Analysis of the Effects of Maritime Logistics on Berth Efficiency of Nigerian Ports

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ABSTRACT

The study evaluated the berth efficiency of Nigerian ports in handling ship calls. It also evaluated the effects of maritime logistics on the berth efficiency in Nigerian ports as it affects the handling of ships that call to the ports. It used the Lagos Apapa Port and Eastern Port of Onne as case studies because both ports handle between 65 and 75% of Nigerian imports. The quantitative and ex-post facto research design were used in which secondary data on the ship turnaround time, waiting time, time at berth and cargo dwell time prevailing in Lagos Apapa Port and Onne Port each year between 2007 and 2019 were obtained and used as proxies for maritime logistics performance and the ship traffic size handled by the port was used as indicators of berth productivity. The time expended per annum in port operations measured in man-hours and the average time vessels spent at berth annually in the ports between 2007 and 2019 were obtained and used as input to estimate the berth efficiency of the port in cargo handling relative to expended efforts in man-hours and the efficiency of the port in handling ship calls. The augmented efficiency model was used to estimate the berth efficiency of the ports while the log-linear multiple regression analysis was used to estimate the effects of maritime logistics performance on the berth efficiency of the seaports in handling ship traffic. The test of hypotheses reveals that in all cases, there is a significant effect of maritime logistics performance on berth efficiency in both ports. The models showing the relationships and effects of maritime logistics on the various berth efficiency of port are shown: *InBERTHEFFICIENCY = 1.103+ 1.667InSHTRTIME + 0.193InCARGODWELLTIME + 0.264InWAITINGTIME -5.706InBERTHTIME and InBERTHEFFICIENCY = 23.320 + 0.252InSHTRTIME + 0.072InCARGODWELLTIME - 0.041InWAITINGTIME -8.535InBERTHTIME* respectively for Onne and Apapa ports. The main findings and contributions of the study is that for each unit annual increase in ship turnaround time in the port, berth efficiency in ship output productivity increased by 1.667 units while a unit increase in cargo dwell time also increased berth efficiency in the

port by 0.193 units. Similarly, a unit increase in vessel waiting time increases berth efficiency in the port by 0.264 units while a unit increase in the average time spent by vessels at berth being worked decreases berth efficiency of the port in handling of ship calls by 5.706 units. By implication, increasing ship turnaround time, vessel waiting time and cargo dwell time increases berth efficiency of the ports in ship handling whereas increasing vessel time at berth decreases berth efficiency in the port. It was recommended that in order to improve the berth efficiency of the ports, port authorities and terminal operators should implement logistics strategies to limit vessel waiting time and idle time at berth.

Keywords: Berth-efficiency, Ship-traffic, Maritime, Logistics, Port-performance, Nigeria

1. Introduction

Berth efficiency is one of the key parameters for measuring port performance since cargo throughput, vessel turnaround time, and port revenue are closely related to berth efficiency. Maritime logistics concerns the planning, execution, and control of the movement of vessels and seaborne trade (shipments) and information from origin to destination ports. Maritime logistics is also implemented in intra-port operations to enhance efficiency. In this regard, maritime logistics therefore plays a major role in berth efficiency. This study appraises the extent of the relationship between maritime logistics and berth efficiency in Nigerian ports by highlighting key factors and challenges [1, 2, 3].

The principal factors influencing berth efficiency in Nigerian ports are considered to include infrastructure and port equipment conditions cum availability, berth capacity and depth, time expended in working vessels at berth which have implications on delay factors, superstructures and cargo handling, availability and adequacy of storage and facilities and stacking areas, operations and port procedures, terminal scheduling, and berthing, seamlessness and speed of clearing of cargo and documentation, and labor efficiency which has to do with enhancing efficient port operations through the use of skilled and motivated maritime labour [1].

Similarly, typical maritime logistics activities and operations that are implemented by port authorities and terminal operators to drive efficiency in port operations include the integration of the maritime supply chain system. The integration of port facilities with the overall supply chain function enhances the flux of cargo and reduces dwell time. The deployment of port digitalization tools and information technology: Advanced information technology systems can greatly enhance communication, coordination, and decision making in maritime logistics. Containerization also presents an efficient maritime logistics system for handling cargo, thus reducing turnaround times and port costs. The implementation of maritime logistics strategies and approaches in berth, terminal and port operations is to enhance berth, terminal and port efficiency by optimizing time and cost of port operations and services [4, 5].

It is therefore expected that government policies related to the implementation of port logistics strategies in port development, investment in infrastructure, and facilitating trade have a great influence

on berth efficiency. Having a clear and effective regulatory framework ensures that there are supportive, efficient port operations that eliminates bureaucratic delays through the optimization of time of ship husbandry at berth and overall time spent by shippers and ship-owners in accessing and consumption of port services. The development of these strategies however must be based on the generation of empirical information that provides knowledge of what extent berth (port) efficiency is influenced by maritime logistics [6].

Most empirical studies in the area of maritime logistics agree that the paramount motivation for the integration of logistics and maritime operations is the improvement of efficiency of maritime and port operations by the implementation of planning and organization and scientific management tools aimed at improving performance of the maritime sub-systems and consumer satisfaction. For example, studies by [7, 8] agree that the implementation of the principles of maritime logistics in port operations should lead to improvement in variables of port operational indices such as: ship-turnaround time in ports, cargo dwell time in ports, vessel waiting time in ports, average vessel time at berth, cost of port services (wharfage, ship-dues, berthage etc.), cargo pilferage risk profile of ports (security), level of congestion-induced-delay in ports, level of satisfaction and utility derivable from port services, and quality of service which in turn should improve port efficiency by eliminating wastage of resources, time and effort (in man-hours or machine-hours) expended in port operations [9].

However, the central challenge/problem of the employment and implementation of the principles and tools of professional maritime logistics practices in Nigerian ports, ship-turnaround time, cargo dwell time, waiting time, time at berth, cargo pilferage risk profile, congestion related delays, cost of port services consumption, etc. continues to rise while port efficiency seems to be stagnated over the years [10, 11]. Despite the prevalence of the above identified challenges, not enough empirical studies have been able to investigate what constitute the trend of port efficiency in Nigerian ports relative to the problems of increasing ship-turnaround time, cargo dwell time, waiting time, time at berth, cargo pilferage risk profile, congestion-induced delay, increasing cost of port services, with a view to determining the effects of the identified outputs of implementation of maritime logistics on port efficiency. Moreover, available empirical literature has not been able to investigate using empirical data, how maritime logistics performance indicators such as ship turnaround time, vessels waiting time, cargo dwell time and average time vessels spend at berth being worked in Nigeria major ports affect the efficiency and productivity of the port. The expanded effect is that port operators and users are uncertain how the maritime logistics performance indicators identified above affect their effort aimed at improving port productivity in the ports. It is therefore important to empirically determine the relationship between maritime logistics performance outcomes and port efficiency in Nigeria in order that basis be developed based on empirical evidence for improvement in standards, principles and tools of professional maritime logistics practices in the seaport sector in Nigeria. This will in turn improve port efficiency and port-user satisfaction in Nigeria.

However, the review of available empirical literature suggests that there exist knowledge gaps such that there is a lack of empirical information about to what extent ship turnaround time, ship and cargo dwell time in Nigerian as variables of maritime logistics performance influence berth efficiency of Nigerian ports. The focus of the study is to bridge these existing knowledge gaps. In order to drive improvement in berth efficiency in the Nigerian ports, useful insights into the extent of influence of maritime logistics practices on the efficiency of the berths needs to be provided through qualitative studies, quantitative research is needed to ascertain specifically the magnitude of the effect which the variables of maritime logistics have on berth efficiency in Nigerian ports. Detailed case studies of individual ports can provide useful lessons and best practices that could be used for improvement in berth efficiency. By addressing these gaps in research and further presenting the direction that the research could take in the future, there may be given, to policymakers, port authorities, and industry stakeholders, very useful insight about how berth efficiency could or should be developed to improve the competitiveness of Nigerian ports in the global maritime trade.

In view of the aforementioned knowledge gaps which this study seeks to address, the objectives, research questions and hypotheses which the study will address are identified below:

1.1 Objectives of the Study

(i) To evaluate the berth efficiency of Nigerian ports in handling ship calls in Nigerian ports relative to the quantum of man-hours expended working on vessels at berth.

(ii) To establish the effects of ship turnaround time, cargo dwell time, waiting time, and berth time as proxies for maritime logistics on the trend of berth efficiency in handling ship calls in the Nigerian ports.

1.2 Research Questions

(i) What is the level of berth efficiency of Nigerian ports in handling ship calls relative to the quantum of time expended working on vessels at berth?

(ii) Is there a significant effect of ship turnaround time, cargo dwell time, waiting time, and berth time on the trend of berth efficiency in handling ship calls in Nigerian ports?

1.3 Hypotheses

H_{01}: The level of berth efficiency of Nigerian ports in handling ship calls relative to the quantum of time expended working on vessels at berth is zero.

H_{02}: There is no significant effect of ship turnaround time, cargo dwell time, waiting time, and berth time on the berth efficiency in handling ship calls in Nigerian ports.

2. Literature Review

International trade is the exchange of goods and services among countries. Since consumption of goods must take place at the importing country's domain, these goods must cross international boundaries to land at the importing country's market, warehouse etc. for consumption to take place. Therefore, international seaborne trade is the movement of goods and services from one country (Export) to another (importing country). Movement or carriage of the goods involved may be by air, road, rail or Sea.

Movement of goods and passenger by water is known as maritime trade. The carrying equipment vessel or facility for maritime transport is the ship. Since the usage of ships to convey goods across international boundaries dominates other modes, shipping has come to be taken as international trade [12, 13].

Maritime logistics is responsible for the planning and coordination of the flow of seaborne trade via ports in Nigeria across to and from the supply chain networks linked to the Nigeria international trade routes. Thus, the management of the ports in Nigeria as a maritime node for harnessing ship movement and flow of seaborne trade rest upon the implementation of standard principles of maritime logistics. The outcome of such planning, organization coordination and management of port operations achieved by the implementation of maritime logistics is seen in measurable variables/factors in the port such as: the ship turnaround time (STRT), cargo dwell time, cargo pilferage profile, port charges and costs, cargo examination procedure, port congestion induced delay, etc. thus the success and effectiveness of the implementation of maritime logistics in ports can be assessed on the basis of the above identified variables.

Ship Turnaround Time (STRT) as a port-related factor that influences the flow of shipping trade via the ports is defined as the total time that a vessel spends at a port from its arrival to departure. It encompasses the amount of time it takes the ship to be berthed in port on arrival, the time it takes her to discharge her cargo and take-up new cargo for the reverse journey if available, and leave the berth to embark on the exit or departure leg of the journey. The average ship turnaround time (ASTRT) is usually determined as the average difference between the date of departure and date of arrival of the vessels calling at a port, usually within one month of navigations. According to [10], STRT is a major factor that influences port choice by ship owners and operators as it indicates the level of efficiency of use of port superstructures and cargo handling equipment. Thus, high ship turnaround time may imply longer period of stay in ports by vessels awaiting services with the attendant implications on the economy and finances of the affected ship-owners and operators. Higher STRT also increases the risk of delay in delivery of shipments and cargo to the shippers' warehouses in the hinterland markets, which could result to situation of stock-out and scarcity in the domestic markets, price inflation, shutdown, etc., among other negative economic implications. The strategic deployment of functional logistics tools and principles in the ports and maritime transport industry can help to overcome the risk of high ship turnaround time posed to the swift flow of shipping trade via the ports [10, 14].

Cargo dwell time (CDWT) as a port-related factor influencing the flow of shipping trade via the ports is the measure of the time that elapsed from the time the cargo arrives in the port to the time the goods leave the port premises after all permits and clearances have been secured for the cargo to leave the port to the shipper's terminal and/or warehouse. Longer days of cargo dwell time at the ports implies delays in the movement of the goods and an indication of the existence of congestion-related delay within the port. Nigeria ports is noted to have the highest cargo dwell time in the West African sub-region and this is viewed as a serious factor that hampers efficient shipping trade flow through the ports and an

indication that the port authority and terminal operators are yet to improve the utility and satisfaction of port users through the adoption and implementation of functional logistics strategies and approaches.

Cargo Examination Procedures Bottlenecks to Efficiency (CEPBE): There is a challenge posed by the complexity of cargo examination procedures in most Nigeria ports. In most cases, too many agencies are involved in the examination even when it is not necessary. The varied dates of examination by the various agencies increases the cargo dwell time cost of examination, pilferage risks and the frustration faced by shippers and freight forwarders following the harrowing experiences in the cargo clearing process. There are up to 32 government agencies including the Nigerian Customs Service, all of which cause avoidable delays in the clearing of imported goods and consignments [10].

Port Charges and cost: It is suggested that in order to remove the bottlenecks associated with clearing of imported consignments and the flow of shipping trade in seaports, the number of government agencies directly involved in the examination and clearing of goods at the ports should be reduced to only those required for effective ship and cargo handling operations and national security [15]. This is to reduce the duplicity of functions of the main agencies and payment of multiple charges by shippers. Port tariff and rates in Nigeria is also believed to be higher than those of other states within the West African sub-region. Poor states of port infrastructure and super structure, port congestion related delay, and high cargo pilferage risks are some more factors which are identified, to influence the flow of shipping trade in Nigeria ports as a result of the inability and delay of the port authorities and terminal operators in implementing maritime and port logistics approaches sought to address the dissatisfaction of port users (as consumers of port services) with the quality of service rendered in the ports [10].

As aforementioned, the identified factors influencing port operations arose, following the inability and delay in the implementation of the functional port and maritime logistics strategies in the Nigeria ports industry. Thus, port authorities over the years seem not to have seriously sorted to maximize the utility and satisfaction derivable to the port customers and users, from the consumption of port services. Cost of port services, time of doing business in port are witnessing continual increasing trend while customer satisfaction, port service quality is very low. It is important to note that these have implications on port efficiency which needs to be investigated in Nigeria

Reference [8] views maritime logistics as a concept which involves the process of planning, implementing and managing the movement of goods and information involved in the ocean carriage of goods and trade through the seaports. It is a coinage from two words- ‘maritime, which is an English adjective usually employed in qualifying services, trade, operations, carrier and all forms of objects found in or within the proximity of the seas, ocean and rivers. Typical examples include expressions such as maritime transport, maritime trade, maritime operations, etc.; and ‘logistics’- which according to [8] is the process of planning, organizing and executing the efficient transportation and storage of goods from the point of origin to the point of consumption with the goal being to meet customer requirements in a timely and cost-effective manner. The functions of logistics according Aylin (2016) are identified to include but not limited to:

(i) Transportation
(ii) Warehousing and storage
(iii) Planning and organization of resources (time, labour, finance, equipment, etc.)
(iv) Optimizing and executing the use of vehicles, labour, time, retail locations and customers, planning and optimizing, yards, routes and shipment loading,
(v) Inventory management,
(vi) Demand analysis and order processing, etc.

Studies by [7, 11] agree that the motivation supporting the development of logistics and its application in planning complex operations and processes is to improve the efficiency of operations and firms, in ensuring that limited input resources are employed to turnout greater outputs. This implies also that logistics should be responsibly employed in limiting cost and time, risk, etc., associated with the implementation of complex operations and activities of firms employing it. This will ensure consumer/user satisfaction induced by time and cost saving as well as safety and security benefits.

The maritime industry/sector represents such a complex sector where the integration of logistics for performance improvement is inevitable. In the maritime industry, the complex nature of the maritime sub-sector requires the incorporation of the logistics functions and activity areas when addressing the numerous challenges and bottlenecks to efficiency in service delivery and port-user satisfaction in the sub-sector. For example, all maritime-related fields, such as ship ownership, chartering, shipping agencies, brokering, freight-forwarding, stevedoring, supply management, port operations, etc. are separate operating units. However, they are integrated in the functions of port/maritime logistics [10, 16, 17].

According to [10, 18], Maritime logistics, similar to port 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 the seaports, with focus on improving and/or maximizing efficiency of ports and maritime transport, bring about cost-effectiveness in port operations and use, limiting time of port service delivery, improving maritime safety and security services, improving quality of services, utility/customer satisfaction, etc., associated with the use of maritime transport and seaports in the delivery of consignments by shippers and freight forwarders.

Efficiency is viewed as the accomplishment of (or ability to accomplish) a job with a minimum expenditure of time and effort. The effort in this context may take the form of input resources such as time worked by the labour force (man-hours), time worked by machinery and equipment employed (machine-hours), financial resources expended, etc. According to [16, 19, 20], port efficiency indicates the relationship between port output/performance and the input resources employed in producing a given level of output and it is indicative of the capacity of a given port system to eliminate wastefulness by ensuring that limited input resources is employed to turnout large output. Port efficiency according to [17, 21] is the ability of a port system to limit waste of input resources by producing acceptable higher

levels of output with limited and/or lower level of input resources such as time, labour, superstructure and finance.

Mathematically, efficiency of the maritime transport subsequent with regards to port efficiency is expressed as the ratio of the useful output produced by the port to the level of input resources employed in producing it. Therefore, port efficiency is defined as port output per unit of input, usually expressed as a percentage.

Since efficiency (***E***) is a function of output (O) and input (I), we write that: $E = \left(\frac{O}{I}\right)\left(\frac{100}{1}\right)$

We assert that the output performance of the maritime transport sector particularly the berths in a seaport is generally measured in terms of the ship traffic handled in ports, the cargo throughput handled in ports, the container throughput handled etc. Similarly, since human and machine labour are employed in the handling of the ships and cargo, time and labour measurable in man-hours and machine-hours represent input factors while the financial resources, the berths, etc. also represent input resources towards the production of outputs by port authorities. This study employed ship traffic performance handled in the ports as outputs and man-hours put into handling the ships as well as the number of berths employed in handling them as inputs, in order to determine the efficiency of the berths in handling ship calls in the ports over the years. Since it is rightly believed that maritime logistics has effects on the level of berth efficiency achievable, the identified indicators of the logistics performance such as ship-turnaround time in ports and cargo dwell time in ports, can be used as proxies to assess the effects of maritime logistics on the berth efficiency of Nigerian ports over the years.

Considered at a strategic level, the integration of maritime logistics principles within port operations is generally considered to hold the key to enhancing efficiency and competitiveness in the sector. Indeed, good planning and organization supported by scientific management will enable a port to rationalize its processes and cut costs, hence improving its overall performance. Indeed, various studies like [7, 22, 23], among others, have revealed that the gains of maritime logistics would pertain to aspects like improvements in the turn-around time, dwell time of cargo, vessels' waiting time, cost of services related to the ports, security, congestion, and customer satisfaction.

However, despite the identified benefits of maritime logistics, Nigerian ports have still not been free of vexing problems that make their operations inefficient. With the adoption and application of principles and tools of maritime logistics, critical operational efficiency indicators such as ship turnaround time, cargo dwell time, waiting time, and costs of port services have continued in an uptrend without any improvement in performance on port efficiency [10, 21]. While increases in ship turnaround time, cargo dwell time, waiting time, and costs have been highlighted as challenges, there has been little investigation into precisely how performance indicators affect port efficiency within maritime logistics in Nigeria from the exiting body of research. This implies that a problem is caused by such limited understanding, which guides the development of appropriate evidence-based strategies to help improve maritime logistics practices with the aim of enhancing port performance.

This study therefore attempts to examine the empirical relationship between maritime logistics performance indicators and port efficiency in Nigeria. Through the analysis of variables such as the ship's turnaround time, vessel waiting time, cargo dwell time, and average time which vessels spend at berth, this study would be able to provide valuable inputs to port operators, policymakers, and other stakeholders. The findings will be useful in delineating specific strategies that optimize maritime logistics practices and, by extension, improve the efficiency of ports for the ultimate competitiveness of the maritime sector in Nigeria.

3. Data and Methods

The study area of the research is the Nigeria maritime logistics sub-sector with focus on the Nigeria seaport industry. The Nigerian Port Authority (NPA, 2019) report that the Lagos Port Complex and Onne Port handle between 65% and 70% of total volume of vessel and seaborne trade that come to Nigeria. Thus, the Lagos Apapa Port Complex carry significant volume of vessel and cargo traffic handled in port in Nigeria and therefore dominates port affairs in Nigeria. This is the reason this study adopted and used the Lagos Apapa Port Complex and Onne Port in this study. Both ports are the major ports in the West and Central African sub-regions operate on 24hours service time nonstop and host to the major container terminals and West African Container Terminal (WACT) and other terminal operators. Therefore, the study area of the research is the Nigeria port industry and maritime logistics sector with focus on the performance and productivity of Lagos Apapa Port Complex and Onne Port upon which the efficiency of the port was determined.

3.1 Research Design

The adopted ex-post facto and quantitative research design in which time series data on outcomes of implementation of maritime logistics in Lagos Apapa Port and Onne Port measured by the ship-turnaround time, cargo dwell time, waiting time, and time at berth in the port between 2007 and 2019 (obtained from the Nigerian Ports Authority (NPA)) were used as independent variables to determine the relationship between maritime logistics and port efficiency. Although metrics for assessing the performance of the ports logistics sector encompasses several variables related to port cost, trade volumes (cargo and ship traffic), port time (lead time of port operations) and port user satisfaction; this study focuses on port time (lead time of port operations) in assessing the berth efficiency of ports in ship handling relative to the time spent (Liu et al, 2022). Thus, man-hours spent in handling trade, ship turnaround time, cargo dwell time, waiting time and berth time are used as proxies for maritime/port logistics performance. This is because the relationship indicating the impacts of these time variables associated with port operations and maritime logistics performance have seldom been investigated in available empirical literature [14, 24].

The cargo throughput and ship traffic size of the port over the same period was also obtained from the NPA and used as port output variables to determine the efficiency of the port over the period. Having earlier identified the objectives and research questions to be addressed by the study, the influence of maritime logistics on port efficiency in Nigeria will be determined.

3.2 Sources of Data

This research relied upon both secondary sources of data for the study. Secondary data constitute of data generated from secondary means such as Nigerian Ports Authority annual reports, Shipper Council annual Reports and Statistical publication, and data bases of related maritime organizations, etc. The secondary data of both the dependent and independent variables were obtained from the Nigerian Ports Authority (NPA), Lagos and Onne branches.

3.3 Method of Data Analysis

3.3.1. Port efficiency function

Mathematically, the efficiency function expresses efficiency as the ratio of the useful output produced to the level of input resources expended in producing it.

That is; efficiency (***E***) is a function of output (O) and input (I), we write that: $E = \left(\frac{O}{I}\right)\left(\frac{100}{1}\right)$ (1)

Port efficiency ($\boldsymbol{E_p}$) is thus a function of the ratio of the output or performance of the port to the input resources or effort expended in producing the output.

That is: $\boldsymbol{E_p} = \left(\frac{O}{I}\right)\left(\frac{100}{1}\right)$ (2)

It is important to note that the output of the ports is usually expressed in terms of the cargo throughput ($\boldsymbol{CARPUT_t}$), container throughput ($\boldsymbol{CONPUT_t}$), ship-traffic size ($\boldsymbol{SHIPTR_t}$), port revenue ($\boldsymbol{PORREV_t}$), vehicle throughput ($\boldsymbol{VEHPUT_t}$), etc. produced and/or handled over a given period of time, for example one year period.

Similarly, port input resources constitute financial resources and expenditure ($\boldsymbol{FINEXP_t}$) as cost put into the production of port services, equipment and infrastructure (superstructure and infrastructure); man-hours of port labour expended as effort in producing the output ($\boldsymbol{EFFORT}_t$), machine-hours expended as effort in producing the output, Time expended at berth in working on ship (***BERTHTIME***), number of berths engaged in producing the output, etc. However, since it takes human operators to operate the machines and equipment, run and manage the berths, financial resources and other inputs into port operations as the human labour expend energy over time in carrying out these operations; it implies that the most generalized form of input (the best choice of input to be used in the study to evaluate port efficiency) is the effort ($\boldsymbol{EFFORT}_t$) in (man-hours) expended in producing the outputs. Therefore, to evaluate port efficiency, we modified the port efficiency function as follows:

Port efficiency = $E_p = \left(\frac{CARPUTt}{EFFORTt}\right)\left(\frac{100}{(1)}\right)$ (3);

for cargo handling efficiency or throughput efficiency.

Where: $\boldsymbol{CARPUT_t}$ = cargo throughput handled by the port each year over the period between 2007 and 2019 measured in tons.

$\boldsymbol{EFFORT_t}$ = aggregate effort in man-hours expended in producing the output in the form of cargo throughput each year over the period covered in the study.

Similarly for container throughput, ship traffic size and port revenue, we have:

Port efficiency = $BERTHEEFFICIENCY_p = \left(\frac{\boldsymbol{SHIPTRt}}{EFFORTt}\right)\left(\frac{100}{(1)}\right)$ (4);

for ship output efficiency

Using the port efficiency function described above, we used the Natural log function to convert all input and output variables into common units as shown:

Port efficiency = $E_p = InEFFICARPUT = \left(\frac{InCARPUTt}{In\ EFFORTt}\right)\left(\frac{100}{(1)}\right)$ (5); for cargo handling efficiency

Port efficiency = $BERTHEFF_p = InBERTHEFFICIENCY = \left(\frac{\boldsymbol{InSHIPTRt}}{InEFFORTt}\right)\left(\frac{100}{(1)}\right)$ (6); for ship output efficiency

The efficiency of the Lagos Apapa Port and Onne Port over the period covered in the study was determined using the above efficiency functions.

3.3.2 Log-linear regression analysis method

Using the multiple log-linear regression model approach, the effects of maritime logistics on berth efficiency in Nigeria was determined. The effects of the outcomes of the implementation of maritime logistics in Nigerian ports' ship-turnaround time (***SHPTRT$_t$***), cargo dwell time (***CARDWT***t), waiting time (***WAITINGTIME***), berth time (***BERTHTIME***) on berth efficiency (BERTH***EFFICIENCY***) in handling ship calls to Nigerian port was determined.

The relationship between the berth efficiency and maritime logistics performance was investigated using berth efficiency as a dependent variable; since it is viewed that the implementation of maritime logistics operations in ports should influence port efficiency. The model specifications are shown below:

$$\boldsymbol{BERTHEFFICIENCY = \beta_0 + \beta_1 LogSHPTRT_t + \beta_2 LogCARDWT_t + \beta_3 LogWAITINGTIME + \beta_4 LogBERTHTIME + \mathcal{E}}$$ (7) for berth efficiency.

Normal hypotheses testing methods for OLS estimation using t-test and f-test was used to determine the significances of the effects of implementation of maritime logistics on port efficiency in Nigeria.

4.2 Results and Discussion of Findings

Table 1. Average scores of port productivity indicators, port efficiency and maritime logistics performance indicators

Variable	N	Range	Minimum	Maximum	Sum
CARPUT	13	12018607.00	17480233.00	29498840.00	324581690.00
SHPTRFIC	13	226.00	659.00	885.00	9797.00
EFFORT	13	.00	8760.00	8760.00	113880.00
EFFICARPUT	13	.06	1.84	1.89	24.38
BERTHDAYS	13	2.76	2.04	4.80	40.91
EFFISHTR	13	.03	.71	.75	9.48
CARGODWELLTIME	13	5.00	10.00	15.00	166.00
SHPTURNTIME	13	4.55	2.00	6.55	46.65
AWAITINGTIME	13	2.24	.36	2.60	20.91

Valid N (listwise)	13				

Descriptive Statistics

	Mean	Std. Deviation	Variance
CARPUT	24967822.3077	3352316.82070	11238028066361.900
SHPTRFIC	753.6154	76.14738	5798.423
EFFORT	8760.0000	.00000	.000
EFFICARPUT	1.8753	.01584	.000
BERTHDAYS	3.1469	2.8601	1.345
EFFISHTR	.7293	.01093	.000
CARGODWELLTIME	12.7692	1.73944	3.026
SHPTURNTIME	3.5885	1.45108	2.106
AWAITINGTIME	1.6085	.61334	.376
Valid N (listwise)			

Source: Authors' calculation

The descriptive statistics result in table-1 shows that the average cargo throughput productivity of Onne Port per annum between 2007 and 2019 is 24967822.31 with a standard deviation of 3352316.820. The maximum and minimum cargo throughput output of the port was 29498840.00 and 17480233.00 in the years 2018 and 2009 respectively. It also shows that the aggregate cargo throughput productivity of the port over the 13 years period is 32481690.00. In a similar manner, the average ship traffic productivity of the Port per annum between 2007 and 2019 is 753.615 vessels with a standard deviation of 76.15. The maximum and minimum ship traffic productivity was achieved as 885.00 and 659.00 in the years 2011 and 2016 respectively; giving a range of 226.0 vessels. The aggregate ship traffic productivity of the port over the period is 9797.00 vessels. The aggregate effort (man-hours) expended by all sections of port operations in achieving the outputs between 2007 and 2019 is 113880.00 man-hours, and an average of 8760 man-hours per annum. This translates to a mean of about 2850.20. Tons of cargo worked by the Port per man-hour (2850.20 ton/hour) in all sections in Onne Port and about 0.087 vessels worked per hour in port over the period covered in the study. The average mean number of days vessels spent at berths in Onne port over the period being worked is 3.1469 days with a standard deviation of 2.6801. The maximum and minimum days spent by vessels at berths being worked over the period is 4.80 days and 2.04 days respectively in years 2007 and 2014. Ship turnaround time, cargo dwell time, and vessel average time of awaiting berth; which are all indicators of maritime logistics performance have respective mean scores of 3.5885 days, 12.7692 days and 1.60 days with respective standard deviations of 1.4512, 1.7394 and 0.61334.

Table 2. Berth efficiency of onne port in handling ship traffic over the period covered in the study

Year	**Berth efficiency**
2007	4.20
2008	4.53
2009	5.35
2010	5.20
2011	4.44
2012	5.68
2013	8.18

2014	9.49
2015	6.85
2016	8.77
2017	7.84
2018	5.47
2019	7.47
Average efficiency	6.009

Source: Authors' calculation

Table2 shows the efficiency of the Port in handling ship at berth relative to the time at berth being worked (in days) which is referred to as berth efficiency measured by the ratio of ship traffic produced/handled by the port to the average time spend at berth. The berth efficiency of the Onne Port which measures the efficiency of the berth in turning out output within the limits of the average time vessels spend at berths, being worked in the port, shows an average score of 6.01 (601%). This indicates that, on the average, the Onne Port has a high level of berth efficiency showing that per unit time (in days expended working on vessels at berth) yields very higher output -- about 601% for expended effort. However, in years 2013, 2014, 2015, 2016, 2017, and 2019, the Port operated in berth efficiency levels higher than the average while in years 2007, 2008, 2009, 2010, 2011, and 2018, the Port had high level of berth efficiencies which were however less than that of the prevailing average over the period. The highest berth efficiency of 9.49 (949%) was recorded in the Port in the 2015 while the least berth efficiency in the use of port-time expended in turning out ship output 4.20 (420%) was recorded in 2007. These results corroborate the findings of references [16, 18, 19] using Data Envelopment Analysis (DEA).

Table 3. Relationship between berth efficiency of onne port in handling ship calls and maritime logistics performance in the port

	Mean	Std. Deviation	N
BERTHEFFICIENCY	6.4208	1.77607	13
InSHPTRTIME	6.6215	.09999	13
InCARGODWELLTIME	2.5377	.13875	13
InWAITINGTIME	.3777	.51960	13
InBERTHTIME	1.1054	.30165	13

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.983[a]	.966	.948	.40306	2.218

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	36.553	4	9.138	56.250	.000[b]
	Residual	1.300	8	.162		
	Total	37.853	12			

Coefficients[a]

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		

1	(Constant)	1.103	8.513		.130	.900
	InSHPTRTIME	1.667	1.183	.094	1.409	.196
	InCARGODWELLTIME	.193	1.126	.015	.171	.868
	InWAITINGTIME	.264	.228	.077	1.155	.282
	InBERTHTIME	-5.706	.517	-.969	-11.028	.000

Residuals Statistics[a]

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	3.8609	8.9368	6.4208	1.74531	13
Residual	-.43695	.55324	.00000	.32910	13
Std. Predicted Value	-1.467	1.442	.000	1.000	13
Std. Residual	-1.084	1.373	.000	.816	13

a. Dependent Variable: BERTHEFFICIENCY

Source: Authors' calculation

Table 3 above shows the relationship that depicts the effects of maritime logistics performance on the berth efficiency of Onne Port. The berth efficiency of the Port represents the ratio of the total ships handled in the berths to the average time the vessels were at berth being worked. The Table-3 shows that the coefficient of correlation R between the berth efficiency of the port and maritime logistics performance between 2007 and 2019 is 0.983 which indicates about 98% positive correlation between the berth efficiency of the Port in handling ship calls and the maritime logistics performance. The model shows the effect of maritime logistics performance measured by ship turnaround time, cargo dwell time, vessel waiting time and vessel time at berth on the berth efficiency of Onne Port in ship handling between 2007 and 2019 is:

InBERTHEFFICIENCY = 1.103+ 1.667InSHTRTIME + 0.193InCARGODWELLTIME + 0.264InWAITINGTIME -5.706InBERTHTIME + e

This implies that a unit annual increase in ship turnaround time in the port increases berth efficiency with regards to ship output productivity (number of ship calls handled) by 1.667 units while a unit increase in cargo dwell time also increases berth efficiency in the Port by 0.193 units. Similarly, a unit increase in vessel waiting time increases berth efficiency in the Port by 0.264 units while a unit increase in the average time spent by vessels at berth being worked decreases berth efficiency of the Port in handling of ship calls by 5.706 units. By implication, increasing ship turnaround time, vessel waiting time and cargo dwell time increases berth efficiency of the Port in ship handling while increasing vessel time at berth decreases berth efficiency in the port.

The coefficient of determination R^2 which measures the explanatory power of the model is 0.966. This indicates that about 97% variation in the berth efficiency of Onne Port in handling ship calls is explained by maritime logistics performance of the Port.

Table 4. Average scores of the productivity indicators and maritime logistics performance of lagos apapa port complex between 2007 and 2019

	N	Range	Minimum	Maximum	Sum

	Statistic	Statistic	Statistic	Statistic	Statistic
THRPUT	13	9096166.00	14813072.00	23909238.00	499690851.00
SHTR	13	509.00	1343.00	1852.00	19190.00
STRT	13	4.55	3.75	8.30	87.28
EFFORT	13	.00	8760.00	8760.00	113880.00
ATBERTH	13	1.21	3.39	4.60	54.18
AWAITIBERTH	13	1.59	.36	1.95	14.46
DWELLTIME	13	8.00	15.00	23.00	250.00
Valid N (listwise)	13				

Descriptive Statistics

	Mean		Std. Deviation
	Statistic	Std. Error	Statistic
THRPUT	38437757.7692	882900.31301	3183342.34969
SHTR	1476.1538	42.52538	153.32745
STRT	6.7138	.40513	1.46072
EFFORT	8760.0000	.00000	.00000
ATBERTH	4.1677	.09552	.34439
AWAITIBERTH	1.1123	.13941	.50266
DWELLTIME	19.2308	.64205	2.31495
Valid N (listwise)			

Source: Authors' calculation

The descriptive statistics result in Table 4 shows that the average cargo throughput productivity of Lagos Apapa Port per annum between 2007 and 2019 is 38437757.7692 with a standard deviation of 3183342.35. It also shows that the aggregate cargo throughput productivity of the Port over the 13 years period is 499690851.00. In a similar manner, the average ship traffic productivity of the Port per annum between 2007 and 2019 is 1476.1538 vessels with a standard deviation of 153.32745. The maximum and minimum ship traffic productivity was achieved as 1852 and 1343 in the years 2019 and 2008 respectively; giving a range of 509.00 vessels. The aggregate ship traffic productivity of the Port over the period is 19190.00 vessels. The aggregate effort (man-hours) expended by all sections of Port operations in achieving the outputs between 2007 and 2019 is 113880.00 man-hours, and an average of 8760 man-hours per annum. The average mean number of days vessels spent at berths in Lagos Apapa Port over the period being worked is 4.1677days with a standard deviation of 0.34439. The maximum and minimum days spent by vessels at berths being worked over the period is 4.60 days and 3.39 days respectively in years 2009 and 2007. Ship turnaround time, cargo dwell time, and vessel average time of awaiting berth, which are all indicators of maritime logistics performance, have respective mean scores of 6.7138 days, 19.2303 days and 1.1123 days with respective standard deviations of 1.46072, 2.315 and 0.50266.

Table 5. Berth efficiency of lagos apapa port complex in handling ship traffic ship time at berths (days) over the years

Year	**Berth efficiency**
2007	13.55
2008	12.95
2009	10.93
2010	11.54
2011	11.51
2012	12.13
2013	11.75
2014	11.58
2015	11.11
2016	11.98
2017	11.65
2018	11.62
2019	11.78
Average	11.85

Source: Authors' calculation

Table 5 shows the efficiency of the Port in handling ship at berth relative to the time at berth being worked (in days) is referred to as berth efficiency measured by the ratio of ship traffic produced/handled by the Port to the average time spent at berth. The berth efficiency of the Lagos Apapa Port which measures the efficiency of the berth in turning out output within the limits of the average time vessels spend at berths, being worked in the Port; shows an average score of 11.85 (1185%). This indicates that on the average, the Lagos Apapa Port has a high level of berth efficiency showing that per unit time in days expended working on vessels at berth yields very higher output -- about 1185% for expended effort. However, in years 2007, 2008, 2012, and 2016, the Port operated at berth efficiency levels higher than the average while in the other years, the Port though had high level of berth efficiency, but each was lower than that of the prevailing average of 11.85 over the period. The highest berth efficiency of 13.55 (1355%) was recorded in the Port in the year 2007 while the least berth efficiency in the use of port time expended in turning out ship output 10.93 (1093%) was recorded in 2009. These results corroborate the findings of [21, 23, 24] using Data Envelopment Analysis (DEA). The result of the efficiency of Lagos Apapa Port Complex above was further used as the dependent variables in assessing the effects of maritime logistics performance on the berth efficiency of Lagos Apapa Port as shown in subsequent tables below.

Table 6. Relationship between berth efficiency of lagos apapa port in handling ship calls and maritime logistics performance in the port

	Mean	Std. Deviation	N
BERTHEFFIC	11.8519	.70555	13
InSTRT	1.8783	.24722	13
InATBERTH	1.4240	.08695	13
InAWAITIBERTH	-.0066	.52190	13

InDWELLTIME	2.9496	.12371	13

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.997[a]	.993	.990	.07012	2.477

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	5.934	4	1.484	301.697	.000[b]
	Residual	.039	8	.005		
	Total	5.974	12			

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	23.320	.583		40.001	.000
	InSTRT	.252	.128	.088	1.971	.084
	InATBERTH	-8.535	.359	-1.052	-23.752	.000
	InAWAITIBERTH	-.041	.043	-.030	-.951	.369
	InDWELLTIME	.072	.210	.013	.345	.739

Residuals Statistics[a]

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	10.9491	13.4700	11.8519	.70322	13
Residual	-.08416	.07680	.00000	.05726	13
Std. Predicted Value	-1.284	2.301	.000	1.000	13
Std. Residual	-1.200	1.095	.000	.816	13

a. Dependent Variable: BERTHEFFIC

Table 6 above shows the relationship that depicts the effects of maritime logistics performance on the berth efficiency of Lagos Apapa Port. The berth efficiency of the port represents the ratio of the total ships handled in the berths to the average time the vessels were at berth being worked. Table-6 shows that the coefficient of correlation R between the berth efficiency of the Lagos Apapa Port and maritime logistics performance between 2007 and 2019 is 0.997 which indicates about 100% positive correlation between the berth efficiency of the Port in handling ship calls and the maritime logistics performance. The model showing the effect of maritime logistics performance measured by ship turnaround time, cargo dwell time, vessel waiting time and vessel time at berth on the berth efficiency of Lagos Apapa Port in ship handling between 2007 and 2019 is:

InBERTHEFFICIENCY = 23.320 + 0.252InSHTRTIME + 0.072InCARGODWELLTIME - 0.041InWAITINGTIME -8.535InBERTHTIME + e

This implies that a unit annual increase in ship turnaround time in the Lagos Apapa Port increases berth efficiency with regard to ship output productivity (number of ship calls handled) by 0.252 units while a unit increase in cargo dwell time also increases berth efficiency in the Port by 0.072 units. Also, a unit increase in vessel waiting time decreases berth efficiency in the Port by 0.041 units while a unit

increase in the average time spent by vessels at berth being worked decreases berth efficiency of the Port in handling of ship calls by -8.535 units. By implication, increasing ship turnaround time, and cargo dwell time in Lagos Apapa Port increases berth efficiency of the Port in ship handling while increasing vessel time at berth and waiting time decreases berth efficiency in the Lagos Apapa Port.

The coefficient of determination R^2 which measures the explanatory power of the model is 0.990. This indicates that about 99% variation in the berth efficiency of Lagos Apapa Port in handling ship calls is explained by maritime logistics performance of the Port.

The section 4.3 below shows the test of the hypotheses of the research to determine the significances of the effects of each indicator of maritime logistics performance on port efficiency in each of Onne and Lagos Apapa Port Complexes which handles significant cargo and ship traffic in Nigeria.

4.3 Hypotheses

Table 7. Test of h_{02a}: there is no significant effect of maritime logistics on the berth efficiency of onne port in handling ship calls within the port

Hypotheses	**F-cal.**	**F-critical**	**p-value/sig.**	**Decision**
H_{03}	29.973	3.68	0.000[b]	Reject ***H_{03}***
Variable	**t-cal.**	**t-critical**	**p-value/sig.**	**Decision**
InSHPTRTIME	10.566	1.75	.000	Significant
InCARGODWELLTIME	-.065	1.75	.949	Not significant
InWAITINGTIME	.640	1.75	.540	Not significant
InBERTHTIME	.601	1.75	.565	Not significant

Source: Authors' calculation. Reject *null hypotheses if F-cal. > f-critical; Accept null hypotheses if F-cal.< F-critical*

The test of hypothesis H_{02a} in Table 7 above shows F-score of 29.973, F-critical of 3.68, and p-value of 0.000. Since F-score is greater than F-critical, (29.973> 3.68), the study rejects the null hypothesis H_{02a} and accepts the alternate. The study infers that there is significant effect of maritime logistics performance on the efficiency of Onne Port in handling ship calls in the Port between 2007 and 2019.

Similarly, t-test was conducted to investigate the significance of the individual effects of the maritime logistics performance indicators -- ship turnaround time, cargo dwell time, vessel waiting time, and vessel time at berth on the ship output efficiency of the Port over the 13 years covered in the study. As shown in the table above, only ship turnaround time have t-cal. score greater than t-critical (10.566>1.75). Thus, only ship turnaround time has significant effects on the efficiency of Onne with regard to handling of ship calls in the Port. Vessel waiting time, cargo dwell time and vessel time at berth, all have t-cal. less than 1.75 (0.640<1.75; 0.065<1.75; and 0.601<1.75). Therefore, these have no significant effects on the efficiency of the Port in handling ship calls between 2007 and 2019.

Table 8. Test of H_{02b}: There is no significant effect of maritime logistics on the berth efficiency of Lagos Apapa Port Complex Nigeria

Hypotheses	**F-cal.**	**F-critical**	**p-value/sig.**	**Decision**
H_{04}	301.697	3.68	0.000[b]	Reject ***H_{04}***
Variable	**t-cal.**	**t-critical**	**p-value/sig.**	**Decision**
InSHPTRTIME	1.971	1.75	.084	Significant
InCARGODWELLTIME	0.345	1.75	.739	Not significant
InWAITINGTIME	-0.951	1.75	.369	Not significant
InBERTHTIME	-23.752	1.75	.000	Significant

Source: Authors' calculation. Reject *null hypotheses if F-cal. > f-critical; Accept null hypotheses if F-cal.< F-critical*

The test of hypothesis H_{02b} in Table 8 above shows F-score of 301.697, F-critical of 3.68, and p-value of 0.000. Since F-score is greater than F-critical, (301.697>3.68), we reject the null hypothesis H_{02b} and accept the alternate. We conclude that there is significant effect of maritime logistics performance on the berth efficiency of Lagos Apapa Port between 2007 and 2019.

Similarly, t-test was conducted to investigate the significance of the individual effects of the maritime logistics performance indicators -- ship turnaround time, cargo dwell time, vessel waiting time, and vessel time at berth on the ship output efficiency of the Port over the 13 years covered in the study. As shown in Table-8 above, both ship turnaround time performance and average time spent by vessel at berth while being worked have t-cal. score greater than t-critical (1.971>1.75; 23.752>1.75). Thus, both ship turnaround time and the average time spent by vessel at berth have significant effects on the berth efficiency of Lagos Apapa Port. Vessel waiting time, and cargo dwell time have t-cal. less than 1.75 (0.345<1.75; 0.951<1.75). Therefore, they have no significant effects on the berth efficiency of the Lagos Apapa Port between 2007 and 2019.

5. Conclusion

The maritime logistics performance has significant effects of the berth efficiency of the Onne and Apapa Ports in handling ship calls to the Ports over the period covered in the study.

Ship turnaround time has significant effects on the berth efficiency of Lagos and Onne with regards to handling of ship calls in the port.

The findings of the study have bridged the knowledge gaps and addressed the research focus by providing the empirical models of relationship between berth efficiency and ship turnaround time, cargo throughput and cargo dwell time in Nigerian ports of Lagos Apapa and Onne. These models now form the basis for achieving future improvements in berth efficiency by proactively influencing the trends of ship turnaround time, cargo dwell time, ship traffic calls and cargo throughput performances of the ports. It also provides the basis for the development of algorithms for digitalizing port operations with the aim of improving berth efficiency as a new area of focus for future research.

Finally, there are significant effects of maritime logistics performance on ship output efficiency and berth efficiency in both Lagos Apapa Port and Onne Port in Nigeria.

6. Recommendations

It is recommended among other things, in line with the findings of the study that:

1. Since the result indicates that increasing waiting time causes decline in berth efficiency in handling of ship calls to the port, the Nigerian Ports Authority (NPA) in Lagos Apapa Port and Onne Port as well as the terminal operators such as Integrated Logistics Services Nigeria Limited (INTELS), West African Container Terminals (WACT), Brawal Oil Services Limited, among others, in order to improve the berth efficiency in handling ship calls to the berths should develop and implement berth management strategies that will lead to declining trend in ship waiting time.
2. In order to improve the berth efficiency of the Port, the NPA, INTELS, Brawal and other terminals operators should target to achieve a declining trend in the average times vessels spend at berth while being worked.

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