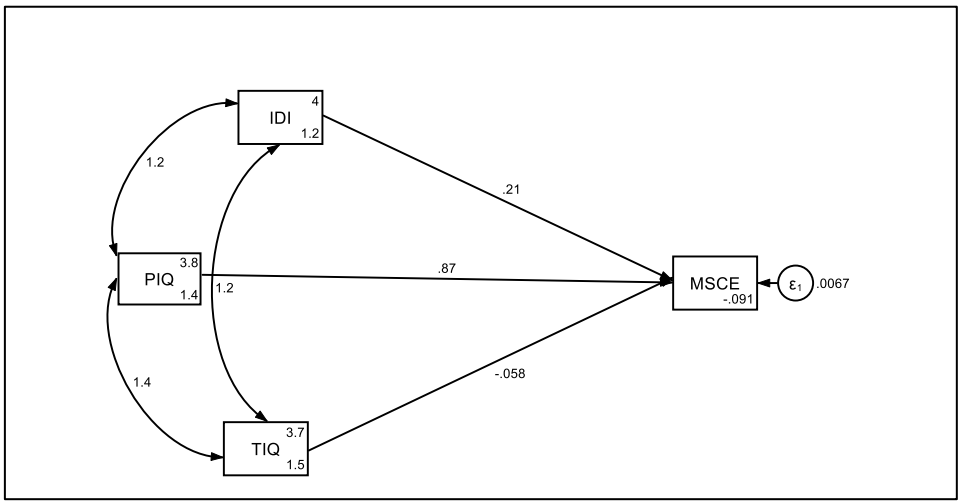

Fig. 2: Path analysis result from the Structural Equation Model (SEM).

Table 4 showed the structural equation modeling (SEM) and the Path analysis conducted using the Maximum Likelihood (ML) estimation method and based on 207 valid observations provides important insights into the influence of infrastructure development variables on maritime supply chain efficiency (MSCE). The model shows a good fit with a log likelihood of -117.34, suggesting the parameters explain a substantial proportion of the variance in the data (Alam et al., 2025).

In terms of direct effects, the coefficient for Port Infrastructure Quality (PIQ) on MSCE is positive and statistically significant (β = 0.8703, $p < 0.001$), indicating that a one-unit increase in perceived quality of port infrastructure is associated with a substantial improvement in maritime supply chain efficiency. This aligns with the understanding that efficient ports enhance cargo handling and vessel turnaround time, which directly supports better logistics outcomes. Similarly, Infrastructure Development Index (IDI) also shows a positive and significant relationship with MSCE (β = 0.207, $p < 0.001$), confirming that broader infrastructural improvements, such as utilities, facilities, and administrative services, play a vital role in supporting maritime logistics.

Contrary to expectations, the coefficient for Transportation Infrastructure Quality (TIQ) is negative and statistically significant (β = -0.0593, $p = 0.007$), implying that increases in this variable are associated with a slight decrease in MSCE. This surprising result might reflect contextual issues, such as congestion, poorly coordinated logistics services, or underutilization of transport infrastructure in the studied locations requiring urge attention.

The mean estimates of the constructs, with values around 3.71 to 3.85, suggest respondents generally agreed with the positive assessment of infrastructure development components. Additionally, the variance estimates indicate sufficient variability in responses for each latent variable, with statistically significant variances (e.g., var(PIQ) = 1.3539, $p < 0.001$), supporting the robustness of the constructs. The covariance values among PIQ, IDI, and TIQ are also positive and significant, reflecting the interrelated nature of infrastructure elements, particularly the strong association between PIQ and TIQ (cov = 1.3781), and between IDI and TIQ (cov = 1.3851). This underscores the importance of integrated infrastructure planning in achieving supply chain efficiency.

Overall, the SEM results confirm that while port infrastructure quality and general infrastructure significantly enhance supply chain performance, challenges may exist within the transportation sector that limit its effectiveness, suggesting the need for more targeted improvements in transport management and coordination.

Discussion of Findings

From the result of tested hypotheses discussion of the findings is being presented as follows:

Port Infrastructure Quality and Maritime Supply Chaing Efficiency

The Hypothesis which stated that Port Infrastructure Quality has no significant relationship with Maritime Supply Chain Efficiency, the result revealed a strong and statistically significant positive relationship between Port Infrastructure Quality (PIQ) and Maritime Supply Chain Efficiency (MSCE), with a coefficient of 0.8703 ($p < 0.001$). This finding confirms that improvements in port facilities, cargo handling equipment, and operational standards contribute meaningfully to efficient maritime logistics. This aligns with the works of Chen et al. (2021), who emphasized that modern port infrastructure reduces vessel turnaround time and increases throughput. Similarly, studies by Wu and Zhang (2020) and Tovar and Wall (2021) noted that port modernization leads to enhanced global connectivity and reduced logistical bottlenecks. Conversely, some researchers have argued that infrastructure alone is insufficient without managerial efficiency; for instance, Notteboom and Rodrigue (2020) highlighted that inefficiencies in customs and bureaucratic delays may counter the advantages of physical infrastructure. Nonetheless, the overwhelming evidence suggests that quality port infrastructure remains a pivotal driver of maritime supply chain performance (Hossen et al., 2023).

Infrastructure Development Index and Maritime Supply Chain Efficiency

On Hypothesis 2 which stated that Infrastructure Development Index has no significant effect on Maritime Supply Chain Efficiency, it was found that Infrastructure Development Index (IDI) has a positive and statistically significant impact on MSCE ($\beta = 0.207$, $p < 0.001$) highlighting the importance of holistic infrastructure beyond ports, such as communication systems, energy supply, and administrative efficiency. This supports the study of Adepoju and Okonkwo (2022), who concluded that comprehensive infrastructure is critical for seamless maritime operations. Similarly, Afolabi et al. (2021) found that the quality of supporting infrastructure like ICT systems and utilities significantly influences the timeliness and coordination of logistics activities. Additionally, Pham et al. (2020) highlighted that improved regional infrastructure translates into better cargo tracking and fewer supply chain disruptions. However, dissenting opinions such as those by Lee and Lee (2021) argue that infrastructure development might not yield the desired impact without adequate policy support and institutional frameworks. Despite these views, the present study affirms that strategic investments in broad infrastructure development have a clear role in enhancing maritime efficiency in Nigeria.

Transportation Infrastructure Quality and Maritime Supply Chain Efficiency

The Hypothesis 3 that stated Transportation Infrastructure Quality has no significant effect on Maritime Supply Chain Efficiency, from the result it was found that Transportation Infrastructure Quality (TIQ) demonstrated a negative and statistically significant relationship with MSCE ($\beta = -0.0593$, $p = 0.007$), indicating that better-rated transport systems were associated with a slight decline in supply chain efficiency. This counterintuitive result may be attributed to poor maintenance culture,

uncoordinated logistics activities, or congestion challenges in the Nigerian context. While most studies, such as those by Huang et al. (2022) and Oke & Adebayo (2023), support the idea that robust transportation systems improve supply chain performance by reducing delays and costs, the Nigerian experience may reflect systemic issues beyond infrastructure quality, including security risks and traffic management inefficiencies. Similarly, Eze and Ekunwe (2021) reported that while transport infrastructure exists, poor road conditions and corruption in logistics oversight often negate potential benefits. This finding emphasizes that infrastructure quality must be matched with institutional effectiveness to realize optimal supply chain outcomes.

Summary of the findings

This study examined the impact of infrastructure development on maritime supply chain efficiency in Nigeria, focusing on three core indicators: Infrastructure Development Index (IDI), Port Infrastructure Quality (PIQ), and Transportation Infrastructure Quality (TIQ) (Rahman, Hossain, et al., 2025). Using a descriptive and quantitative research design, primary data were collected from 207 permanent staff of the Nigerian Ports Authority (NPA) in Warri and Port Harcourt. Structural Equation Modeling (SEM) via STATA version 15 was employed to analyze the relationships between variables. The results demonstrated the varying degrees to which port-related infrastructure factors influence supply chain outcomes in maritime logistics. The findings revealed that: Port Infrastructure Quality (PIQ) had a strong positive and statistically significant effect on Maritime Supply Chain Efficiency, with a coefficient of 0.8703 and a p-value of 0.000. Infrastructure Development Index (IDI) also showed a positive and statistically significant influence on MSCE, with a coefficient of 0.207 and a p-value of 0.000. Transportation Infrastructure Quality (TIQ) had a negative but statistically significant effect on MSCE, with a coefficient of -0.0593 and a p-value of 0.007.

Conclusion

The study concluded that infrastructure development plays a crucial role in enhancing maritime supply chain efficiency in Nigeria, particularly through improved port infrastructure and overall facility support systems. The findings revealed that while investments in port operations and supporting infrastructure significantly and positively impact supply chain outcomes, weaknesses in external transportation networks can undermine these gains. This underscores the need for a integrated infrastructue planning that not only upgrades port facilities but also addresses the broader transport linkages connecting ports to inland destinations. Ultimately, achieving efficient maritime logistics in Nigeria requires coordinated investment and policy action across all facets of infrastructure development to reduce delays, improve cargo handling, and strengthen supply chain integration.

Recommendations

Firstly, the Nigerian government should prioritize sustained investment in modernizing port facilities, including cargo handling equipment, terminal expansions, and digital systems. The robust positive impact of port infrastructure quality (β = 0.8703) on supply chain efficiency underscores the urgency of these upgrades. Enhanced port capacity will reduce vessel turnaround times, minimize congestion, and align operations with global standards (Bassey & Udoh, 2022; NPA, 2022). Secondly, expanding and maintaining transport networks connecting ports to inland hubs is imperative. The negative association between transportation infrastructure quality and supply chain efficiency (β = -0.0593) highlights critical gaps in road/rail connectivity. Investments should target high-congestion corridors like Apapa, integrate rail for cargo evacuation, and rehabilitate inland waterways. This will alleviate

bottlenecks, lower logistics costs, and ensure seamless cargo movement beyond port gates (Okafor & Adebayo, 2023; World Bank, 2023). Thirdly, stakeholders including the NPA, logistics firms, and regulatory bodies—must institutionalize data-driven infrastructure planning. Collaborative frameworks should leverage real-time monitoring technologies to track port and transport performance metrics. Such coordination will enable proactive maintenance, optimize resource allocation, and align infrastructure development with evolving supply chain demands (Aderibigbe & Musa, 2022; AfDB, 2023).

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