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Shippers' demand for port services in Nigeria: A comparative analysis of Apapa and Onne ports using the analytic hierarchy process

Obioma Reuben Nwaogbe, Victor Timiebimene

Department of Transport and Nautical Science, Nigeria Maritime University, Okerenkoko, Warri, 331104 Delta State, Nigeria

nwaogbe.obioma@nmu.edu.ng

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Abstract: *Purpose*. This study compares shippers' demand for port services at Nigeria's Apapa and Onne ports, evaluating operational efficiency, safety/security, and cost of doing business as determinants of port competitiveness and sustainable port selection. *Methodology*. The study combines primary survey data (300 shippers) analyzed via the Analytic Hierarchy Process (AHP) with secondary operational data (2005–2020) analyzed using Ordinary Least Squares regression and time-series forecasting in R. *Results*. Turnaround time and berth occupancy rate significantly explain vessel traffic at Apapa ($R^2 = 0.603$, $p < 0.01$), whereas they are not significant predictors at Onne. AHP results rank Apapa above Onne overall (0.556 vs 0.444), driven primarily by superior operational efficiency, despite Onne's cost advantage. *Theoretical contribution*. The paper extends the port-competitiveness literature by jointly applying AHP and regression-based forecasting to two structurally different Nigerian hub ports, offering a replicable multi-method framework for developing-country port comparisons. *Practical implications*. Findings suggest that Apapa Port should prioritize reducing turnaround time and automating berth scheduling, while Onne Port needs targeted infrastructure and policy investments to close its operational efficiency gap and support more balanced, sustainable port utilization across Nigeria's regions.

Keywords: analytic hierarchy process, port selection, turnaround time, berth occupancy, maritime logistics, Nigeria, developing economies

Sustainable Development Goals (SDGs): SDG 8: Decent Work and Economic Growth; **SDG 9:** Industry, Innovation and Infrastructure; **SDG 17:** Partnerships for the Goals

Corresponding author: *Obioma Reuben Nwaogbe*
E-mail: nwaogbe.obioma@nmu.edu.ng

1. Introduction

Over 80% of worldwide trade in goods is carried by water, and this figure is much higher in most poor countries, making maritime transportation the backbone of global trade and the global economy (UNCTAD, 2021). Nigeria is a significant player in global trade, receiving 70% of commodities from Central Africa and the West. Eighty percent of the traded items are shipped by sea (UNCTAD, 2009). As a result, the sub-region depends on the study of port operations. Nigeria was identified as the top reformer in the World Bank's African Infrastructure Nation Diagnostics assessment of ports in Sub-Saharan Africa (Vagliasindi, 2009). According to World Bank research from 2008, the private sector invested $1.3 billion in ports in Sub-Saharan Africa, of which 62% were container terminals, 32% were multipurpose terminals, and very little was in bulk cargo facilities.

It is essential to the efficient operation of any nation's economy and a key part of its transportation system. Countries like Nigeria would become landlocked without maritime transportation, which would impede economic development and competitiveness in international markets. To reduce transportation costs, enterprises deliberately locate near seaports, which in turn promotes the development of other modes of transportation, such as railroads (Chizea, 2008). Seaports play a crucial role in the growth of regional and worldwide trade by acting as important entry and exit points (Oriaku, 2011).

The person or business that owns the goods being transported from the port of origin to the port of destination is referred to as the shipper, also called the consignor. For the transportation of commodities, shippers seek affordable port services, and demand for these services is closely linked to demand for the items being transported (Talley, 2009). The estimation of shippers' demand for port services at the Apapa seaport is affected by several factors, including inadequate infrastructure development, inefficient berth occupancy, adherence to safety regulations, accident frequency, high tariff charges, antiquated cargo-handling equipment, insecurity, and port congestion. Some of these issues are the focus of this study.

Seaports are significant contributors to any nation's economy, both operationally and financially. The seaport area is described as the catalyst that drives economic activity through the import and export of goods, with duties paid through cargo clearance and port charges, and other revenues generated for the nation through the seaports. This process drives rapid growth in the nation's trade and commerce. The maritime industry includes all enterprises engaged in the business of constructing, manufacturing, acquiring, operating, supplying, repairing, and maintaining vessels, or parts thereof; of managing and operating shipping lines, stevedoring and customs brokerage services, shipyards, dry docks, marine railways, marine repair shops, shipping and freight forwarding services and similar enterprises.

Generally, the industry encompasses all maritime-related business activities within the country's maritime environment. These include offshore economic activities such as fishing, salvage, towage, and underwater resources, as well as onshore economic activities such as port activities, maritime transport (shipping), ship construction, repairs, and maintenance. The Nigerian economy has witnessed an exponential rise in the importation of goods in recent times, leading to acute congestion at its ports. These congestions are partly attributed to a favorable business environment occasioned by the liberalization of trade in the country, the stable political situation, and, above all, the craze to import anything, even toothpicks.

Furthermore, a port is a location on a coast or shore with one or more harbors where ships can dock and transfer people or cargo to or from land. Port locations are selected to optimize access to land and to navigate waterways for commercial demand, and to provide shelter from wind and waves. Since ports throughout history handled every kind of traffic, support and storage facilities vary widely, may extend for miles, and dominate the local economy. Some ports have an important military role. However, port performance is measured by its capacity for cargo handling, the size of vessels, the amount of cargo traffic, and ship turnaround. Ports have been, and still are, an integral part of freight transportation as they play a major role in a country's development and prosperity (Nwachukwu, Stephens, Okoli, & Akpudo, 2022).

Ports play a crucial role in international marine trade and human mobility, making them significant logistical and transportation centers. Since the beginning of civilization, they have served as hubs for trade, investment, and invention, and as sites of modal exchange between land and ocean transportation. Many nearby settlements have grown into economically and politically significant urban agglomerations, or cities, as a result of the benefits that ports offer to their communities. The idea of the port-city interface has been used to try to explain this significant shift in the division of shared interests between the port and the city since the advent of containerization. Studying the idea of the port-city interface leads to the conclusion that, despite their separation, the interaction between the port and the city is becoming more complex and entwined as new developments affecting both the port and the city continue to occur. To align infrastructure and services with future requirements, Apapa Port and Onne Port must conduct regular assessments and demand projections. The port can maximize resource allocation and make sure it has the facilities and technologies necessary to manage anticipated cargo volumes by precisely predicting shipper demand. In addition to attracting new business, this proactive strategy promotes efficient operations by reducing wait times and congestion, two major problems in high-demand ports like Apapa and Onne.

Furthermore, forecasts can guide decisions on modernization expenditures, including expanding container storage or modernizing equipment, which will ultimately increase the port's competitiveness. Data on historical cargo movements, economic trends, and trade agreements could be examined to improve prediction accuracy, with additional input from shipping firms and other key stakeholders. Utilizing sophisticated analytics and simulation models can also yield insights that enable Apapa Port to dynamically adjust its plans in response to shifting market conditions (Jugović et al., 2021).

Additionally, several studies have examined forecasting methods in the shipping sector, providing insights into efficient forecasting models. For example, Zhang et al. (2019) proposed a hybrid model combining artificial neural networks and wavelet decomposition to forecast container throughput at the Port of Ningbo-Zhoushan in China. This model predicted monthly throughput with an accuracy of more than 90%. In a similar vein, Zhang et al. (2020) developed a deep learning-based method to predict container throughput at the Port of Tianjin, China, achieving 99.2% accuracy.

Other research has concentrated on predicting demand for particular port services, including bunkering. Wang et al. (2020) forecast bunker demand at the Port of Singapore using a support vector regression model, achieving monthly bunker sales prediction accuracy of more than 90%.

The role of infrastructure development in determining the competitive advantage of domestic companies has been highlighted by the recent gradual elimination of trade barriers within the African Continental Free Trade Area (AfCFTA) and the West African Community (Ecowas). Infrastructure related to ports and roads is crucial to regional integration. The competitiveness of Nigerian companies and the overall cost of goods in the Ecowas are directly impacted by the operational efficacy and efficiency of the Apapa Port, which serves as a vital link in the logistical chain and the main route for the importation of raw industrial goods for manufacturing in Nigeria and its neighbors (Baird & Valentine, 2007).

According to Emeghara & Ndikom (2012), Nigerian ports are not user-friendly. "In a world of competitiveness, inefficiency in port operation and management brews high cost of doing business in ports which spells doom to the economy." In this case, the inefficiency of the ports shows up as delays and expensive usage of the ports in a favorable position. Here, ships and freight activity that were once planned for Nigerian ports are redirected to nearby ports. The liners will completely boycott the port due to its inability to upgrade.

In recent years, the port has handled fewer transshipment items. These items now account for a very small share of port operations (less than 1% of all goods handled in 2009). Nigerian ports have seen a variety of investments in physical and movable assets over the years. The resulting inefficiencies and low productivity, unwieldy workforce (more than 70% performing administrative functions), bureaucratic bottlenecks occasioned by many government agencies operating in the ports, insecurity of cargo, and excessive charges, poor environmental management, among other challenges (Umar & Celik, 2020). Nigeria's port system has yet to achieve the organization's goals and objectives despite these regulations and improvements. As a result, the shortage of storage and warehousing facilities in the ports has caused port congestion and disrupted economic manufacturing activity.

Since the mid-2000s, Nigeria's port sector has been gradually deregulated in accordance with the global trend of moving state-owned ports to concessions and granting licenses to private terminal operators under the landlord system (Wanke & Barros, 2015). Although many of the ports owned by the federal and state governments in Nigeria have gradually shifted their operational focus to terminal concessions to the private sector, ports have historically operated in a regulated environment. Nigeria's port infrastructure has been updated, expanded, and better managed since 2005, in compliance with international best practices (Nwanosike, Tipi, and Warnock-Smith 2016). In this regard, Anagor (2015) points out that the transfer of port operations to private terminals has led to operational improvements, driven by significant investments in infrastructure and cargo-handling equipment, thereby increasing cargo throughput in Nigerian ports.

The study is to investigate the demand for port services among shippers in Nigeria's hub ports in the country's eastern and western regions. To achieve this aim, are the following objectives: to examine the Cargo operational efficiency in the study area; to assess the number of vessels, call in the study area; to examine the port infrastructure in the study area; to evaluate the Quality service and competitiveness in the study area; to ascertain the cost and tariff in the study area; and finally, evaluates delay causative factors in the study area. The report will serve as a guide for those involved in port operations and maritime transportation when developing and implementing policies.

2. Literature

Efficiency in Nigerian ports using a two-stage fuzzy technique to handle imprecise data (Wanke, Nwaogbe, & Chen, 2018). This study used a two-stage fuzzy-based methodology to evaluate the efficiency of six major Nigerian ports between 2007 and 2013. More specifically, the productivity of Nigerian ports is evaluated over time using fuzzy data envelopment analysis models using conventional assumptions on scale returns. In the second step, the relationship between a set of contextual variables and port efficiency is predicted using fuzzy regressions based on various rule-based systems. Various features of port service level, berth utilization, accessibility, cargo type, and operator type are associated with these contextual variables. The findings show how operator and cargo type affect efficiency levels. There are policy ramifications for ports in Nigeria.

Furthermore, using criteria selected by experts, Van Dyck & Ismael (2015) examined the competitiveness of key ports in West Africa. Port competitiveness was assessed using the Analytic Hierarchy Process, and ports were ranked based on the total weights derived from the applied criteria. Despite recent political unrest, the Port of Abidjan has become the most competitive port in West Africa thanks to its infrastructure, efficiency and performance, and prospects for political stability. Due in large part to its forecast of political stability, the Lagos Port Complex, the largest port in West Africa in terms of both scale and throughput, ranked fifth, trailing only the Ports of Lomé, Tema, and Dakar. Benin's Port of Cotonou was the least competitive.

Nwanosike, Tipi, and Warnock-Smith (2016) used a Malmquist productivity index decomposition approach to examine productivity change at Nigerian seaports following reform. Nigerian seaports were regarded as ineffective and dangerous due to widespread cargo theft (also known as the "wharf rat phenomenon") and as among the costliest port systems globally during the 1990s. Long ship turnaround times and longer container dwell times resulted from this. Consequently, concession contracts were used to transfer port operations to the private sector. In order to compare the pre- and post-reform total factor productivity growth of the six major Nigerian seaports (Apapa, Calabar, Onne, Port Harcourt, TinCan Island, and Warri) for the years 2000–2011—six years before (2000–2005) and six years after (2006–2011) the reform—this study uses the Malmquist productivity index (MPI) technique. The findings show a decline in technological advancement but an increase in the ports' technical efficiency following reform. Compared with the post-concession period, overall productivity growth was higher during the pre-concession period. Technological advancement was the cause of the pre-concession period's productivity growth, whereas improvements in scale efficiency were the cause of the post-concession period's productivity shift. This implies that the much-needed investment in contemporary technologies to boost port efficiency has not been made by concessionaires. The Onne ports recorded the lowest productivity growth, while Calabar and Apapa recorded the highest.

Nwaogbe, Erhijivwo, and Miracle (2023) conducted a study comparing the operational performance of two eastern Nigerian ports, Rivers and Delta. The Nigeria Port Authority (NPA) Portal provided secondary data for the study between 2008 and 2013. Multiple regression models are used in the paper's data analysis. With R-squared values of 81.34% and 79.47%, respectively, the findings demonstrate that Rivers Port operates more efficiently than Delta Port. Additionally, the findings show a strong correlation between cargo throughput and independent variables including vessel traffic, turnaround time, berth occupancy, and crew count. Theoretical contribution: By using multiple regression models to evaluate the operational effectiveness of two Nigerian ports, the study adds to the body of knowledge on port performance measurement and enhancement.

Additionally, the study offers empirical data on the variables influencing port performance in developing nations. The government, shipping firms, port authorities, and maritime organizations can all benefit from the paper's practical implications. The study offers policy recommendations to enhance port infrastructure, pricing policy, and strategic competition to improve the operational performance of the eastern ports.

The transportation industry has seen an increase in the use of multiple-criteria decision-making techniques (Kriswardhana, Toaza, Esztergár-Kiss, & Duleba, 2024), making it difficult to identify the most pertinent research topics and applicable techniques. The study examines how the well-known analytic hierarchy process (AHP) has been applied to support transportation-related decisions during the past 20 years using a mix of two advanced review methodologies: the bibliometric review approach and the systematic review technique. The bibliometric analysis identifies keywords from 2659 screened scientific documents, and the systematic review examines 108 pertinent publications using those keywords. The findings indicate that, in addition to the environmental effects of transportation, the sub-themes of transportation infrastructure, location selection, and accident prevention are the most crucial subjects. TOPSIS, Delphi, and fuzzy-AHP approaches are typically used with AHP as hybrid models. The AHP method's ability to determine safety factors for various modes of transportation, its capacity to handle both quantitative and qualitative criteria in location selection, and its potential to yield a reliable choice among transportation infrastructure development alternatives are all clarified by the systematic review.

Furthermore, a study evaluating Apapa Port performance by Dere et al. (2021) found increasing returns to scale (IRS), with pure efficiency of 49.8% and scale efficiency of 81.3%. 50.2% of inputs could be saved by improving Apapa Port's operations, and 18.7% could be saved by growing the company to its ideal size. The Apapa Port continued to see rising returns to scale in 2017, with a pure efficiency score of 59.2% and a scale efficiency value of 77.1%. 40.8% of inputs could be saved by improving Apapa Port's operations, and 22.9% by growing the company to its ideal size. According to the analysis, Apapa attained scale efficiency of 75.5% and pure efficiency of 61% in 2016, with rising returns to scale. 39% of inputs could be saved by improving Apapa Port's operations, and 24.5% could be saved by growing the company to its ideal size. The analysis unequivocally shows that the Apapa Port's performance and efficiency have improved (Dere et al, 2021).

Using certain port performance measures, Nwaogbe et al. (2024) assessed and contrasted the operational performance of two significant seaports in Lagos, Nigeria: Apapa Port and Tin Can Island Port. The study analyzes data from the operational bulletin records of the Nigeria Ports Authority using the Ordinary Least Squares (OLS) method and the Cobb-Douglas production function. According to their findings, ship traffic, berth occupancy, turnaround time, and employee count all have a significant positive linear relationship with cargo throughput, the dependent variable. Apapa Port's R-square score is 85.89%, but Tin Can Island Port's is 98.79%, indicating that Tin Can Island Port is more productive.

The study also demonstrates a theoretical contribution. By offering empirical data on the productivity and efficiency of Nigerian seaports, this study advances the fields of marine transportation and logistics. It emphasizes the crucial role of contemporary infrastructure and efficient port operations in improving seaport performance. Lastly, the study's practical implications suggested that the Nigerian government should focus on easing port congestion, improving the roads leading to the ports, and expediting port documentation procedures. These steps are necessary to improve the operating effectiveness of Nigerian seaports.

3. Material and method

The researchers used a descriptive research survey design in this investigation. The advantage of this research approach is that it may be used to determine the characteristics of a large population from a collection of individuals. Since the study's goal was to predict shippers' demand for port services at Apapa and Onne ports, the methodology was suitable.

3.1. Sample size and method of data collection

We used a questionnaire to survey 150 participants at each port as part of our study on shippers' needs for port services at Apapa and Onne ports. A balance between obtaining statistical significance and practical data collecting is achieved by selecting 150 participants for each port. A database of registered companies, representing a range of industries and shipping preferences, was used to select shippers randomly. Important topics covered in the poll include expectations for improvement, preferences for certain services, and satisfaction with current services. To improve the effectiveness and responsiveness of both ports to shippers' needs, the objective is to gain insights into the specific requirements and expectations of shippers using Apapa and Onne ports.

3.2. Method of data analysis

The Analytic Hierarchy Process (AHP) model and Ordinary Least Squares (OLS) regression analysis were used.

3.3. Model specification

Analytic Hierarchy Process (AHP)

The AHP model will be used to analyze the primary data, whereas the other two methods will be used to analyze the secondary data gathered directly. Below are the formulas for the respective models:

Below is the Analytical Hierarchy Process structure adapted for this study

AHP consistency index

In the Analytic Hierarchy Process (AHP), the Consistency Index (CI) is a measure used to assess the reliability and consistency of decision-makers' pairwise comparisons when constructing the decision matrix. The purpose of the CI is to ensure that the judgments provided by decision-makers are coherent and internally consistent.

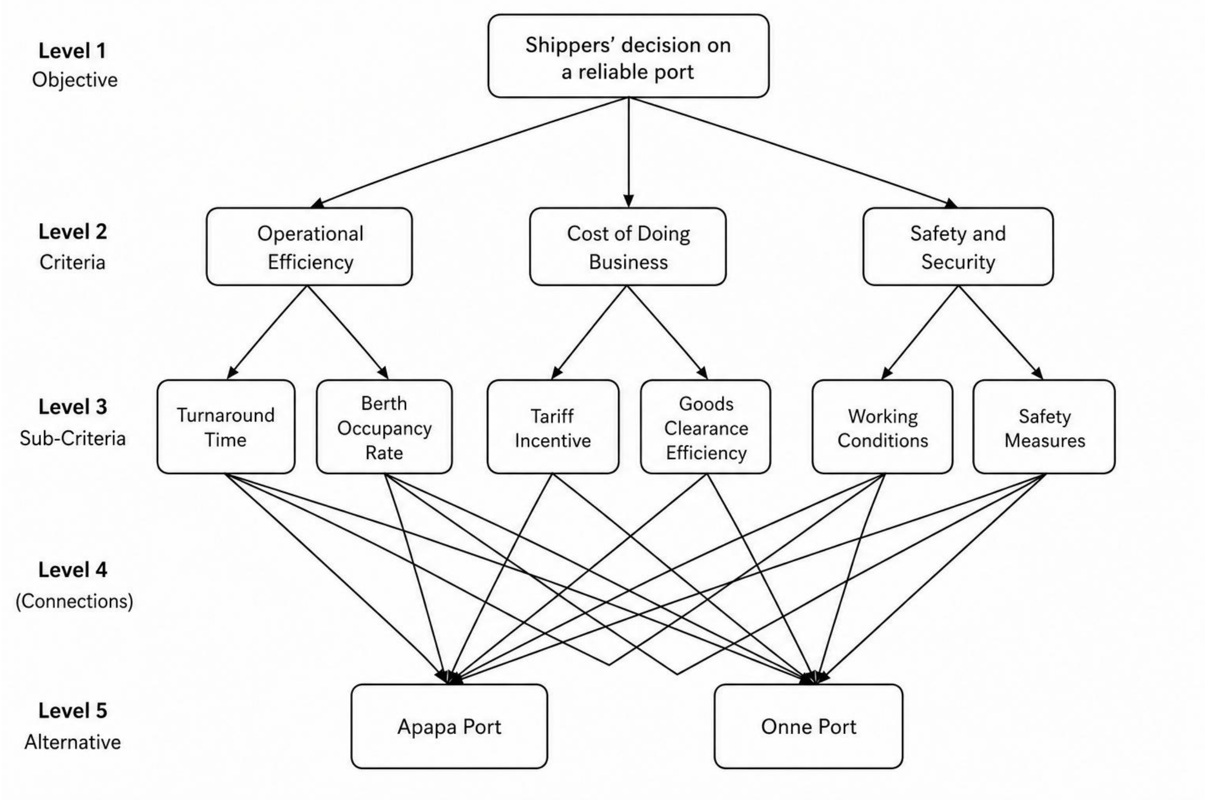
$$CI = \frac{\mu - n}{n - 1}$$

Consistency ratio

In the Analytic Hierarchy Process (AHP), the Consistency Ratio (CR) is a measure of the consistency of a decision matrix derived from pairwise comparisons. It is used to determine whether decision-makers' judgments are sufficiently consistent. The CR is derived from the Consistency Index (CI) and the Random Index (RI).

$$CR = \frac{CI}{RI}$$

Figure 1: AHP hierarchical structure for shippers' port selection decision



3.4. Multiple regression analysis

Multiple regression analysis, often simply referred to as regression analysis, examines the effects of two or more independent variables, or regressors, on one dependent variable, or regressand. Regression estimates the effect of each independent variable on the dependent variable, along with its statistical significance, by calculating coefficients for each independent variable. Determinants of ship traffic: this model will explain the influence of turnaround time and berth occupancy rate on ship traffic.

The model is given mathematically as;

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + e$$

The dependent variable

Y = number of vessels

The independent variables:

X_1 = turnaround time

X_2 = berth occupancy rate

e = Error term

Suppose that there are *p* independent variables and *n* observations $(x_{11}, x_{12}, \ldots, x_{1p}, y_i)$, $i = 1, 2, \ldots, n$, and the model relating the independent variables to the dependent variable is specified in equation 2.1. Given the value of *y* denoted by y_i, the system of the above equation becomes:

$$\begin{array}{ccl} y_1 & = & \beta_0 + \beta_1 X_{11} + \beta_2 X_{12} + \cdots + \beta_p X_{1p} + \varepsilon_1 \\ y_1 & = & \beta_0 + \beta_1 X_{21} + \beta_2 X_{22} + \cdots + \beta_p X_{2p} + \varepsilon_2 \\ \vdots & \vdots & \quad \vdots \qquad \vdots \qquad\qquad \vdots \qquad \vdots \\ y_1 & = & \beta_0 + \beta_1 X_{n1} + \beta_2 X_{n2} + \cdots + \beta_p X_{np} + \varepsilon_n \end{array}$$

Expressing the above system in matrix form, we obtain as follows;

$$\begin{pmatrix} y_1 \\ y_2 \\ \vdots \\ y_n \end{pmatrix} = \begin{pmatrix} 1 & X_{11} & X_{12} \cdots & X_{1p} \\ 1 & X_{21} & X_{22} \cdots & X_{2p} \\ \vdots & \vdots & \vdots & \vdots \\ 1 & X_{n1} & X_{n2} \cdots & X_{np} \end{pmatrix} \begin{pmatrix} \beta_0 \\ \beta_1 \\ \vdots \\ \beta_k \end{pmatrix} + \begin{pmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \vdots \\ \varepsilon_n \end{pmatrix}$$

The model is a system of n equations that can be expressed in matrix notation as defined:

$$y = X\beta + \varepsilon$$

We desire to obtain the vector of least squares estimator, $\hat{\beta}$, that minimizes the error sum of squares (SSE).

Using $y = X\beta + \varepsilon$, make ε the subject of the formula

$$\varepsilon = y - X\beta$$

The sum of squares of SSE

$$L = \sum_{i=1}^{n} \varepsilon_i^2 = \varepsilon'\varepsilon = (y - X\beta)'(y - X\beta)$$

The least squares estimator $\hat{\beta}$ is the solution for β in the equations

$$\frac{\partial L}{\partial \beta} = 0$$
$$\varepsilon'\varepsilon = (y - X\beta)'(y - X\beta)$$
$$y'y - y'X\beta - X'\beta'y + X'\beta'X\beta$$
$$y'y - y'X\beta - y'X\beta + X'\beta'X\beta$$
$$\frac{\partial \varepsilon'\varepsilon}{\partial \beta} = 0 \to -y'X - y'X + 2X'X\beta$$
$$-2X'y + 2X'X\beta = 0$$
$$2X'X\beta = 2X'y$$
$$X'X\beta = X'y$$
$$\beta = \frac{X'y}{X'X}$$
$$\hat{\beta} = (X'X)^{-'}X'Y$$
$$\hat{\beta} = (X'X)^{-'}X'Y = \begin{pmatrix} \hat{\beta}_0 \\ \hat{\beta}_1 \\ \vdots \\ \hat{\beta}_k \end{pmatrix}$$

3.5. Limitations of the research

A key limitation of this study is the **restricted availability of data** used for the analysis. Specifically, the dataset covers the period **2005 to 2020** for both **Apapa Port** and **Onne Port**, which constrains the temporal scope of the findings. Despite considerable efforts to obtain more recent and comprehensive data from the Nigerian Ports Authority, it was confirmed that updated datasets are still being compiled as of **April 2026**. Consequently, the study could not incorporate post-2020 developments in port operations, infrastructure upgrades, policy changes, or shifts in trade patterns.

This restriction has several ramifications:

• Because port performance and logistics systems are dynamic, the analysis could not accurately reflect current operational reality.

• Neither port's efficiency, cost structures, or safety conditions have recently improved or declined. • As a result, the results and conclusions—including the AHP ranking—should be seen as indicative of the study era (2005–2020) rather than the current circumstances. However, long-term trends and comparative performance patterns between the two ports can still be found using the dataset. To validate or improve the existing findings, it is advised that future studies update the analysis as soon as more recent data becomes available.

4. Results

The goal of Fig. 2 and 3 and Tables 1, 2 and 3 is to evaluate how turnaround time and berth occupancy rate influence ship traffic at Apapa port.

Figure 2: Relationship between turnaround time and ship traffic at Apapa

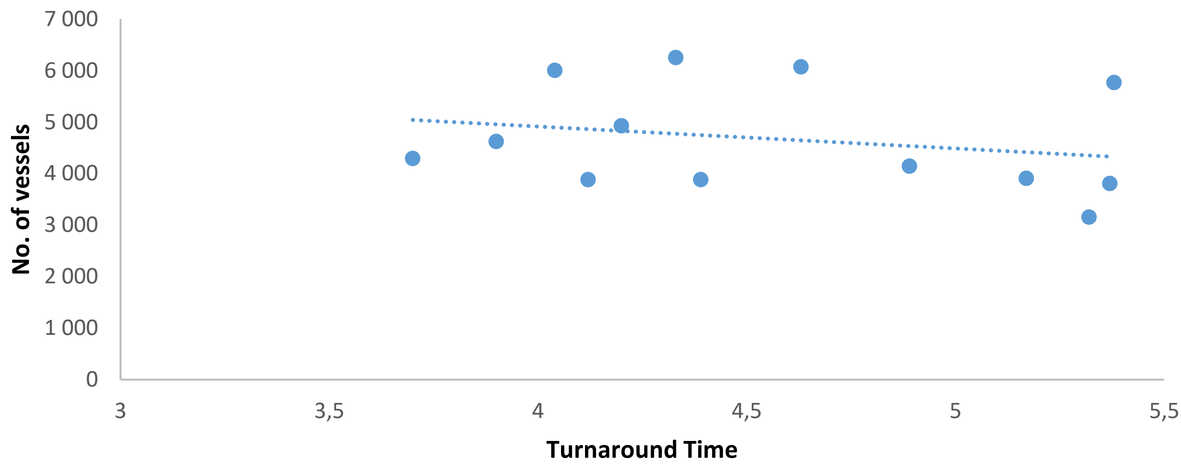
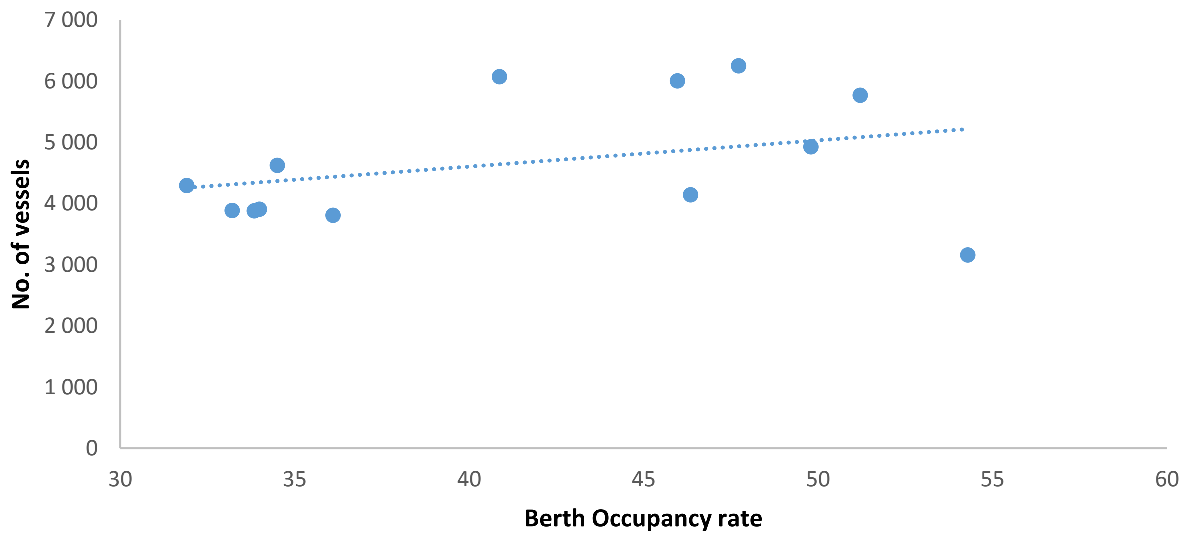


Figure 3: Relationship between berth occupancy rate and ship traffic at Apapa



A random association between turnaround time and vessel traffic in Apapa is depicted in Fig. 1, indicating that lower vessel traffic is associated with longer turnaround times. The tendency of greater ship traffic volumes into Apapa port is explained by the rising berth occupancy rates seen in Fig. 3. The regression result below will provide more information about this.

Table 1: Model Performance metrics for regression model in APAPA

Regression Statistics	
Multiple R	0.776699
R Square	0.603262
Adjusted R Square	0.523914
Standard Error	690.6478
Observations	13

Table 2: Regression coefficient table for Apapa

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	2472.851	1625.129	1.521633	0.159073	-1148.16	6093.865
turnaround time (days)	-419.999	361.3876	-1.16218	0.272147	-1225.22	385.2227
berth occupancy rate	104.6979	26.93362	3.887255	0.003023	44.68602	164.7097

Table 3: ANOVA test of regression model adequacy for Apapa

	df	SS	MS	F	P-value
Regression	2	7252955	3626478	7.602768	0.009829
Residual	10	4769944	476994.4		
Total	12	12022899			

Table 1 shows that the combined effect of turnaround time and berth occupancy rate can account for about 60.3% (R-square) of the variation in the number of boats at the port. This suggests that these variables are significantly correlated, though other factors also affect them. A more thorough knowledge of the dynamics of vessel traffic may be possible with future research into other factors. Table 2 analysis shows that the anticipated annual number of boats at the Apapa port is around 2473 when both turnaround time and berth occupancy rate are set to 0.

Higher berth occupancy rates are associated with increased vessel influx, whereas longer turnaround times are associated with decreased vessel numbers. This emphasizes the significance of effective turnaround procedures and berth management in effectively accommodating vessels while avoiding congestion and operational difficulties. We may deduce from Table 3 that turnaround time and berth occupancy rate have a substantial impact on ship traffic at Apapa port, as the p-value of 0.0098 is less than the level of significance. Analyzing the effects of turnaround time and berth occupancy rate on ship traffic at the Onne port is the goal of Figures 4 and 5 as well as Tables 4, 5, and 6.

Figure 4: Relationship between turnaround time and ship traffic at Onne

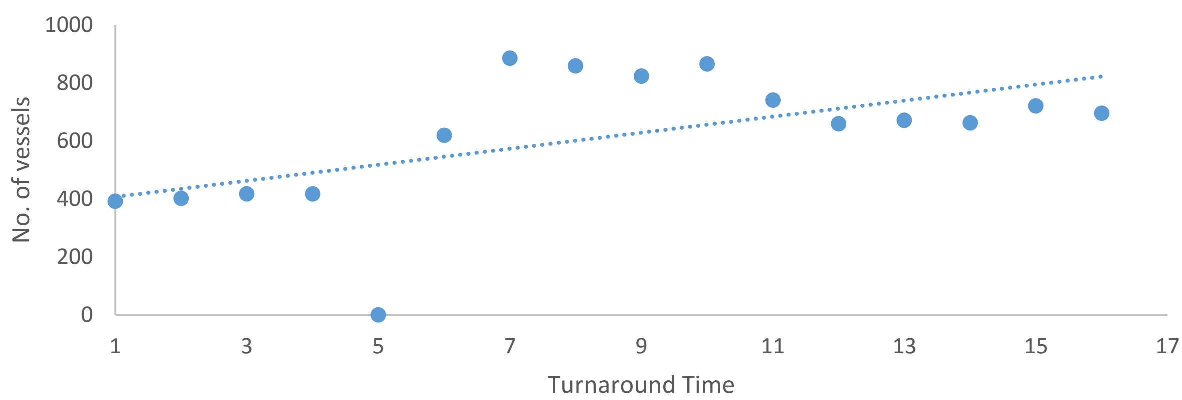
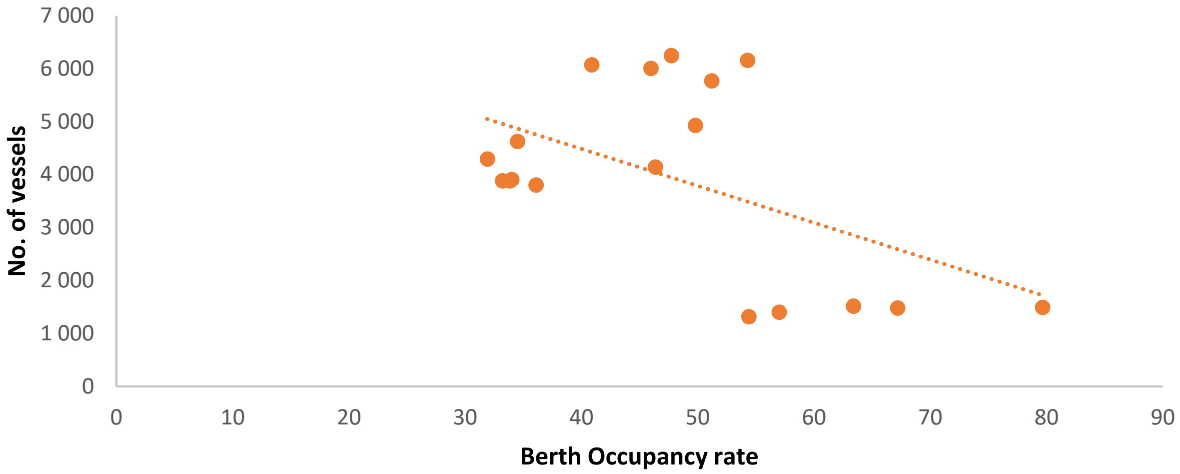


Figure 5: Forecast plot for ship traffic at Onne Port (random walk with drift model, 2021–2032)



The turnaround time is strongly correlated with the volume of ship traffic at Onne port, as seen in Figures 4 and 5 above. Additionally, the berth occupancy rate is inversely correlated with the number of ships arriving at the port. Practically speaking, this means there is less berthing space available as more ships arrive.

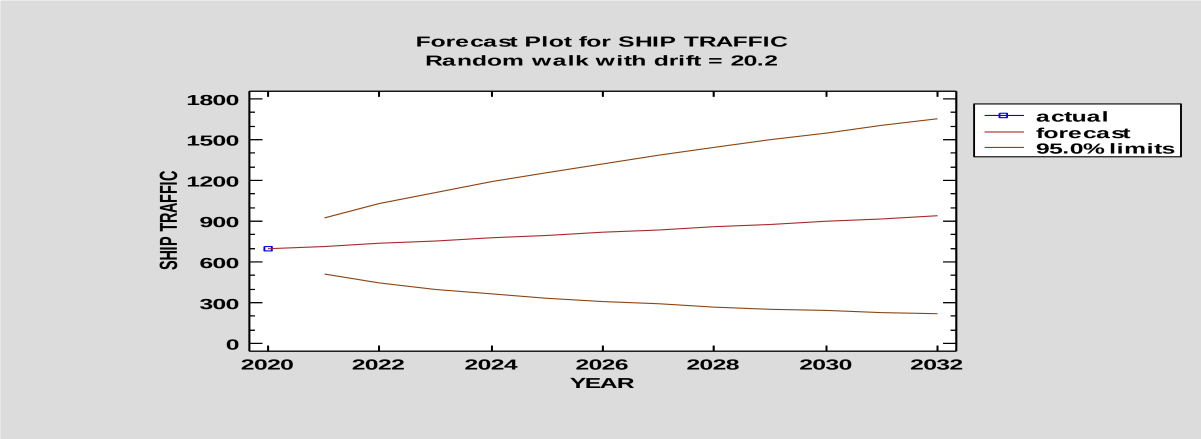
Table 4: Ship traffic forecast for Onne port

Period	Forecast	Lower 95% Limit	Upper 95% Limit
2021	715	508.241	922.159
2022	735	442.716	1028.08
2023	756	397.137	1114.06
2024	776	361.882	1189.72
2025	796	333.226	1258.77
2026	816	309.257	1323.14
2027	836	288.838	1383.96
2028	857	271.232	1441.97
2029	877	255.924	1497.68
2030	897	242.539	1551.46
2031	917	230.795	1603.6
2032	937	220.474	1654.33

Forecast summary

The chosen forecast model is displayed in Table 4. The drift of the random walk is 20. 2. Twelve forecasts were produced, and zero periods were deferred for validation. The data cover 16 time periods. As of right now, a random walk with a drift model has been chosen. The predicted values for SHIP TRAFFIC are displayed in the table above. It also shows the residuals (data-forecast) and the anticipated values from the fitted model throughout the time when actual data is available. It displays the forecasts' 95.0% prediction limitations for time periods after the series' conclusion. Assuming the fitted model is suitable for the data, these limits indicate the range of values expected for the true data at a chosen future time with 95.0% confidence.

Figure 5: Forecast plot for ship traffic random walk drift =22.0



Analytical Hierarchy Process (AHP)

Three criteria were considered: Operational Efficiency, Cost of Doing Business, and Safety and Security. Based on the previous analysis, these are competitive factors that are shared by both ports. There will be two sub-criteria for each criterion.

Table 5: Pairwise comparison matrix for operational efficiency

Ports	Apapa	Onne
Apapa	1/1	3/1
Onne	1/3	1/1

Table 6 Pairwise comparison matrix for Security and Safety

Ports	Apapa	Onne
Apapa	1/1	2/1
Onne	1/2	1/1

Table 7 Pairwise comparison matrix for cost of doing business

Ports	Apapa	Onne
Apapa	1/1	1/3
Onne	3/1	1/1

Table 8 Pairwise comparison matrix for six criteria

	Operational Efficiency	Security and Safety	Cost of doing Business
Operational Efficiency	1	5/1	7/1
Security and Safety	1/5	1	1/1
Cost of doing Business	1/7	1/1	1

Where
1 = equal importance
3 = moderate importance
5 = strong importance
7 = very strong importance
9 = extreme importance
1/5, 1/7 are inverse importance

Three criteria were considered in the AHP process: Operational Efficiency, Cost of Doing Business, and Safety and Security. Based on earlier studies, these are competitive elements that are shared by both ports. There will be two sub-criteria for each criterion. The results in Tables 9 and 10 are designed to assess each port's operational efficiency and identify which has the highest efficiency rating. R 4.3.2 Statistical Programming software was used to test the AHP, and the results are displayed in the tables below.

Table 9: AHP priority vectors estimates

	Operational Efficiency	Security and Safety	Cost of doing business	Priority average	Priority vector	Ratio
Operational Efficiency	4.33	3.65	4.97	4.33	12.95	2.9874
Security and Safety	0.866	0.73	0.71	0.73	2.306	3.1395
Cost of doing Business	0.6062	0.73	0.71	0.71	2.0462	2.9583
					Lmax	3.0273
					Criteria index	0.0149
					Consistency	0.0258

Criteria's relative importance

The priority vector estimations from Table 13 show that the most important factor in choosing a port is operational efficiency, which has the highest normalized weight (≈ 2.99). Cost of Doing Business (≈ 2.96) and Security and Safety (≈ 3.14 ratio, but lower absolute priority) come next, with comparable significance but far lower than Operational Efficiency. This implies that, while cost and safety concerns remain crucial, stakeholders prioritize a port's operational efficiency, including turnaround time, cargo handling, and logistical flow.

Consistency of judgments

The consistency metrics show:

- $\lambda max = 3.0273$
- Consistency Index (CI) = 0.0149
- Consistency Ratio (CR) = 0.0258

The pairwise comparisons are dependable and consistent because the Consistency Ratio is less than 0.1. This confirms that the decisions made in building the AHP model make sense and are appropriate for making decisions.

Performance of Ports by Criterion

From the pairwise comparison matrices:

Operational Efficiency:

Apapa is strongly preferred over Onne (3:1), indicating better operational performance.

Security and Safety:

Apapa again outperforms Onne (2:1), though with a smaller margin, suggesting moderate superiority.

Cost of Doing Business:

Onne is strongly preferred over Apapa (3:1), meaning it is more cost-effective for users.

Table 10: Priority matrix for port selection

	Operational Efficiency	Security and Safety	Cost of doing business	Overall priority	Ranked Selection
Apapa	0.75094	0.666667	0.24906	0.555556	1
Onne	0.24906	0.333333	0.75094	0.444444	2

According to the data, Apapa port had an overall priority rating of 0.56 (56%), and Onne had 0.44 (44%), as shown in Table 9. This suggests that shippers in Nigeria prefer the Apapa port to the Onne port. Despite this, the majority of importers and exporters come from the country's eastern region, which is close to the Onne port. Additionally, the weights of the criteria are combined with port performance in Table 9: Apapa Port Overall Priority: 0.5556 (Rank 1). Overall Priority for Onne Port: 0.4444 (Rank 2). Despite Onne's cost advantage, Apapa Port is ranked higher overall due to its superior Operational Efficiency, the decision model's most important factor. Additionally, Table 9 shows that operational efficiency has the highest weight (4.33), suggesting it is the most crucial factor in the decision-making process. This implies that the decision-maker is highly concerned with aspects of the port's operational efficiency, such as turnaround time, berth occupancy, and commodities clearance.

With a weight of 0.73, security and safety are likewise considered significant, albeit to a lesser degree. This suggests that while the port's safety and security protocols should be considered, operational effectiveness is more important. With a weight of 0.71, Cost of Doing Business is the third most important criterion. This suggests that financial factors, such as tariff incentives and the total cost implications for companies using the port, are taken into account, but marginally less so than security and safety.

Ultimately, the AHP research shows that Apapa Port is the best choice overall, mainly because of its greater operational efficiency, the most important component of port competitiveness. Although Onne Port has cost advantages, these are not enough to overcome Apapa's advantages in higher-priority categories. The model's consistency further supports the robustness of this finding.

Forecasting ship traffic in Apapa port

Based on the data available for Apapa Port ship traffic, we estimated the trend of ship traffic using the time series model, and the following result was obtained;

Table 11: Apapa port ship traffic trend estimates

	Coefficients	Standard Error	t Stat	P-value
Intercept	2560.967	825.6984	3.101577	0.006857
Time (Years)	144.9742	76.28153	1.900515	0.075537

Based on the established trendline equation of $\hat{y}_t = 2560.967 + 144.974 time_{years}$

Figure 6: Apapa port ship traffic trend

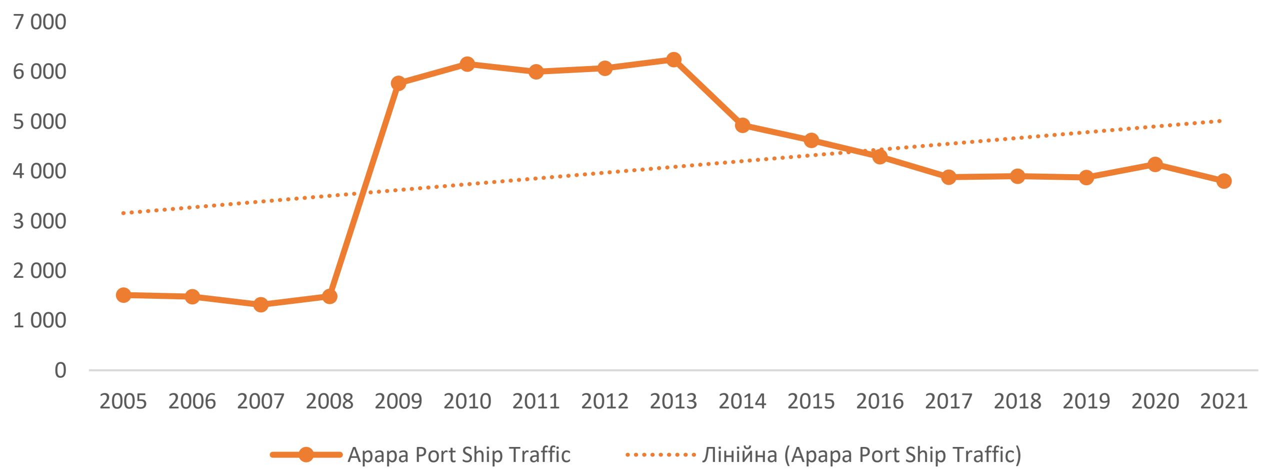


Table 12: Ship traffic forecast for Apapa port

Year	Expected Ship Traffic at Apapa Port
2023	5,315
2024	5,460
2025	5,605
2026	5,750
2027	5,895
2028	6,040
2029	6,185
2030	6,330

If all working conditions and operational efficiencies remain the same or improve, Table 12 predicts that the number of vessels at the port will increase annually by an average of 145, reflecting the number of ships seeking Apapa port services.

5. Discussion

To provide a thorough assessment of port performance and competitiveness, this study combined regression analysis, forecasting, and multi-criteria decision-making (AHP) to examine how turnaround time and berth occupancy rate affect ship traffic at Apapa and Onne ports. The regression results for Apapa Port indicate a substantial, statistically significant correlation between ship traffic and the explanatory variables. Turnaround time and berth occupancy rate appear to be significant factors influencing port activity, as the model accounts for roughly 60.3% of the variation in vessel traffic (R2 = 0.603). In particular, turnaround time and ship traffic are negatively correlated, which means that longer vessel delays deter port usage. On the other hand, berth occupancy rate exhibits a positive, statistically significant effect ($p < 0.01$), suggesting that higher vessel calls are associated with higher berth usage, likely due to efficient berth allocation and increased demand. The overall model is significant, as indicated by the ANOVA result ($p = 0.0098$). These results highlight the crucial role of operational efficiency in maintaining high traffic levels at Apapa, particularly by reducing turnaround time and maximizing berth utilization.

These variations are confirmed by forecasting findings. Ship traffic at Onne Port is expected to increase gradually, following a random walk with drift, but with broad confidence intervals that reflect system instability and uncertainty. In the meantime, Apapa Port shows a persistent growth trend; under stable or enhanced operational conditions, ship traffic is expected to rise steadily by about 145 vessels annually. This demonstrates Apapa's more consistent performance and stronger growth trajectory.

The Analytic Hierarchy Process (AHP) uses three factors to assess port competitiveness: cost of doing business, security and safety, and operational efficiency. The findings indicate that the most crucial element is operating efficiency, followed by cost, security, and safety. Onne has a cost advantage; however, Apapa Port performs better in terms of safety and operational effectiveness. However, Apapa receives a higher overall priority score (0.56) than Onne (0.44), making it the favored port because operational efficiency is given the highest weight. The reliability of the AHP results is confirmed by the low consistency ratio (CR = 0.0258) (Ezzat & Hamoud, 2016, and Bartolj & Murovec, 2024).

In conclusion, the results show that, despite higher expenses, Apapa Port is more effective, more utilized, and more appealing to shippers, largely because of its superior operational efficiency. Despite being more economical, Onne Port has little operational impact on traffic and needs more extensive upgrades to become more competitive. Overall, the most important factor influencing ship traffic and port preference is operational efficiency, especially in reducing turnaround time and controlling berth occupancy.

6. Conclusion

This study demonstrates that operational efficiency, more than cost, drives shipper preference at Nigeria's hub ports, with Apapa outperforming Onne overall (AHP priority 0.556 vs 0.444) despite Onne's cost advantage. Regression results confirm that turnaround time and berth occupancy significantly shape vessel traffic at Apapa ($R^2 = 0.603$, $p < 0.01$), while Onne's traffic patterns appear driven by factors outside the operational variables tested here, pointing to structural rather than purely operational constraints. Theoretically, the study extends the AHP-based port competitiveness literature by pairing it with time-series forecasting in a dual-port developing-country context. Practically, port authorities should prioritize reducing turnaround time and optimizing berth scheduling at Apapa, while Onne requires targeted infrastructure and regulatory investments to close its efficiency gap and support more balanced, sustainable port development across Nigeria's coastal regions. Limitations include the restricted 2005–2020 dataset and the small Apapa regression sample (n=13); future research should update the analysis with post-2020 data and explore additional non-operational determinants of Onne's traffic patterns.

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Conflicts of interest

The authors declare no conflict of interest

Declaration of generative AI and AI-assisted technologies

During manuscript preparation, OpenAI ChatGPT was used for document structuring, English-language editing, statistical workflow checking, and preparation of the working Word layout. All numerical results were calculated from the supplied dataset, and the authors must independently verify the analysis, references, interpretations, and final wording. The authors retain full responsibility for the submitted manuscript.

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