

Comparative analysis of hub and spoke seaport performance in Nigeria: Case of Apapa Port and Tin Can Island Port

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Article history:

Received: September 29, 2023

1st Revision: April 12, 2024

Accepted: May 15, 2024

DOI:

[10.14254/jsdtl.2024.9-1.10](https://doi.org/10.14254/jsdtl.2024.9-1.10)

Abstract: *Purpose:* The primary aim of this study is to evaluate and compare the operational performance of two major seaports in Lagos, Nigeria – Apapa Port and Tin Can Island Port – using specific port performance indicators. *Methodology:* The study employs the Cobb-Douglas production function and the Ordinary Least Squares (OLS) method to analyse data sourced from the Nigeria Ports Authority's operational bulletin records. The analysis was conducted using E-view software version 10.0. *Results:* The findings indicate that cargo throughput, used as the dependent variable, has a strong positive linear relationship with ship traffic, berth occupancy, turnaround time, and the number of employees. The R² value is 85.89% for Apapa Port and 98.79% for Tin Can Island Port, suggesting that Tin Can Island Port is more productive. *Theoretical Contribution:* This study contributes to the field of maritime transport and logistics by providing empirical evidence on the efficiency and productivity of Nigerian seaports. It highlights the importance of modern infrastructure and effective port operations in enhancing seaport performance. *Practical Implications:* The study recommends that the Nigerian government should focus on reducing port congestion, improving road conditions leading to the ports, and streamlining port documentation processes. These measures are essential for enhancing the operational efficiency of Nigerian seaports.

Keywords: port performance, turnaround time, port operation, ship traffic

1. Introduction

Maritime has been a primary driver of the economy of any developed nation because transport is an integral part of the booming economy of any nation. The seaport is liable for the socio-economic development of nations worldwide. The seaport is the lifeline of maritime activities. Thus, the seaport system's downfall would mean the maritime industry's failure. The expansion and development of Nigeria's seaports represent a crucial factor in the nation's development. Over 70% of businesses in Nigeria are situated close to the ports. The Lagos area constitutes about 40% of the businesses (Ogunsanya & Olawepo, 2008). The Apapa Port and Tin Can Port, strategically situated in Lagos, operate largely under poor equipment and obsolete infrastructure, which is an issue that upsets the seaport's performance, productivity, and efficiency. However, the concessions carried out between 2005 and 2006 brought about more development in the Nigerian seaports in terms of equipment and cargo handling infrastructures by the concessionaires.

Congestion is a significant factor hindering the Apapa and Tin Can Island port performance as it affects the rate of discharge and loading of the consignment at the port. Poor road condition of the major roads leading to Apapa and Tin Can Island ports is another major factor that affects the seaports' operational performance. This problem causes delays in cargo deliveries and arrivals of shippers, clearing and forwarding agents, port authority staff, and other maritime stakeholders to carry out their operations at the port. Other significant issues facing the Apapa and Tin Can Island port are low revenue, low patronage of vessels due to the poor road network, and traffic congestion on the Apapa road. This determines if port turnaround time will be low or high. One of the primary measures of vessel performance is the turnaround time. When the turnaround time for ships is too long, it will lead to congestion in the port, discouraging other vessels from calling in. Turnaround time is usually assessed in weeks or months, subject to the freight being burdened or cleared (Nwaogbe, 2021).

The study aims to compare the seaport performance of Apapa and Tin Can Island ports in Lagos. The objectives of this study are to assess the seaport operational performance in the study area, to identify various operational performance indicators in the seaports, to examine the cargo throughput, ship traffic, berth occupancy, turnaround time, and the number of employees of the ports, to assess the seaport performance at Apapa port, to assess the seaport performance at Tin Can port and to compare the port operational performance of Apapa seaport and Tin can island port.

2. Literature review

According to Tongzon (2009), performance conveys an efficiency element on how satisfactory the resources exhausted are utilised and, in this regard, seaports and terminals remodel inputs in a procedure into outputs. Ha (2017) initiated a hybrid multi-stakeholder context for modeling seaport performance indicators. The structure bargains as an analytical tool for performance assessment of terminals and seaports. Though they consider the various seaport investors to calculate port performance, the investors do not embrace various types of users, and the coefficient of those indicators is not attained from investors but subject matter specialists.

Applying the Cobb-Douglas production model, (Sun, 2006) estimated the efficiency of the container port production. Annual panel information from 1997 to 2005 was collected for each of the 83 container terminal operators. Their inputs were the handling capability between the ship, and also the quay, the handling capability between the quay and the yard, the number of berths, the length of quay lines, the terminal area, the storage capability of the port, and the refers points whereas the product throughput was the output. Moreover, (Hanaa, 2016) applied the standard data envelopment Analysis (DEA) of 9 seaports in Saudi Arabia. They used 2 outputs and 3 inputs to measure port performance for 2014, and the author concluded that Jazan Port is considered inefficient and most of the ports are also inefficient.

Furthermore, (Somuyiwa, 2015) studied the link between freight handling equipment and seaport productivity at Apapa and Tin Can Island, Lagos. The research employed 50 plant operatives as sampled size based on an easy random sampling procedure, during which questions like how the storing facility of Apapa and Tin can seaport can be analysed and the connection between equipment and productivity within the seaport. This information was afterwards analysed through regression analysis and Pearson Product Moment Correlation Co-efficient. The study disclosed that port productivity elements were

insufficient, unserviceable, and outdated, and storing facilities were insufficient and incapable of catering for freight's present capacity in the pre-reform era. Using the cross-sectional data for 2002, (Trujillo, 2007) conjointly employed the Cobb Douglas production function to analyse the technical efficiency of 22 European ports and estimate their legislation. They concluded that their analysis couldn't justify the factors that verify the extent of port efficiency.

Moreso, (Wanke, Nwaogbe & Chen, 2017) studied efficiency in Nigerian ports, handling imprecise data with a two-stage fuzzy approach. The study assessed six major Nigerian ports' efficiency from 2007 to 2013 by applying a two-stage fuzzy-based methodology adequate to handle imprecise data. Fuzzy data envelopment analysis models for traditional assumptions concerning scale returns are employed to assess Nigerian ports' productivity over time. In the second stage, fuzzy regressions based on different rule-based systems are used to predict contextual variables' relationship with port efficiency. These contextual variables are related to different aspects of port service level, berth utilisation, accessibility, cargo type, and operator type. The results reveal the impact of operator and cargo type on efficiency levels. Policy implications for Nigerian ports are derived.

Omoke, V., Diugwu, I.A., Nwaogbe O.R., Mohammed M., & Wokili H. (2017) studied the competitiveness analysis of selected seaports in the West African coast region using the Analytical Hierarchical Process (AHP). The study analysed the competitiveness of selected ports in the West Africa Coast region concerning vessel traffic, cargo throughput, and container traffic. The result reveals the percentage competition of each port during the study, and the results show Apapa Port with (26.36%), Tema Port (21.41%), Tin-Can Island Port (17.85%), Cotonou Port (12.86%), Lome Port (12.56%) and Takoradi Port (8.96%).

Finally, from the literature reviews, the study will utilise Cobb Douglas Production Function and Ordinary Least Square method to compare the operational performance of the two major seaports in Lagos, Nigeria. Several works of literature have used Cobb Douglas or other methods to study Nigeria's seaport performance. However, this study will use the two methods to derive the best operational performance or efficiency of the two ports, compare their results, and make policy implications for the stakeholders and the government so that good decision-making can be employed in the ports.

3. Materials and method of data analysis

Data were collected from Nigeria Ports Authority Apapa and Tin-can Island ports from 2003 to 2017. Data obtained are berth occupancy, cargo throughput, ship turnaround time, ship traffic, and the number of employees. Data collected were analysed using the ordinary least square (OLS) method and the Cobb Douglas production function. E-view software version 10 was used to run the analysis. The model tries to find the correlation between cargo throughput and Ship traffic, Berth occupancy, Turnaround time, and the number of employees. The model estimates simplified port operational performance and its production function in the study area by comparing the two ports' output and inputs.

3.1.1. Model formulation

3.1.1.1. Production function model

The production function model used for the analysis is as follows:

$$C(s_t|T_t) = bs_t^\alpha T_t^\beta \quad (3.1)$$

where: C = Total production (Cargo throughput representing all the cargo shipped in a year).

s_t = Ship traffic. T_t = Turnaround time α and β are the output elasticity of ship traffic and turnaround time, respectively. b = Total factor productivity.

$$C(B_o|N_E) = bB_o^\alpha N_E^\beta \quad (3.2)$$

Where: C= Cargo throughput. B_o = Berth occupancy. N_E =number of employees. α and β are the output elasticity of berth occupancy and number of employees. b = Total factor productivity.

3.1.1.2. Cobb Douglas production model

The Cobb–Douglas production function is a specific practical method of the production model, broadly used to illustrate the technical association concerning two or more inputs (specifically physical capital and labour) and the number of outputs created by those inputs.

$$Y(L, K) = AL^\beta K^\alpha,$$

where: Y = overall production (the actual worth of all cargo manufactured in a year or 365.25 days). L = labour input (the total number of person-hours worked in a year or 365.25 days)

K = capital input (a gauge of all apparatus, gear, and structures; the value of capital input divided by the price of capital). A = Total factor productivity α and β are the output elasticities of capital and labour. These values are constants determined by available technology.

Further, if $\alpha + \beta = 1$, the production function has constant returns to scale. If L and K each improve by 20%, then P rises by 20%. However, if $\alpha + \beta < 1$, returns to scale are declining, and if $\alpha + \beta > 1$,

3.2. Hypothesis

H₁: *There is a significant relationship between cargo throughput, ship traffic, berth occupancy, turnaround time, and number of employees for Apapa port*

H₁: *There is a significant relationship between cargo throughput, ship traffic, berth occupancy, turnaround time and number of employees for Tin Can Island port*

4. Result and discussion

This section emphasises the exhibition, discussion, and estimation of the operational performance of the study.

4.1. Analysis of sea port performance of Apapa Port

Table 4.1: Output model summary result Apapa Port

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	13597969	4591538.	2.961528	0.0143
SHIP_TRAFFIC	3953.635	3315.805	1.192361	0.2606
BERTH_OCCUPANCY_	79896.71	51511.79	1.551037	0.1519
TURN_AROUND_TIME	-199334.0	176881.6	-1.126935	0.2861
NO_OF_EMPLOYEES	-1993.936	685.3111	-2.909535	0.0156
R-squared	0.858870	Mean dependent var	18762883	
Adjusted R-squared	0.802418	S.D. dependent var	3145210.	
S.E. of regression	1398053.	Akaike info criterion	31.40026	
Sum squared resid	1.95E+13	Schwarz criterion	31.63628	
Log-likelihood	-230.5020	Hannan-Quinn criteria.	31.39775	
F-statistic	15.21414	Durbin-Watson stat	2.010693	
Prob(F-statistic)	0.000296			

Where: C_{APP} = Cargo

Throughput for Apapa port. ST = Ship Traffic. BOY = Berth Occupancy. TAT = Turnaround Time. NOE = Number of Employees

Source: Authors

$$C_{APP} = 13597969 + 3953.635 ST + 79896.71 BOY - 199334.0 TAT - 1993.936 NOE$$

4.1.1. Significance of estimate and overall regression model for Apapa Port

The coefficient of determination (R^2) for Apapa Port is 0.858870 for the model, and this indicates that there is a very positive linear relationship between the dependent variables (cargo throughput) and explanatory variables (ship traffic, berth occupancy, turnaround time, and the number of employees)

and that the explanatory variable accounted for 85.89% of the variations in the cargo throughput in Nigeria from 2003 to 2017, While the remaining 14.11% variation in the actual cargo throughput for Apapa port is explained by other exogenous variables that are excluded in the models (error term). This implies that the coefficients are as high as 86% for Apapa. The coefficient of determination (R^2) measures the proportion of the variation in the dependent variable that is explained by the combination of the independent variables in the regression model (Omoke, Aturu, Nwaogbe, Ajiboye & Diugwu, 2017; Salvatore & Reagle, 2002).

The Durbin-Watson statistic was used to detect the presence of autocorrelation (a relationship between values separated by a given time lag) from a regression analysis, which tests the independence of error in the least square regression. As a rule of thumb, if D-W is less than 2.0, there is an indication that the successive error terms are, on average, close in value to one another and positively correlated. It, therefore, means that there is a presence of autocorrelation, and if it is more significant than 2.0, there is no autocorrelation. The Durbin-Watson statistics for the Apapa port is 2.0, which shows that autocorrelation is present because it is not greater than 2.

The standard error and mean of the dependent variable test were carried out to ascertain the estimated parameters' correctness, statistical significance, and reliability. The standard error of estimate for Apapa port is computed to be 4591538, which is small compared to the mean of the dependent variable cargo throughput, which is 18762883. This indicates a statistical significance between ship traffic, berth occupancy, turnaround time, number of employees, and cargo throughput for Apapa Port.

4.2. Analysis of sea port performance of Tin Can Island Port

Table 4.2: Output model summary result Tin Can Island Sea Port

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	5772904.	2647245.	2.180721	0.0542
SHIP_TRAFFIC	8519.958	1229.961	6.927016	0.0000
BERTH_OCCUPANCY_	-23568.32	16933.82	-1.391790	0.1942
TURN_AROUND_TIME	36097.77	181701.3	0.198665	0.8465
NO_OF_EMPLOYEES	-3974.048	1521.220	-2.612408	0.0259
R-squared	0.987865	Mean dependent var	12279674	
Adjusted R-squared	0.983011	S.D. dependent var	4820532.	
S.E. of regression	628324.4	Akaike info criterion	29.80070	
Sum squared resid	3.95E+12	Schwarz criterion	30.03672	
Log-likelihood	-218.5053	Hannan-Quinn criteria.	29.79819	
F-statistic	203.5108	Durbin-Watson stat	2.025168	
Prob(F-statistic)	0.000000			

$$C_{TC} = 5772904 + 8519.958 ST - 23568.32 BOY + 36097.770 TAT - 3974.048 NOE$$

Where: C_{TC} = Cargo Throughput for Tin Can port. ST = Ship Traffic. BOY = Berth Occupancy. TAT = Turnaround Time. NOE = Number of Employees

From the regression equation above, the value of the constant term C_{TC} (CARGO THROUGHPUT) is 5772904. This signifies that if the explanatory variables are constant, the C_{TC} is 5772904. Thus, this is the autonomous value of the CARGO THROUGHPUT.

4.2.1. Significance of estimate and overall regression model for Tin Can Island Port

The coefficient of determination (R^2) for Tin Can Port is 0.987865 for the model, and this indicates that there is a powerful positive linear relationship between the dependent variables (cargo throughput) and explanatory variables (ship traffic, berth occupancy, turnaround time, and the number of employees) and that the explanatory variable accounted for 98.79% of the variations in the cargo throughput in Nigeria from 2003 to 2017, While the remaining 1.21% variation in the actual cargo throughput for Tin Can port is explained by other exogenous variables that are excluded in the models

(error term), This implies that the coefficients are high as 99% for Tin Can island port. This indicates that the Tin Can Island port has a stronger relationship between the dependent and exploratory variables. The coefficient of determination (R^2) measures the proportion of the dependent variable variation explained by the combination of the independent variables in the regression model (Omoke, Aturu, Nwaogbe, Ajiboye & Diugwu, 2017). The Durbin- Watson statistics for Tin can port is 2.025168. The standard error of estimate or Cargo throughput for Tin Can Port is 2647245, which is small compared to the mean of the dependent variable cargo throughput, which is 12279674. This indicates a statistical significance between ship traffic, berth occupancy, turnaround time, number of employees, and Tin Can Island Port cargo throughput.

4.3. Test for hypothesis one

H₁: There is a statistically significant relationship between cargo throughput and Ship traffic, berth occupancy, turnaround time, and number of employees for Apapa seaport.

Using the Prob (F-statistic) value, the P-value for the Apapa seaport is 0.000296. Since the P-value for Apapa seaport is less than 0.05, this indicates a statistically significant relationship between the dependent variable, Cargo throughput and the explanatory variables (ship traffic, berth occupancy, turnaround time, and the number of employees). This implies that the more the input parameters work effectively, the more the operational performance increases, resulting in an optimal operational output (Pius, Nwaogbe, Akerele & Masuku, 2017; Nwaogbe, Diugwu, Mohammed, Omoke & Gidado, 2016).

4.4. Test for hypothesis two

H₁ = There is a significant relationship between cargo throughput and Ship traffic, berth occupancy, turnaround time, and number of employees for Tin Can Port.

Using the Prob (F-statistic) value, the P-value for Tin Can seaport is 0.000000. Since the P-value for Tin Can port is less than 0.05, this indicates a significant relationship between the dependent variable, Cargo throughput and the explanatory variables (ship traffic, berth occupancy, turnaround time, and the number of employees). This implies that the higher the parameter operations regarding the ship's turnaround time, employee operational services, and berth occupancy, the higher cargo throughput, thereby increasing seaport to operational performance (Nwaogbe, Diugwu, Mohammed, Omoke & Gidado, 2016; Nwaogbe, Monday, Matthew, Omoke & Nze, 2019). Wanke (2017) states that airports' operational performance is the measurement of how the productivity and efficiency of the airport are rated based on the input and output variable estimation.

4.5. Discussion

Table 4.2 shows the exponents of the explanatory variables that become the coefficients; this, therefore, qualifies the coefficients of the explanatory variables (independent variables) as a measure of the degree of responsiveness (elasticity) of the dependent variable to the change in the explanatory variables. The coefficients of each explanatory variable (ship traffic, berth occupancy, turnaround time, and the number of employees) are the elasticity response of the dependent variables (CARGO THROUGHPUT) concerning relative explanatory variables. The regression equation above shows that the value of the constant terms C_{APP} (CARGO THROUGHPUT) is 13597969. This signifies that if the explanatory variables are held constant, the C_{APP} is 13597969. Thus, this is the autonomous value of the CARGO THROUGHPUT.

In the context of the computed elasticity (i.e. coefficient of the explanatory variables), the result suggested that a unit change in output ST will cause a 3953.635 unit rise in C_{APP} . This means there is low output for Apapa Seaport, and for this to develop, more output from this sector will enhance the performance. A unit change in BOY will cause a 79896.71 unit change in C_{APP} . This means that the performance of Tin Can Island is low compared to Apapa Port, and for this to develop, an increase in berth capacity will be mobilised, eventually affecting the cargo throughput positively. A unit change in TAT will result in a -199334.0 unit change in C_{APP} . This means that the Apapa seaport's turnaround time is lower than that of Tin Can Island. A unit change in NOE will result in a 1993-936 change in C_{APP} . This

means that a unit change in the number of employees for Apapa seaport is more significant than that of Tin Can Island.

The F statistics are used to ascertain the overall significance of the model. This decision compares the calculated F statistics (Fcal) and the tabulated F (Ftab). Since $F_{cal} > F_{tab}$ ($15.21414 > 6.06$ and 3.48) at both 1% and 5% levels of significance, table 4.2 shows a positive statistically significant relationship between ship traffic, berth occupancy, turnaround time, number of employees, and cargo throughput.

Furthermore, table 4.3 shows the context of the computed elasticity (i.e. coefficient of the explanatory variables). The result suggested that a unit change in ST will cause an 8519.958 unit rise in C_{TC} . This means there is low output for Apapa Seaport compared to Tin Can Port, and for this to develop, more output from this sector will enhance the performance. A BOY unit change will also cause a -23568.32 unit change in C_{TC} . This means that Tin Can Island's performance is low compared to Apapa Port, and for this to develop, an increase in berth capacity will be mobilised, eventually affecting the cargo throughput positively. A unit change in TAT will result in a 36097.77 unit change in C_{TC} . This means that the Apapa Seaport's turnaround time is lower than that of Tin Can Island. A unit change in NOE will also result in a -3974.048 change in C_{TC} . This means that a unit change in the number of employees for Apapa seaport is more significant than that of Tin Can Island.

The F statistics were used to ascertain the overall significance of the model. This decision is based on comparing the calculated F statistics (Fcal) and the tabulated F (Ftab). Since $F_{cal} > F_{tab}$ ($203.5108 > 6.06$ and 3.48) at both 1% and 5% levels of significance, as shown in Table 4.3, there is a positive statistically significant relationship between ship traffic, berth occupancy, turnaround time, number of employees, and cargo throughput.

Comparing the Apapa port and Tin Can Island port, from the output summary, the result shows that Tin Can Island has R^2 square of 0.987865 (99%), Adjusted R of 0.983011 (98%), and Prob (F-statistics) of 0.00000 while Apapa port has R^2 of 0.85887 (86%), Adjusted R of 0.802418 (80%) and a Prob (F-Statistics) of 0.000296. The result shows that Tin Can Island Port is more productive and efficient than Apapa Port in terms of port performance because it has an F-statistics of 0.000000 while Apapa Port has an F-statistics of 0.000296. This is due to the heavy traffic congestion at the Apapa road that leads to the port, which also causes many delays for the articulated vehicles that come to carry cargo from the port.

5. Conclusion

In conclusion, the study findings reveal that independent variables (ship traffic, berth occupancy, turnaround time, and employee number) are significantly related to the dependent variable (cargo throughput). The Apapa port operational performance analysis demonstrated a statistically significant relationship between the dependent variable, Cargo throughput and the explanatory variables (ship traffic, berth occupancy, turnaround time, and the number of employees). Secondly, the Tin Can Island port operational performance analysis results show a statistically significant relationship between the dependent variable, Cargo throughput and the explanatory variables (ship traffic, berth occupancy, turnaround time, and the number of employees). Moreover, comparing the two major ports, the result shows that Tin Can Island Port is more productive in terms of performance than Apapa Port, with Apapa Port R^2 of 88% and Tin Can Island with R^2 of 99%. Based on the study findings, recommendations were made to improve operational service at Apapa port to meet port users' demands. The government should work toward rebuilding the access road to the Apapa port complex and developing an integrated multimodal transport system to enhance port operation logistics services and transportation of cargoes to decontaminate the port. The two significant seaports (Apapa Port and Tin Can Island Port) should also develop and maintain customer-oriented marketing strategies to improve affordability and repeat patronage at the port. Lastly, the government should create industry-specific policy implications to encourage and support direct investment in the maritime sector to help bring port users to comfort the ports. Finally, there is a need to rebuild Apapa Port Road to have a free traffic flow and reduce delays in transporting goods from the seaports.

Acknowledgement

The authors thank the Department of Transport Management Technology, Federal University of Technology Minna, Nigeria, for supporting this study.

Ethics approval and consent to participate

Not applicable.

Availability of data and material

The data are available on request.

Competing interests

The author declares that he has no competing interests.

Funding

This work received no funding.

Citation information

Nwaogbe, O. R., Abdulhamid, H. Y., Omoke, V., & Eru, J. U. (2024). Comparative analysis of hub and spoke seaport performance in Nigeria: Case of Apapa Port and Tin Can Island Port. *Journal of Sustainable Development of Transport and Logistics*, 9(1), 137-145. doi:10.14254/jsdtl.2024.9-1.10.

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