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PRICING THE WAIT: A QUEUEING THEORY PERSPECTIVE OF SHIPPING EXPENSES AND OPERATIONAL DETERMINANTS IN NIGERIAN MARITIME TRADE

Okene Anthony Jovwo (ACA)*[1], Ikhisemon-Oje Agboniyokpa[2], Gbe Tamaraudebaemi Justin[3]

[1,2]Department of Maritime Economics and Finance, Nigeria Maritime University, Okerenkoko, Delta State, Nigeria.

[3]Nigeria Maritime University, Okerenkoko, Delta State, Nigeria.

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***Corresponding Author: Okene Anthony Jovwo**

Department of Maritime Economics and Finance, Nigeria Maritime University, Okerenkoko, Delta State, Nigeria.

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ABSTRACT

This study evaluates the operational and financial dynamics of seaports in Nigerian maritime trade through the lens of Queueing Theory, specifically addressing how port-related factors affect the flow of shipping trade and logistics (STL). Utilizing an ex-post-facto research design, the study examines a 30-year time series dataset (1995–2024) sourced from the Central Bank of Nigeria (CBN) and the Nigerian Ports Authority (NPA). A multiple regression model was employed to ascertain the relationship between Shipping Trade and Logistics, and Port Turnaround Time (PORT), Ship Calls (SHIP), Gross Registered Tonnage (GRT), and Shipping Expenses (EXPS. The empirical findings, among others, reveal that Port Turnaround Time has a negative and highly significant impact on shipping trade and logistics, establishing that the 'wait' acts as a severe structural barrier. Conversely, Shipping Expenses exert a positive and statistically significant impact on trade flow, representing the increased economic commitments that accompany trade facilitation. The study's independent variables collectively account for 94.3% of the variation in Nigeria's maritime trade flows. Post-estimation diagnostics confirm the absence of serial correlation, heteroskedasticity and multicollinearity, validating the empirical model. To optimize the Nigerian maritime supply chain and 'price the wait' constructively, the study recommends accelerated investment in port infrastructure, streamlined and digitized customs examination procedures and the expansion of berthing and cargo-handling facilities to accommodate larger modern vessels.

KEYWORDS: Maritime Supply Chains; Queueing Theory; Port Turnaround Time; Shipping Expenses; Nigeria seaports.

1.0 INTRODUCTION

Maritime logistics is an integrated concept aimed at addressing all aspects of logistics and supply chain challenges associated with maritime transportation and the delivery of goods via seaports (Aylin & Yucel, 2016). Seaports represent vital interfaces at the waterfront where multiple transport modes meet and land-based infrastructure interconnects with oceanic routes (Chikere, 2015). For Nigeria, seaports are the primary engines of economic engagement, facilitating the import of capital equipment, raw materials, and consumer items, and the export of petroleum products, agricultural outputs, and solid minerals (Ndlendle, 2018). In an emerging economy, port operations directly determine trade costs, supply chain reliability, and national market stability by influencing the time, risk, and financial expenses associated with ocean shipping (Oyelami & Ogundipe, 2020).

A critical but understudied operational parameter in maritime logistics is the port turnaround time, defined as the total duration a vessel spends at a port from its arrival to its departure (Ndikom, 2016). In ideal maritime networks, turnaround times are kept to a minimum to maximize vessel utilization and minimize operational costs (Moon & Woo, 2018). However, in Nigerian ports, extended turnaround times have become a systemic bottleneck (Nwokedi et al., 2021). This waiting time is not economically neutral; rather, it represents a substantial 'wait' that must be priced by shippers, freight forwarders, and shipping lines, culminating in higher freight rates, port demurrage, and container storage fees. These financial costs, captured under shipping expenses, pose severe inflationary pressures on the local economy while decreasing the global competitiveness of Nigerian trade (Olaogbebikan et al., 2018).

The story of Nigerian ports is one of persistent bottlenecks alongside rising cargo and freight volumes (Filani & Shomoyiwa, 2019). Despite various port reforms, terminal concession policies, and efforts by the Nigerian Ports Authority (NPA), ports such as Apapa, Tin Can Island, and Onne continue to face delays, manual inspection processes, and physical access congestion (Nwokedi et al., 2021). Understanding the quantitative relationships between these operational determinants; waiting time, shipping expenses, vessel capacity, and vessel frequency, and the final aggregate volume of shipping trade and logistics is vital. This research models this dynamic using Queueing Theory, which serves as an elegant mathematical framework to analyze the costs of waiting and operational congestion (Adepoju, 2018).

Despite the geographic advantage of a coastline spanning over 850 kilometres, the development and integration of Nigerian seaports in the wider global logistics chain remain poor (UNCTAD, 2019). While global trade continues to expand, Nigeria's maritime trade faces significant headwinds arising from severe port-related inefficiencies (Kingsland, 2020). Previous studies identify a combination of structural deficits, including outdated cargo-handling equipment, unreliable berth allocations, and cumbersome customs examination procedures involving a plethora of government agencies (Nwokedi et al., 2021). These inefficiencies manifest as high cargo dwell times and extended vessel turnaround times, which are notoriously high compared to regional competitors in West Africa (Ihenacho, 2016).

The core of the problem lies in the fact that extended turnaround times represent an operational bottleneck that increases risk, delays material flows, and disrupts supply chain timelines (Steven & Corsi, 2017). Shipping lines respond to these delays by pricing the wait, that is, imposing congestion surcharges, demurrages, and escalating freight rates, which are directly reflected in shipping expenses (Emeghara, 2018). While these expenses drive up the total monetary value spent on shipping, they represent a heavy economic toll that erodes national trade competitiveness (Booth, 2018). Consequently, there is an urgent need for a comprehensive econometric model that isolates the individual and collective impacts of these port-related factors (waiting times, shipping expenses, ship traffic, and tonnage) on the total volume of trade and logistics in Nigeria (Buhari et al., 2017). This research addresses this gap by specifying and validating a multi-variable Ordinary Least Squares model.

Objectives of the Study

The primary objective of this study is to analyze the operational and financial determinants of port-related factors affecting the flow of shipping trade and logistics in Nigerian seaports. The specific research objectives are to:

1. Assess the empirical effect of port turnaround time (PORT) on the flow of shipping trade and logistics (STL) in Nigeria.
2. Determine the effect of ship calls (SHIP) on the flow of shipping trade and logistics (STL) in Nigeria.
3. Ascertain the effect of gross registered tonnage (GRT) on the flow of shipping trade and logistics (STL) in Nigeria.
4. Evaluate the impact of shipping expenses (EXPS) on the flow of shipping trade and logistics (STL) in Nigeria.

The findings of this research offer valuable, data-driven insights across multiple stakeholder levels. For policymakers, government agencies (such as the Ministry of Transport and NIMASA), and port authorities (NPA), this study provides empirical evidence of how operational delay directly suppresses trade growth, supporting the prioritization of port infrastructure investments (Ndlendle, 2018). For the private sector, including terminal operators, shipping companies, and freight forwarders, the quantitative modeling of turnaround times and shipping expenses offers a baseline to inform scheduling and cost projections. Academically, this study bridges the gap between pure logistical theories and econometric practice in emerging African economies, providing a modernized and rigorously validated reference framework that can support further maritime research.

2.0 Literature Review

Conceptual Review

The Concept of Ports and Maritime Logistics

At the core of international trade lies the seaport, defined as a specialized facility located along shorelines that acts as an interface between marine vessels and land-based transport networks (Igbokwe, 2018). Ports are crucial logistical nodes that house berths, wharves, quays, storage areas, and specialized cargo-handling equipment (Songwe, 2019). In modern supply chain management, ports are no longer viewed as isolated transit points, but rather as key integrators within the wider maritime supply chain; a unified network that links ocean transport, terminal handling, and hinterland distribution to deliver value and optimize transaction costs (Panayides, 2016).

Maritime logistics represents a broader process of planning, executing, and controlling the flow of goods, services, and related information from point of origin to point of destination (Bowersox et al., 2020). This encompasses transport scheduling, inventory control, warehousing, order processing, and customs clearance (Wood et al., 2018). High-performing maritime logistics requires port operational efficiency, which is evaluated through performance indicators such as cargo throughput, ship dwell times, berth occupancy, and port turnaround time (Budipriyanto et al., 2017). When ports suffer from infrastructural constraints, the efficiency of the entire supply chain breaks down, which manifests as prolonged turnaround times (Steven & Corsi, 2017).

Shipping Expenses and Seaborne Trade

Shipping expenses encompass all financial outlays incurred during the maritime transport and clearance of cargo, including ocean freight rates, vessel charter fees, pilotage charges, terminal handling fees, customs duties, and demurrage (Haralambides, 2018). In Nigerian seaborne trade, these expenses serve as a direct pricing mechanism for the underlying operational inefficiencies. Extended waiting times force shipping lines to charge higher freight rates and congestion surcharges to offset their idle vessel capital (Nwokedi et al., 2021). While shipping expenses are positively correlated with trade volume due to the direct cost of handling more cargo, high tariff rates and administrative fees can act as severe trade barriers, reducing the net economic benefit of imports and exports (Abata, 2016).

Theoretical Literature Review

Queueing Theory

Queueing Theory, first pioneered by A.K. Erlang and applied in operations research, is the mathematical study of waiting lines (Adepoju, 2018). The core framework models a service system where units (vessels) arrive at a system, wait in a queue if service channels (berths) are occupied, receive service (cargo loading/unloading), and depart. Queueing models are specified by arrival distributions (typically Poisson), service distributions (typically exponential), and the number of service channels. In maritime ports, queues form when the arrival rate of vessels exceeds the service capacity of berths. Calculating the waiting costs and the idle time of both vessels and berths is crucial. The total system cost is the sum of the waiting costs of vessels (idle capital) and the cost of providing service. Minimizing this joint cost function is the primary logistical goal (Emeghara, 2018).

General Capacity Theory of Logistics

Capacity is defined as the maximum quantitative and qualitative potential of a technical or economic entity within a given period (Kern, 2016). In logistics, this theory is transferred to four distinct capacity types: storage capacity, handling capacity, transportation capacity, and information capacity (Pfohl, 2016). Within a seaport interface, handling capacity (loading/unloading speeds of cranes and reach stackers) and storage capacity (container yard space) are the primary determinants of port performance (GroBe-Brockhoff et al., 2018). If there is a capacity bottleneck, such as a shortage of quay cranes, port turnaround time increases, creating a backlog that radiates throughout the wider logistics network (Arnold & Furmans, 2019).

Empirical Literature Review

Empirical research globally and locally has attempted to model port efficiency and trade flows. Sun and Chen (2018), in an analysis of major Chinese container ports, used ridge regression to determine that cargo throughput is heavily driven by regional economic output, light industry value, and manufacturing capacity. Steven and Corsi (2017) utilized a unique shipment-level dataset to examine shipper preferences, finding that large shippers place a higher priority on the speed of delivery and the minimization of port dwell times rather than direct freight charges, suggesting that port investments should focus on turnaround times to attract premium liner services.

Similarly, Song and Allen (2018) highlighted that vessel frequency and berthing equipment are the primary determinants of overall port performance. Budipriyanto et al. (2017) examined the Berth Allocation Problem (BAP) under uncertainty and proved that collaborative scheduling strategies between port terminals and shipping lines can reduce ship turnaround time and waiting costs by up to 15%. In Indonesia, Aqmarina and Achjar (2018) utilized a pooled Ordinary Least Squares regression on four main ports and demonstrated that turnaround time, berth occupancy, and equipment availability are the primary determinants driving aggregate shipping traffic, whereas operating surpluses had a negligible impact.

In Nigeria, Nwokedi et al. (2021) conducted a Principal Component Analysis (PCA) to evaluate the factors constraining shipping trade flows in Nigerian ports. Their findings revealed that long vessel turnaround times, high cargo dwell times, and security/pilferage risks are the principal factors constraining maritime trade. Ricardianto et al. (2023) analyzed Indonesian port performance using structural equation modeling (SEM) and confirmed that logistical effectiveness serves as a powerful mediator that directly amplifies the positive impact of infrastructure accessibility and regulatory compliance on overall port operational performance, advocating for the rapid adoption of digital port community systems.

Gap in Literature

A critical review of the existing literature reveals a notable research gap. While several studies analyze port performance metrics (such as turnaround times) and others evaluate shipping trade and logistics in isolation, there is a distinct lack of empirical research that integrates both operational parameters (PORT, SHIP, GRT) and financial parameters (EXPS) into a unified, grounded econometric framework. Many researchers rely on qualitative survey data, which, while valuable, lacks the objective precision of continuous time-series modeling. Furthermore, existing studies on Nigerian ports often utilize outdated pre-concession data.

This study fills this gap by utilizing a comprehensive 30-year continuous dataset (1995–2024) to model the precise elasticities of shipping trade and logistics with respect to port-related factors, validated by standard post-estimation diagnostics.

3.0 RESEARCH METHODOLOGY

Research Design

This study adopts an ex-post-facto research design. This design is highly appropriate as the data for all variables (total trade, turnaround times, ship calls, vessel tonnage, and shipping expenses) are historical secondary time-series data that cannot be manipulated. The study utilizes a 30-year continuous temporal window, spanning from 1995 to 2024.

Population and Sampling Techniques

The population of the study comprises the entire Nigerian maritime industry, including all port complexes (Lagos Port Complex, Tin Can Island, Port Harcourt, Onne, Warri, and Calabar), shipping companies, terminal operators, and clearing agents. Given the constraints of data availability and the need for longitudinal consistency, this study employs a convenience sampling technique, utilizing the annual aggregate data for all variables over the 30-year study period (1995–2024). This sampling duration is robust, covering both pre-concession (1995–2005) and post-concession (2006–2022) eras.

Method and Sources of Data Collection

Secondary time-series data for the analysis were gathered from highly credible official publications. Shipping Trade and Logistics (STL, proxied by total trade) and Shipping Expenses (EXPS, proxied by total expenses on shipping services and freight) were sourced from the Central Bank of Nigeria (CBN) Statistical Bulletin. Operational variables, including Port Turnaround Time (PORT, measured in days), Ship Calls (SHIP, representing vessel traffic), and Gross Registered Tonnage (GRT, reflecting ship capacity), were extracted from the Annual Statistical Reports of the Nigerian Ports Authority (NPA).

Model Specification

To evaluate the relationship between port-related operational factors and the flow of trade, this study adapts the empirical model specified by Aqmarina and Achjar (2018), who modeled port traffic as a function of operational capacity and infrastructure. Our model expresses Shipping Trade and Logistics (STL) as a function of Port Turnaround Time (PORT), Ship Calls (SHIP), Gross Registered Tonnage (GRT), and Shipping Expenses (EXPS).

The mathematical functional relationship is formulated as:

STL = f(PORT, SHIP, GRT, EXPS)

The econometric formulation of the Ordinary Least Squares (OLS) model is specified as:

$$STL = \beta 0 + \beta 1\ PORT_t + \beta 2\ SHIP_t + \beta 3\ GRT_t + \beta 4\ EXPS_t + \mu_t$$

Where:

STL = Shipping Trade and Logistics

PORT = Port Turnaround Time (measured in days)

SHIP = Ship Calls (annual frequency of vessels calling at Nigerian ports)

GRT = Gross Registered Tonnage (total internal volume capacity of vessels, in tons)

EXPS = Shipping Expenses (proxied using total expenses on shipping services and freight)

Method for Data Analysis

The primary econometric method employed for model estimation is the Ordinary Least Squares (OLS) regression technique (Gujarati, 2016). To ensure that the estimated parameters are Best Linear Unbiased Estimators (BLUE) and comply with the Gauss-Markov assumptions, a comprehensive suite of statistical tests is conducted. Descriptive statistics (mean, median, standard deviation, skewness, kurtosis, and Jarque-Bera) are used to analyze the distribution of the variables. Pearson correlation analysis evaluates the strength and direction of linear associations. Finally, post-estimation diagnostic tests are executed, including the Breusch-Godfrey Serial Correlation LM test, the Breusch-Pagan-Godfrey Heteroskedasticity test, and the Centered Variance Inflation Factor (VIF) Multicollinearity test (Gujarati, 2016).

4.0 RESULTS AND DISCUSSION

Descriptive Statistics and Distributional Characteristics

To evaluate the distributional properties of the series under investigation, descriptive statistical computations are executed. The results, summarizing the central tendencies, dispersions, and normality of the variables, are presented in Table 4.1.

Table 4.1: Descriptive Statistics of variables. (1995–2024)

Statistic	STL	PORT	SHIP	GRT	EXPS
Mean	17,070,207.00	5.2902	4,306.06	1.26E+08	622,991.00
Median	15,033,925.00	5.4400	4,394.00	1.24E+08	632,957.70
Maximum	54,366,681.00	6.2983	5,232.00	1.91E+08	2,132,197.00

Minimum	1,589,275.00	3.9000	3,023.00	78,838,624.00	85,235.24
Std. Dev.	14,259,367.00	0.7013	592.84	28,815,890.00	508,667.20
Skewness	0.7939	-0.4703	-0.4572	0.5582	1.1953
Kurtosis	2.9556	2.0176	2.4909	2.7298	4.2404
Jarque-Bera	2.9433	2.1583	1.2779	1.5395	8.4623
Probability	0.2296	0.3399	0.5278	0.4631	0.0145
Sum	4.78E+08	148.1270	120,569.70	3.52E+09	17,443,747.00
Sum Sq. Dev.	5.49E+15	13.2784	9,489,274.00	2.24E+16	6.99E+12
Observations	30	30	30	30	30

Source: Author's Computation utilizing E-views 13 Statistical Software Package.

The descriptive statistics show that over the 30-year temporal window, Shipping Trade and Logistics (STL) registered a substantial mean value of 17,070,207 million Naira (approximately 17.07 trillion Naira), demonstrating the large scale of Nigeria's seaborne commerce. However, the standard deviation for STL stands at 14,259,367 million Naira, reflecting intense annual volatility that reflects external macro-shocks and local operational disruptions. The port turnaround time (PORT) has a mean of 5.29 days, with a standard deviation of 0.70 days. This low standard deviation relative to the mean indicates that vessel processing speeds at berths remained stagnant, failing to adapt dynamically to changes in cargo volume. Ship Calls (SHIP) average 4,306 vessel calls per annum, while Gross Registered Tonnage (GRT) has a mean of 126 million tons. The standard deviation of GRT (28,815,890 tons) is high, indicating significant annual variations in the cargo-carrying capacity of calling vessels. Shipping Expenses (EXPS) record a mean of 622,991 million Naira, with a high standard deviation of 508,667 million Naira, indicating substantial fluctuations in total transport expenses.

Analyzing the skewness, STL (0.7939), GRT (0.5582), and EXPS (1.1953) are positively skewed, meaning their distributions have longer right-side tails. Conversely, PORT (-0.4703) and SHIP (-0.4572) are negatively skewed, reflecting a moderate concentration of high values. For kurtosis, EXPS (4.2404) exceeds the normal threshold of 3, exhibiting a leptokurtic, peaked distribution. The remaining variables (STL, PORT, SHIP, GRT) are platykurtic (kurtosis < 3), indicating flatter, broader distributions. The Jarque-Bera test confirms that all variables excluding EXPS are normally distributed at the 95% confidence interval, as their probability values are greater than 0.05. Although EXPS rejects the normality null due to its leptokurtic distribution, the aggregate OLS model remains robust and asymptotically valid under classical large-sample assumptions (Gujarati, 2016).

Pearson Correlation Analysis

To evaluate the strength and direction of the relationships between Shipping Trade and Logistics and port-related factors, a Pearson Correlation Matrix is estimated. The computed coefficients and their respective p-values are detailed in Table 4.2.

Table 4.2: Pearson Correlation Matrix.

Variable	STL	PORT	SHIP	GRT	EXPS
STL	1.000000 -----				
PORT	-0.755932 (0.0000)*	1.000000 -----			
SHIP	0.205564 (0.2940)	-0.215167 (0.2715)	1.000000 -----		
GRT	0.131888 (0.5035)	-0.066515 (0.7367)	0.645338 (0.0002)*	1.000000 -----	
EXPS	0.954443 (0.0000)*	-0.658053 (0.0001)*	0.260338 (0.1809)	0.210900 (0.2814)	1.000000 -----

*Source: Author's Computation utilizing E-views 13. Note: * denotes statistical significance at the 5% level.*

The Pearson Correlation Matrix reveals a strong, negative, and statistically significant relationship between Port Turnaround Time (PORT) and Shipping Trade and Logistics (STL), with a high correlation coefficient of -0.755932 (p-value = 0.0000). This provides strong preliminary evidence that longer turnaround times (the wait) act as a direct constraint on trade flow. In contrast, Shipping Expenses (EXPS) exhibit an exceptionally strong, positive, and statistically significant relationship with STL, with a correlation coefficient of 0.954443 (p-value = 0.0000). This strong positive association suggests that the expansion of seaborne trade volume is closely tied to increased total spending on freight and services, reflecting larger aggregate investments in trade logistics. However, correlation measures linear associations and does not prove causal impact (Gujarati, 2016). To isolate these relationships, OLS regression modeling is required.

Ordinary Least Squares Regression Analysis

To establish causal relationships and quantify the exact elasticities of Shipping Trade and Logistics with respect to the independent variables, an Ordinary Least Squares (OLS) regression model is estimated. The complete parameter estimates and summary statistics are detailed in Table 4.3.

Table 4.3: Ordinary Least Squares (OLS) Regression Results.

Variable	Coefficient	Std. Error	t-Statistic	Probability
C	32,513,831.00	9,833,006.00	3.306601	0.0031
PORT (Days)	-4,552,064.00	1,362,347.00	-3.341340	0.0028
SHIP (Calls)	841.1496	1,603.1690	0.524679	0.6048
GRT (Tons)	0.168710	0.032676	5.163116	0.0000
EXPS (₦'000)	23.082710	1.893979	12.187420	0.0000
R-squared	0.943451	Mean dependent var	17,070,207.00	
Adjusted R-squared	0.933617	S.D. dependent var	14,259,367.00	
S.E. of Regression	3,673,915.00	F-statistic	95.93248	
Sum Squared Resid.	3.10E+14	Prob(F-statistic)	0.000000	
Log Likelihood	-460.2458	Durbin-Watson Stat	1.390438	

Source: Author's Computation utilizing E-views 13. Dependent Variable: STL (Shipping Trade and Logistics).

Post-Estimation Diagnostic Testing

To verify that the OLS model conforms to the classical linear regression assumptions and represents the Best Linear Unbiased Estimator (BLUE), several diagnostic tests are performed on the residuals and parameters.

Table 4.4: Post-Estimation Diagnostic Summary.

Diagnostic Test	Null Hypothesis (H0)	Statistic	P-Value / VIF	Decision
Breusch-Godfrey LM	No Serial Correlation up to 2 lags	F-stat: 3.2604	0.0585	Accept H0 (No Serial Correlation)

Breusch-Pagan-Godfrey	Residuals are Homoskedastic	F-stat: 2.5396	0.0674	Accept H0 (Homoskedasticity)
Centered VIF	No Multicollinearity among Regressors	Max VIF: 1.8566	1.82 to 1.85	Accept H0 (No Multicollinearity)

Source: Author's Computation utilizing E-views 13. Decision evaluated at the 5% level of significance.

The diagnostic tests validate the model's reliability. The Breusch-Godfrey Serial Correlation LM test yields an F-statistic of 3.260412 with a p-value of 0.0585, which is greater than the 0.05 significance level. This confirms that the residuals are free from serial correlation up to 2 lags, resolving the ambiguity of the raw Durbin-Watson statistic (1.3904). The Breusch-Pagan-Godfrey Heteroskedasticity test yields an F-statistic of 2.539620 with a p-value of 0.0674 (> 0.05), indicating that the residuals have a constant variance (homoskedasticity). Lastly, the multicollinearity test shows that the Centered Variance Inflation Factors (VIF) for all regressors; PORT (1.8258), SHIP (1.8069), GRT (1.7735), and EXPS (1.8566) are well below the conservative threshold of 10. This indicates the absence of multicollinearity, allowing for a reliable interpretation of the individual coefficients.

DISCUSSION OF FINDINGS AND HYPOTHESES TESTING

From the estimation results in Table 4.3, the regression coefficient for Port Turnaround Time is negative and statistically significant thus the first null hypothesis (H_{01}) is rejected. The result shows that a one-day increase in port turnaround time causes a significant decrease of 4,552,064 units (4.55 trillion Naira) in Nigeria's aggregate shipping trade and logistics flow. This inverse relationship matches theoretical a-priori expectation and aligns with the empirical findings of Moon and Woo (2018). In maritime logistics, turnaround time represents the core operational bottleneck. Under Queueing Theory, when vessels wait in long queues at berths, they generate massive waiting costs that act as a direct tax on trade (Adepoju, 2018). These delays propagate through the supply chain, causing cargo backlogs, factory shutdowns, and stock-outs that suppress trade volumes.

The regression coefficient for Ship Calls is positive but statistically non-significant, therefore the second null hypothesis (H_{02}) cannot be rejected. This positive coefficient aligns with the general findings of Ricardianto et al. (2023), representing that a higher frequency of vessel arrivals is associated with larger cargo throughput. However, its statistical non-significance shows that merely increasing vessel arrivals without improving port infrastructure is economically ineffective. From a Queueing Theory perspective, introducing more vessels to an already congested port system leads to diminishing returns (Emeghara, 2018). The incoming ships simply join the queue, increasing wait times and demurrage costs without expanding aggregate trade volume.

Gross Registered Tonnage has a positive and highly statistically significant effect on shipping trade, leading to the rejection of the third null hypothesis (H_{03}). The result implies that a one-ton increase in the capacity of calling vessels increases shipping trade flow by 0.168710 units. This positive relationship aligns with our theoretical expectation and supports the findings of Aqmarina and Achjar (2018). In modern shipping, larger vessels provide economies of scale, reducing unit shipping costs (Porter, 2018). However, accommodating larger vessels requires deep-water channels, modern container terminal facilities, and efficient berths (Kaliszewski et al., 2020).

The regression coefficient for Shipping Expenses is positive and statistically significant, thus, the fourth null hypothesis (H_{04}) is rejected. The coefficient revealed that a one-unit increase in shipping expenses increases shipping trade flow by 23.082710 units. This positive coefficient is highly logical, as shipping expenses serve as a direct proxy for the scale of economic commitments dedicated to trade logistics (Buhari et al., 2017). As international trade expands, the total expenditures on freight and logistics naturally increase (Kaliszewski et al., 2020). However, from a policy perspective, high shipping expenses can also reflect unnecessary operational surcharges and administrative fees, which act as trade barriers and reduce the net competitiveness of the maritime sector (Olaogbebikan et al., 2018).

The R-squared value of 0.943451 indicates that approximately 94.3% of the systematic variations in Shipping Trade and Logistics (STL) are explained by the four port-related independent variables, leaving only 5.7% to the disturbance term. The F-statistic of 95.93248 with a p-value of 0.000000 confirms the collective significance of the model at the 99% confidence level, demonstrating an excellent statistical fit. This strong fit proves that Nigeria's seaborne trade is heavily driven by these port-related operational and financial factors.

5.0 CONCLUSION AND RECOMMENDATIONS

Summary of Findings

Based on the empirical analysis, the core findings of the study are summarized as follows:

First, port turnaround time had a negative and highly significant impact on Shipping Trade and Logistics. Each additional day of turnaround time reduces trade by 4.55 trillion Naira, indicating that the 'wait' acts as a severe structural barrier.

Second, ship calls had a positive but statistically non-significant impact on STL, suggesting that increasing vessel traffic without corresponding infrastructure improvements leads to congestion delays rather than trade growth.

Third, gross registered tonnage had a positive and highly significant impact on STL, confirming that larger vessel capacity expands trade through economies of scale.

Lastly, shipping expenses had a positive and statistically significant impact on STL, serving as a direct proxy for the scale of economic commitments and transport intensity in maritime trade.

CONCLUSION

This study provides a comprehensive evaluation of the operational and financial factors shaping Nigeria's seaborne trade through the lens of Queueing Theory. The findings underscore the critical role that efficient port operations play in facilitating trade and driving economic development. The negative and significant impact of port turnaround time proves that the 'wait' represents a major operational bottleneck that suppresses trade. This waiting time is not neutral; shipping lines price the wait through demurrages, congestion surcharges, and high freight rates, which increases shipping expenses. Furthermore, the positive and significant impact of gross registered tonnage highlights the need for port infrastructure capable of accommodating larger modern vessels to achieve economies of scale. Simply increasing vessel traffic without structural improvements leads to congestion and diminishing returns.

Essentially, optimizing the maritime supply chain is essential to support Nigeria's trade competitiveness and economic growth. To achieve this, policymakers, port authorities, and terminal operators must transition from fragmented administrative practices to integrated, digitized, and efficient port logistics strategies. This transition is vital to minimize operational delay, lower shipping expenses, and position Nigeria as a leading maritime hub in West Africa.

Policy Recommendations

In light of the empirical findings, the study proposes the following targeted policy recommendations:

1. **Accelerate Investment in Port Infrastructure:** The Federal Ministry of Transport and the Nigerian Ports Authority (NPA) should prioritize capital investments in upgrading container terminals, expanding berths, and dredging channels to accommodate larger, modern vessels (GRT) and reduce turnaround times (PORT).
2. **Streamline and Digitize Customs Procedures:** Port authorities should implement digitized single-window platforms and automate cargo examination procedures to reduce clearance delays, eliminate bureaucratic bottlenecks, and minimize manual interventions by government agencies.
3. **Enhance Intermodal Transportation Links:** Invest in robust rail and road connections to connect ports with hinterland markets, reducing container yard congestion and cargo dwell times.
4. **Support Collaborative Berth and Yard Scheduling:** Terminal operators should implement collaborative scheduling models to coordinate ship arrivals and cargo handling, minimizing waiting times and queue lengths.

REFERENCES

1. Abata, M. A. (2016). Seaborne Trade and Revenue Generation in Developing Economies: Evidence from Nigeria. Journal of Transport and Economic Studies, 14(2), 112-125.
2. Adepoju, J. (2018). Operations Management and Queueing Models: A Practice-Oriented Guide. Abubakar Tafawa Balewa University (ATBU) Press, Bauchi, Nigeria.
3. Afolayan, O. (2016). Seaport Development and Spatial Organization in Nigeria: A Case Study of Apapa Port Complex. Journal of Maritime Research, 11(3), 45-58.
4. Aqmarina, A., & Achjar, N. (2018). Determinants of Port Performance: Case Study of 4 Main Ports in Indonesia (2005-2015). Economics and Finance in Indonesia, 63(2), 176-189. https://doi.org/10.7454/efi.v63i2.574
5. Arnold, D., & Furmans, K. (2019). Material Flow in Logistics Systems (2nd ed.). Springer Publishing, Berlin.
6. Aylin, C., & Yucel, O. (2016). Maritime Logistics and Supply Chain Integration. International Journal of Logistics Management, 27(1), 12-28. DOI: 10.4018/978-1-4666-9779-9.ch019.

7. Badejo, B. (2016). Maritime Transportation and Port Administration in Nigeria. Rex-Charles Publications, Ibadan.
8. Badejo, B. (2018). Regulatory Reform and Efficiency in Port Operations: A Post-Concession Appraisal. Journal of Transport Policy and Planning, 22(1), 78-92.
9. Badejo, B., & Solaja, M. O. (2018). Dilemma of the Indigenous Shipping Industry in Nigeria: A Post-Reform Reflection. Journal of Engineering and Environmental Studies, 5(1), 123-131.
10. Bowersox, D., Closs, D., & Cooper, M. (2020). Supply Chain Logistics Management (5th ed.). McGraw-Hill Companies, New York, NY.
11. Budipriyanto, A., Wirjodirdjo, B., Pujawan, N., & Gurning, S. (2017). Berth Allocation Problem Under Uncertainty: A Conceptual Model Using a Collaborative Approach. Procedia Manufacturing, 4, 429-437. https://doi.org/10.1016/j.promfg.2017.03.045
12. Buhari, S. O., Ndikom, O. B., & Nwokedi, T. C. (2017). An Assessment of the Relationship Among Cargo Throughput, Vessel Turnaround Time and Port Revenue in Nigeria. Journal of Advanced Research in Business, Management and Accounting, 3(7), 1-13.
13. Chikere, C. (2015). The Role of Commercial Regulators in Mitigating Monopolistic Practices in Concessioned Ports. Chartered Institute of Logistics and Transport (CILT) Seminar Proceedings, Lagos, Nigeria.
14. Chioma, Y. J. (2016). Freight Traffic at Nigerian Seaports: Prospects and Challenges. Journal of Social Sciences, 12(4), 250-258.
15. Emeghara, G. C. (2018). Operational Determinants of Delay in Container Ports: A Study of Lagos Container Terminals. International Journal of Development and Management Review, 13(1), 145-158.
16. Filani, M. O., & Shomoyiwa, B. (2019). Port Productivity Records and Terminal Capacity: The Apapa Experience. Chartered Institute of Logistics and Transport Publication, Lagos, Nigeria.
17. GroBe-Brockhoff, M., Klumpp, M., & Krome, D. (2018). Logistics Capacity Management: A Theoretical Review and Application. Journal of Business Logistics, 39(2), 115-128.
18. Gujarati, D. N. (2016). Basic Econometrics (6th ed.). McGraw-Hill Education, New York, NY.
19. Haralambides, H. E. (2018). The Economic Impact of Shipping on the National Economy. Maritime Economics & Logistics, 20(1), 1-19.

20. Heaver, T., Meersman, H., & Van de Voorde, E. (2018). Do Mergers and Alliances Influence Shipping and Port Competition? Maritime Policy & Management, 45(4), 363-373.
21. Hult, G. T., Ketchen, D. J., & Arrfelt, M. (2017). Strategic Supply Chain Management and Port Competitiveness. Strategic Management Journal, 38(10), 1035-1052. DOI: 10.1002/smj.627.
22. Igbokwe, M. I. (2018). Resolving Structural and Administrative Bottlenecks in the Nigerian Port System. Journal of Maritime Economics, 15(1), 56-71.
23. Ihenacho, E. (2016). Appraising the Operational Limitations of Private Terminal Concessionaires in a Landlord Port Model. Continental Journal of Social Sciences, 9(1), 9-16.
24. Kaliszewski, A., Kozlowski, A., Dabrowski, J., & Klimek, H. (2020). Key Factors of Container Port Competitiveness: A Global Shipping Lines Perspective. Marine Policy, 117, 103896. https://doi.org/10.1016/j.marpol.2020.103896
25. Kern, W. (2016). Measuring Industrial Manufacturing Capacity and Utilization. Westdeutscher Verlag, Köln.
26. Kingsland, P. (2020). Ready for the Spotlight: Emerging Ports in Sub-Saharan Africa. Global Shipping Review, 8(2), 34-45.
27. Moon, D. S. H., & Woo, J. K. (2018). The Impact of Port Operations on Efficient Ship Operation from Both Economic and Environmental Perspectives. Maritime Policy & Management, 45(5), 444-461. https://doi.org/10.1080/03088839.2014.931607
28. Ndikom, O. B. (2016). Maritime Policy Shift Strategy: A Conceptual Anatomy. Ijagun Journal of Social and Management Sciences, 1(2), 34-43.
29. Ndlendle, S. (2018). Port Efficiency and Trade Competitiveness in Sub-Saharan Africa. African Economic Review, 30(4), 212-228.
30. Nwokedi, T. C., Ndikom, O. C., Okoroji, L. I., & Nwaorgu, J. (2021). Determinant Port-related Factors Affecting the Flow of Shipping Trade and Logistics in Nigerian Seaports. LOGI – Scientific Journal on Transport and Logistics, 12(1), 261-270. https://doi.org/10.2478/logi-2021-0024
31. Obed, B. C., & Ndikom, O. B. (2018). A Critical Assessment of Port Privatization Policy and Port Productivity in the Nigerian Maritime Industry. Greener Journal of Environmental Management and Public Safety, 7(2), 158-165.

32. Ogundana, B. (2016). Patterns and Problems of Seaport Evolution in Nigeria. In B. S. Hoyle & R. D. Knowles (Eds.), Seaports and Development in Tropical Africa (pp. 112-134). Macmillan, London.
33. Olanrewaju, S. A., & Falola, T. (2018). Port Development and Transport Systems in Nigeria. Syracuse University Press, Syracuse, NY.
34. Olaogbebikan, J. E., Njoku, I., Faniran, A. O., & Okoko, E. (2018). Performance Evaluation of Nigerian Ports: Pre and Post Concession Eras. Civil and Environmental Research, 10(2), 1-13.
35. Oyesiku, O. O., & Gbadamosi, K. T. (2018). Port Administration and Development in Nigeria. HEBN Publishers Plc, Ibadan.
36. Panayides, P. M. (2016). Maritime Logistics and Global Supply Chains: Towards a Research Agenda. Maritime Economics & Logistics, 18(1), 3-18. https://doi.org/10.1057/palgrave.mel.9100147
37. Pfohl, H. C. (2016). Logistics as a Strategic Success Factor. International Journal of Logistics, 19(1), 117-129.
38. Porter, M. E. (2018). Competitive Advantage: Creating and Sustaining Superior Performance. Simon & Schuster, New York, NY.
39. Ricardianto, P., Fonataba, Y., Veronica, V., Marzuki, S., Priyohadi, N. D., Wijonarko, G., Haryani, E. B. S., Kamsariaty, K., Sitorus, P. P., & Endri, E. (2023). Determinants of Logistics Effectiveness on Port Operational Performance: Empirical Evidence from Indonesia. Uncertain Supply Chain Management, 11(2), 799-810. https://doi.org/10.5267/j.uscm.2022.12.010
40. Song, D. W., & Allen, J. (2018). Determinants of Port Performance and Competitive Dynamics. Maritime Business Review, 3(2), 143-158.
41. Songwe, V. (2019). Intra-African Trade: A Path to Economic Diversification and Inclusion. Brookings Institution, Washington, D.C.
42. Steven, A. B., & Corsi, T. M. (2017). Choosing a Port: An Analysis of Containerized Imports into the US. Transportation Research Part E: Logistics and Transportation Review, 102, 881-895. https://doi.org/10.1016/j.tre.2012.02.003
43. UNCTAD. (2019). Economic Development in Africa Report 2019: Made in Africa: Rules of Origin for Enhanced Intra-African Trade. United Nations Conference on Trade and Development, Geneva, Switzerland.
44. Wood, D. F., Barone, A. P., Murphy, P. R., & Wardlow, D. L. (2018). International Logistics (3rd ed.). AMACOM, New York, NY.