

**ESTIMATION OF COST OF DELAYS ON VESSEL OPERATIONS IN CONTAINER  
TERMINALS OF NIGERIAN SEAPORTS**

**BY**

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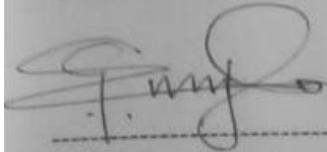
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## CERTIFICATION

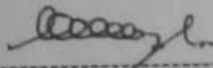
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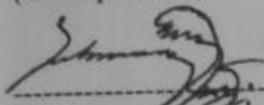
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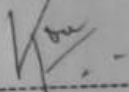
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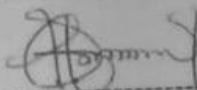


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## **DEDICATION**

I dedicate this work to God Almighty for his faithfulness in seeing me through the difficult times during this program.

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## Abstract

The study evaluated the cost of delays on vessel operations in container terminals of Nigerian seaports. The objectives of the study are to estimate the average delay in vessel operations in Nigerian ports container terminal, to estimate the economic cost implications of delay in vessel operations in Nigeria container terminals, determine the average service rate of vessel at berth in Nigerian ports container terminal, derive the container terminal utilization coefficient of Nigeria ports, model the relationship between delay in vessels operations and trend of shipping operations in Nigeria container terminals, determine the effect of cost of delays on trend of shipping operations in Nigerian container terminals and to measure the extent of port users satisfaction with port operations relative to the extent of delay in vessel operations in container terminals in Nigeria. The study used a mixed design method consisting of the use of both secondary data and primary data obtained from survey. The major container terminals in Onne, Rivers, Tin Can Island and Apapa ports were used to carry out the study. Secondary data on ship turnaround time of vessels at the terminals, vessel traffic calls to the terminals, TEU throughput trade handled at the terminals, berth occupancy rates of the terminals Gross Registered Tonnage (GRT) of vessels worked at the terminals, and tariff and charges for vessels operations in each port terminal were obtained from the Nigerian Ports Authority (NPA) statistical reports. Each dataset covered a period of 16 years from 2007 to 2022, representing the port concession era in the Nigerian port sector. Primary data on the level of port users' satisfaction with the services of the terminals relative to the extent of delay in ship operations in the port terminals was obtained by the use of questionnaires as survey instrument. The study used the queuing model, customer satisfaction and loyalty index, Log-linear multiple regression analysis and descriptive cum inferential statistics to analyze the data. The findings of the study reveal that the ship operators experienced annual average of between 2.8 days and 14 days delay in vessel operations in the Nigerian port sector between 2007 and 2022. The Nigerian economy lost an average of USD 26935.33 per annum between 2007 and 2022 in the port sector with standard deviation of 11468.24, as result of delay in vessel operations in the container terminals in Tin Can Island port, Apapa port, Rivers port and Onne port. The container terminal utilization coefficient of the Onne, Tin Can Island, Apapa and Rivers are 99%, 99%, 99.5% and 96% respectively. The findings of the study also indicate an average port user's satisfaction score of 54.38% with standard deviation of 31.623 relative to the extents of delay in vessel operations in Nigerian port sector. There is significant effect of cost of delays in Vessels Operations on Trend of Container Shipping Operations in Nigerian Container Terminals. The study recommended that terminal operators and port management should comply with the 2days ship turnaround benchmarks operational in global ports in order to reduce the economic cost of delay imposed by vessel operations delay in the Nigerian port sector.

**Keywords:** *seaports, container-terminals, vessel-operations, delay-cost,*

## CHAPTER ONE

### INTRODUCTION

#### 1.1 Background Information

In recent years Nigeria port industry has been transformed in phases through various policy reform strategies to achieve efficiency, productivity and competitiveness in port terminal operations to best practice in the global maritime commerce (Kareem, 2010). Today, the port industry has been privatized to various private organizations who provide basic port functions such as ship and cargo handling services and pay loyalty to the Nigerian Ports Authority (NPA) under Landlord port management model. According to Katsarova, (2013), Landlord port model is a management approach whereby the ports authority owns the basic infrastructure, leasing them out to private operators, mostly on a long-term concession basis (25-30years), while retaining all regulatory functions in the port. In a landlord model, the basic factors of port terminal operations such as dock labour, berths, cranes, warehouse, trucks services etc., are managed by private terminal operators in Nigeria ports.

Port operations refer to the range of activities involved in the management and handling of vessels, cargo, and passengers at a seaport. These operations are critical to the efficient functioning of seaports, which plays a crucial role in global trade and commerce. Port terminal operations are array of duties or services legally provided by the local port industry to port users in order to receive reward in terms of monetary gain from the users of those services. Port operations are set of activities/services which the port industry provides through the experts (Concessionaires) to satisfy the port users. Cost effective and efficient port operations fosters cargo throughput, vessel turnaround time, vessel traffic volume, berth occupancy etc., which are the basic factors used for performance rating of the port industry. Port terminal operations include:

Ship operations: these are the services provided by the port industry to a calling vessel. It involves various activities such as pilotage service, tug service, mooring service and onboard cargo handling services. These are important services which the port industry either by the private operators or the port authority provides to the vessel owner or his agent at the port of call in which payments are made according to prescription.

Cargo operations: these are services rendered on import or export cargoes. Cargo operations are the array of legal services the port industry provides for safe and efficient delivery of cargo at the port. It involves custom examination, warehousing, crane services, stevedores, etc., provided by the port industry to the cargo owner or his agent at the port which payments are made according to prescription. Passenger operations involve the handling of passengers, including embarkation and disembarkation, immigration and customs clearance, and passenger safety and security at the local ports.

In Nigerian ports today, terminal operations are carried out by private companies (concessionaires), who provide and maintain their own superstructure including cargo-handling equipment at the terminals. The concessionaires provide services to port users at a given cost. Port Cost is the price paid for using port facility (Ugboma, Ibe and Ogwude, 2014). It is measured by services provided in a unit time period. Port Cost is monetary value attached to a product, goods or services provided by the port operators. Delay at the port occurs when a calling vessel cannot berth due to backlog of vessels awaiting berthing space or vessels at the berths are awaiting loading or discharging. Port delays are disruption in terminal operations that can give rise to increase in cost due to long awaiting time at the ports. Delays in handling vessels and containers can lead to congestion, overcrowded container yards, and high demurrage and detention charges. Nigeria port industry has pass through processes of development to ensure operational efficiency. Operations efficiency is the ratio of the input to run an operation and the output gained from the operation (Timothy, Coelli, Prasada, Christopher, Donnell and George, 2015). This definition took note of both port users and the port operators. Port is said to operate efficiently when the operational efficiency of both the users and operators are optimally achieved at a given time frame and cost. When operational efficiency is improved, the output to input ratio improves. Globally, ports industries are faced with challenges of new technology, globalization and competition (Othman, Al-Kake, Diah, Othman and Hasan, 2019). To meet customers' desire, port industry must ensure a satisfactory service delivery. A port could only continue to be relevant to customers if it operates with minimum delay, utmost efficiency and at a reasonable cost to users (Port Technology, 2017).

There are so many factors militating against efficient running of Nigerian ports, before the concession in 2006, Nigerian port system was a public port run by Federal government budgetary allocation, which made the ports suffer from inadequate infrastructural development which caused delays, high service cost and epileptic operations in the ports (Nwokedi, Emeghara and Ikeogu, 2021), this was as a result of insufficient budgetary allocation, late release of budget finance for

development port projects. Adebayo (2015) observes that the problem of delay was cumbersome cargo clearing system in Nigerian ports. According to Adebayo (2015) the cargo clearing procedure which depends on manual transactions i.e., physical movements of documents to and from various processing centers across locations within and outside the ports was tedious and obsolete. Uzoanya (2020) concludes that the presence of so many government agencies in the port cause a lot of bottleneck in cargo clearance process which results into delays and financial extortion and high cost of doing business at the ports. Gwandu (2020) refers that the inability of Nigerian ports to deliver customer friendly services is as result of delays fostering corrupt practices vice versa, at the ports. According to Gwandu (2020), corruption is the greatest viral disease the ports in Nigeria have to tackle in order to remain relevant in the global maritime industry. In his paper titled “Eradication of Corruption and Sharp Practices in the Seaports,” he points that Nigeria aspiration of serving as a hub centre through her ports and playing a leading role in maritime industry in the West and Central African sub-region can only be achieved in an atmosphere devoid of corrupt practices and this situation can only be achieved under an atmosphere of transparency, accountability and commitment to universally accept ethical standards which will lead to universally accepted operational standard in terms of port costs and operational delay in the ports. Emeghara (2012), posits that the issues of delays in Nigeria ports have shifted from berth scarcity-related to cargo-service problems. This informs that delays as witnessed in Nigerian ports are related to service time of ships at berth rather than waiting to service time. This is as a result of massive investment and port expansion projects by the concessionaires whereby more berths were built to accommodate vessels at the ports, however, delays at the ports is attributed to both waiting time/queuing time and service time at the ports (Emeghara, 2012).

## **1.2 Problem Statement**

Operational delays and inefficiency of vessel management at port container terminals could be an obstacle to increasing shipping trade, particularly for a developing country like ours. The ports have the challenge to keep pace with the rate of expansion of the overseas and coastal shipping trade. Demand for port services especially terminal operations of container ports is on increase globally with rise in population and industrialization which Nigeria is not an exception. Presently in the era of port concession, Nigeria ports still experience delays caused by many factors described in Emeghara, (2012); Nze and Onyemaechi (2018) to include administrative bottleneck, deliberate attempt by port workers to extort money from port users, and corrupt practices at the ports etc., a situation that has jeopardized the growth of the ports industry in the era of ports concession. Port

congestion or delays at the ports is a problem that affects efficiency levels, performance and productivity of seaports (Nze and Onyemaechi, 2018). According to Nwokedi, Emeghara, and Ikeogu, (2015), there are yet cases of capital flight whereby importers prefer using the neighbouring ports of Cotonou, Benin and Lome to Nigeria ports.

These problems were attributed to unnecessary delays in vessel turnaround time, custom clearance, high cost of cargo clearance, stringent government policies and corrupt practices in the port industry (Nwokedi, Emeghara, and Ikeogu, 2015), hence, the following remains relevant by the submission of Gwandu (2015) as reasons why delays persist in Nigerian ports which include: - Cumbersome documentation system; Deliberate delay in performing official duties in order to elicit gratifications; Incursion of miscreants into the ports thus jeopardizing port security and vandalism of port and navigable facilities such as buoys and use of wreck vessels on the sea routes to deter ships from accessing the entry channel; indiscriminate litigation and the resultant high incidence of detention of vessels at the berths, thus delaying incoming vessels and prolonging the average turnaround time of vessels at the ports; change in shipping policy whereby adequate logistics are not put in place for the adoption of the new system before announcement or introduction, the resultant bottleneck and problems cause delays and often scare shippers who divert their shipment to neighboring ports. These changes in policy often put custom officials as well as importers into confusion and before they could realize themselves, congestion may result at the port due to delays. These challenges are the causes of delays and the high operational cost suffered by ship and cargo owners in Nigerian ports and also the reasons for cargo diversion.

Delay in vessel operations in container terminals in Nigeria port has remained a serious issue cause port congestion and delay in the processing of seaborne trade in Nigeria over the years. This has equally been associated with increase port cost and port user dissatisfaction with the operations and practices in most container terminals in Nigeria. It generally viewed that delay in ship operations in any given port, for example Nigerian port, have severe negative impacts on the value of seaborne trade processed in Nigeria port terminals, port cost, commodity price inflation, trend of unemployment, ship call to Nigeria ports, trend of ship turnaround time, container terminal utilization rate, among other port economic variables. However, available empirical literature has seemingly failed to provide empirical evidence of the extent and significances of these identified impacts of delay in vessel operations in Nigerian container terminal. Available literature seems to also suggest that increasing trend in shipping trade and ship calls to the container terminals, without similar increase in infrastructural provision in the port terminals is responsible for increasing delay

in vessel operations in the port terminals. The extent to which increasing shipping trade and ship calls to the terminal influence delay has not be determined in any empirical study.

This has remain a problem because without the empirical information on the extent and significances of delay in vessels operations in Nigerian container terminals, it is difficult for port operations policy to developed to reverse the adverse effects of delay in vessel operations in Nigeria ports. To overcome this problem, the need for the provision of empirical information to bridge the gap in knowledge of what constitute the extent of delay in vessel husbandry operations in Nigerian container terminals and the associated cost implications on of Nigeria's seaborne trade, ship calls to Nigerian ports, container trend of ship turnaround time, container terminal utilization rate, among other economic variables for measuring port operations need to be determined for purposes of developing port and container terminal operations policies that limits the impacts of delay on the Nigerian port logistics sector. These are the problems which this study is designed to actualize.

### **1.3 Aim and Objectives of the Study**

The aim of the study is to estimate cost of delays in vessel operations in container terminals of Nigerian seaports, whereas, the specific objectives include to:

1. Estimate the average delay in vessel operations in Nigerian ports container terminal.
2. Estimate the economic cost and implications of delay in vessel operations in Nigeria container terminals.
3. Determine the average service rate of vessel at berth in Nigerian ports container terminal.
4. Find the optimal service rate of ships in Nigerian ports container terminal.
5. Derive the container terminal utilization coefficient of Nigeria ports.
6. To model the relationship between delay in vessels operations and trend of shipping operations in Nigeria container terminals
7. Determine the effect of cost of delays on trend of shipping operations in Nigerian container terminals.
8. To measure the extent of port user's satisfaction with port operations relative to the extent of delay in vessel operations in container terminals in Nigeria.

## 1.4 Research Questions

1. What is the extent of delay in vessel operations in Nigerian ports container terminals?
2. What is the economic cost implication of delay in vessel operations in Nigeria container terminals?
3. What is the average service rate of vessel at berth in Nigerian ports container terminal?
4. What is the optimal service rate of ships in Nigerian ports container terminal?
5. What is the container terminal utilization coefficient of Nigerian ports?
6. Is there a significant relationship between delay in vessels operations and trend of shipping operations in Nigeria container terminals?
7. What is significant effect of cost of delays on trend of shipping operations in Nigerian container terminals?
8. What is the extent of port user satisfaction with the operations of the ports relative to the extent of delay in vessel operations in the port?

## 1.5 Hypotheses

**H<sub>01</sub>:** There is no delay in vessel operations in Nigerian ports container terminals.

**H<sub>02</sub>:** The economic cost implications of delay in vessel operations in Nigeria container terminals is zero.

**H<sub>03</sub>:** The coefficient of the average service rate of vessel at berth in Nigerian ports container terminal is zero.

**H<sub>04</sub>:** The optimal service rate of ships in Nigerian ports container terminal is zero.

**H<sub>05</sub>:** The container terminal utilization coefficient of Nigerian container ports is zero.

**H<sub>06</sub>:** There is no significant relationship between delay in vessels operations and trend of shipping operations in Nigeria container terminals

**H<sub>07</sub>:** There is no significant effect of cost of delays on trend of shipping operations in Nigerian container terminals

**H<sub>08</sub>:** The extent of port user satisfaction with the operations of the ports relative to the extent of delay in vessel operations in the port is less than 40%.

## **1.6 Scope of the Study**

**Time scope:** The secondary data collected for the study covered a period of 16 years from 2007 to 2022. The time scope of the data is thus between 2007 and 2022 covering the period over which data was collected.

**Geographical Scope:** The study covered the Eastern ports of Onne and Port Harcourt; also, the busiest Western ports of Lagos Apapa and Tin Can Island Ports from which secondary data was generated.

**Theoretical Scope:** The theories considered for the study were Bureaucratic Management Theory, Traffic Congestion Theory, Resources Based Theory and Queue Theory, which were the basis for the application of the estimation models to determine the cost of delays associated with vessel operations in container terminals in Nigerian ports as well as ship arrival rate, queue length, port service rate, berth utilization, optimality of terminal utilized, the container terminal utilization coefficient, the ship queuing costs, the cost of idle berth (berth non-occupancy) in container terminals and the effect of cost of delays on container terminal output.

## **1.7 Justification of the Study**

This study is focused on estimation of cost of delays on vessel operations in container terminal of Nigerian Seaports. The study is very relevant and timely in this era of competitive shipping trade among African Nations. The study would be informative and significantly useful in Nigeria maritime industry. Port operators, shipping companies, ship-owners and general public will find the research results very resourceful and useful for decision making. The review of literatures would provide good knowledge and instances on delay factors in Nigeria port container terminal and ways to mitigate the challenges. The findings of this study will provide information on service waiting time of vessel at berth; length of time vessel spend on queue and cost on delay of vessel in Nigeria ports container terminal. The research would provide useful guide to solve the problems of port operational delay in Nigeria ports container terminal.

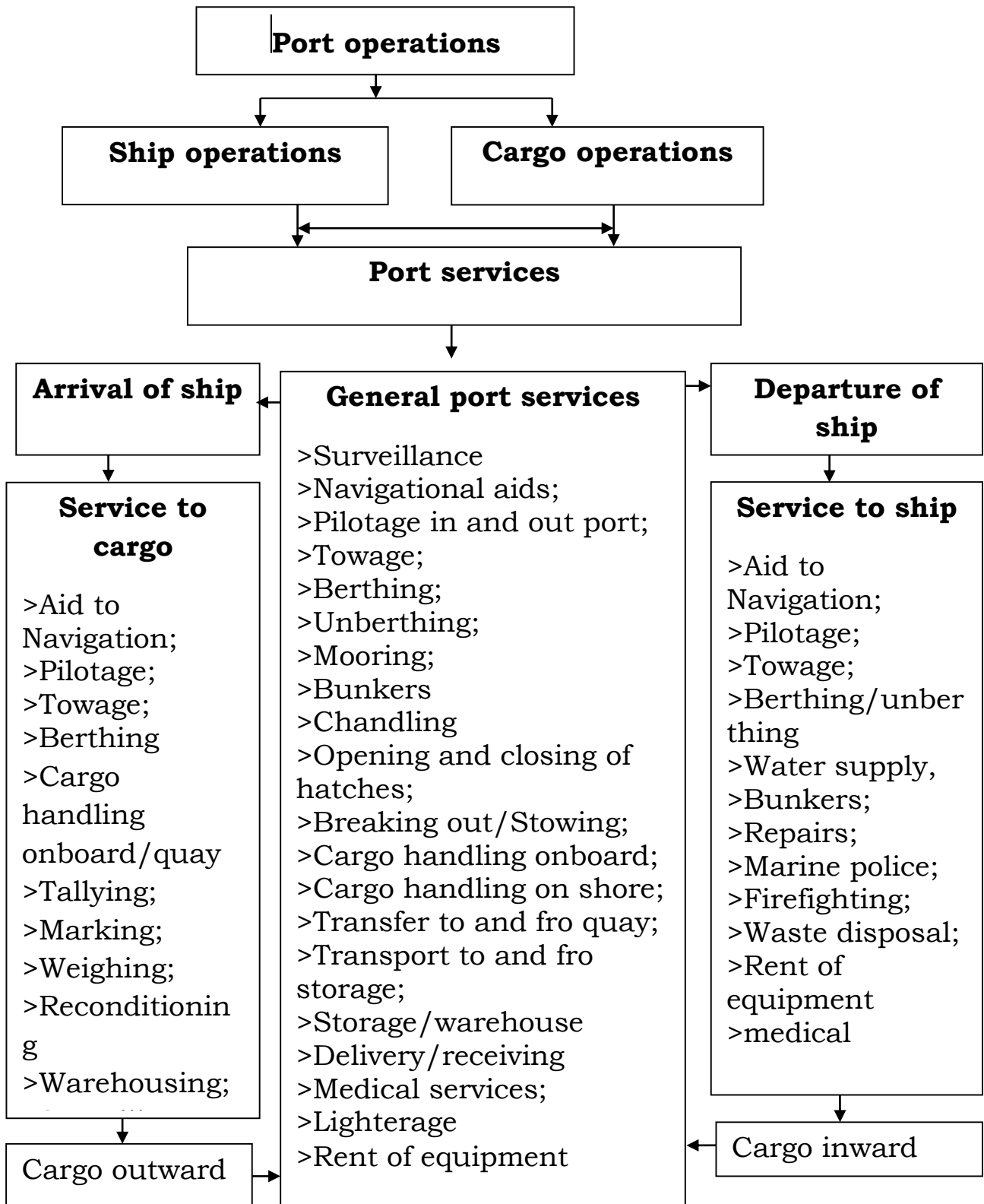
## **CHAPTER TWO**

### **LITERATURE REVIEW**

#### **2.1 Conceptual Review**

A seaport is an important interface between various modes of transportation. It plays vital roles in the movement of ships and cargoes in which the port organization or port operators are required to provide various services to enable smooth flow of commercial functions of the port industry. The Maritime operations is a complex system/structure that comprises both the ship and cargo operations and these operations involve activities that make use of resources in terms of labour, equipment and other port facilities to provide the basic port functions and services which attract payment on rendering such services to shipping companies and other port users.

Port operations are those activities carried out on vessels and cargoes at the port for effective berthing, loading, discharging and other necessary services that may be required by vessel and cargo at the port terminals. Port operations can be classified into two basic operations which are; Ship operations and Cargo operations. The diagram below shows the basic port functions and services provided by ports industry to ensure effective and efficient ship and cargo operations in the port system.



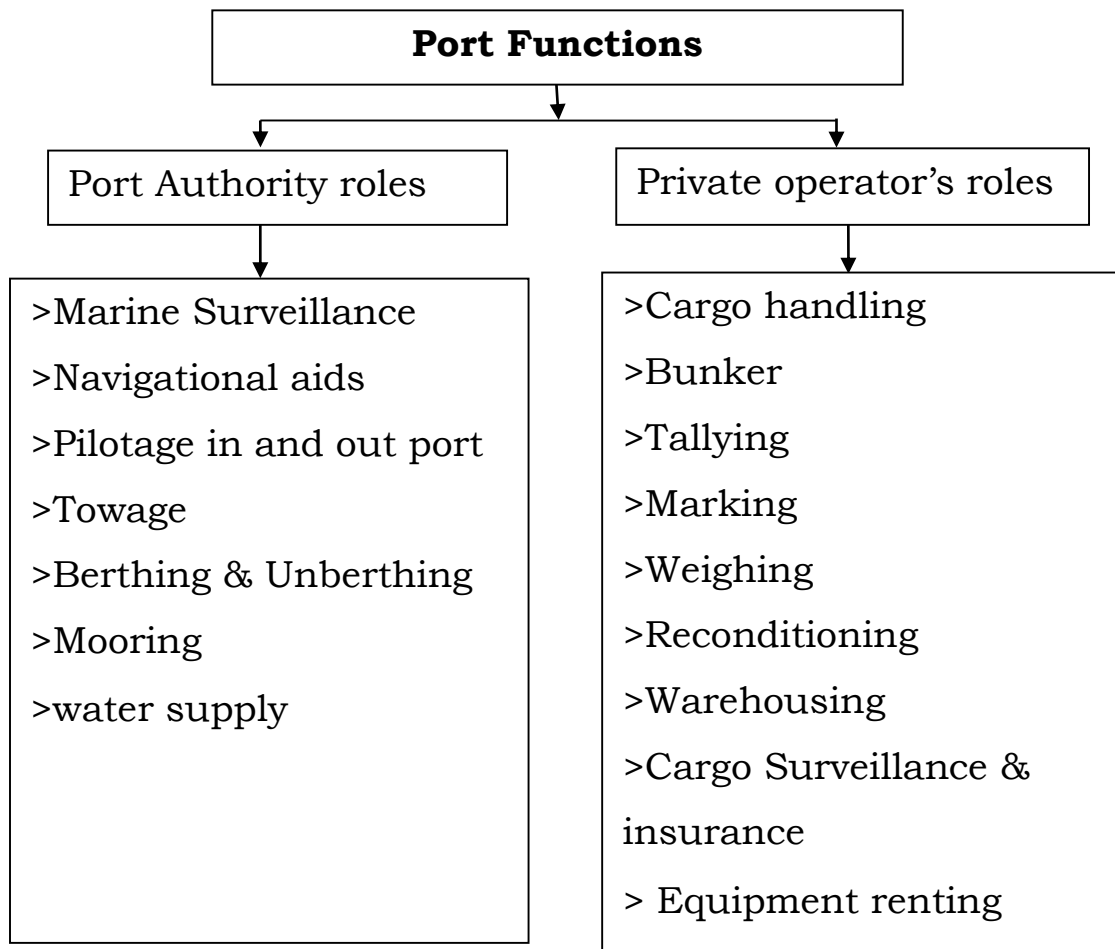
**Fig. 2.1: Diagrammatical Representation of Port Operations**

Source: Developed by the Researcher

The port authority and private operators respectively provide the above functions to cargoes and vessels coming into the port and those leaving the port.

Delay is one factor that affects the effectiveness and efficiency of port terminal operations. Delay occurs when there is overlap or backlog on the activities resulting from terminal operations and NPA workers negligence of duty, as noted in Emeghara (2012), that delays in the port industry has shifted from time waiting to berth rather time waiting in service. Maritime activities are such that is very sensitive to time as it is always said that there is no idle time in shipping which implies that ship incur costs at every point in time.

Ship delay at the ports attracts additional cost on the part of ship and cargo owners. Port functions can be classified into two distinct roles in a landlord port model. In Nigerian ports especially, the basic port functions are clearly defined and classified between the port authority and the concessionaires. There are some provisions by law and regulations of the port industry that allow the port authority the right and sole responsibility to carry out some port functions while the roles of the private concessionaires are primarily on terminal operations on ship and cargo handling services. The classifications of the port basic functions are demonstrated on the Figure 2.2 below:



**Fig. 2.2: Diagrammatical Representation of Basic Port Functions**

**Source:** Developed by researcher

### **2.1.1 Nigeria Port Authority (NPA)**

The Nigerian Ports Authority was established by the federal government following the Act of 1954 and commenced operation in April 1955. The Nigeria ports at incision was managed as a public corporation comprising only the Lagos and Port Harcourt ports which were the first two established ports. The Lagos pier was the first establish by Portuguese (the Colonial masters) to transport the artifact such coals, graphite and cash crop from Nigeria to foreign country (Europe) as export commodities and the Port Harcourt (Rivers port) was later opened to support the Lagos port to handle excess cargoes and trade follow. Later, other ports were developed such as Onne port, Warri port and Calabar port to support the crude oil exploration in the Eastern Nigeria. While Lagos and Port Harcourt ports were managed as a public corporation, others were managed as private companies under Nigeria n Ports Authority (Emeka 2016). The Nigerian Ports Authority has the sole responsibility to managing cargo handling, quay and berthing facilities at the Lagos and Port Harcourt ports, the initial law also gave it the responsibility of managing harbours and approaches to all ports in Nigeria (Emeka 2016). NPA accelerated the expansion of port facilities after the end of the cement armada which was the federal government-initiated project. The government built a new port, the Tin Can Island port with two Roll-on Roll-off (RoRo) facilities and also built a wharf in Apapa and expanded facilities at the Warri and Calabar ports. It also constructed three lighter terminals in Kiri Kiri, Onne and Ikorodu (Henry, 2016).

Not quite later, during the administration of president Olusegun Obasanjo, port reform program was initiated which brought a change of tide in port administration to improve the efficiency, productivity and competitiveness of the Nigerian ports. The consequent was the concession of the port terminals to private operators for a period of time between 25-30 years as contained the concession agreement. Based on this, the functions of the port are categorized: NPA will continue to act as the landlord and provide common user facilities, technical oversight and other marine services. The private operators will be involved in loading and offloading of cargoes at the terminals (Emeka, 2016).

However, the Nigerian Ports Authority was actually established for a particular purpose and the purpose is to regulate the activities of other stakeholder of Nigerian Ports, which are the operators of the ports. In other words, the Nigerian Ports Authority was designed to govern, as well as control the activities within the Nigerian Ports systems. As a federal government agency, it was empowered to oversee all operations within Nigerian Ports, some of these ports include, the Apapa

Port and Tin Can Island Port in Lagos; and Calabar Port in Cross River; Warri Port in Delta; Port Harcourt and Onne Ports in Rivers. The Nigerian Ports Authority is working under the direct supervision of the Federal Ministry of Transport, as well as, the Nigerian Shippers' Council. Through the activities and roles of the Nigerian Ports Authority, the ports within Nigeria have been more competitive, and as a result has helped increased the national resources, especially in the era of port concession (Eromosele, 2023).

Therefore, the following are the core roles and/or functions of NPA under the Act and applicable in the concession agreement:

**Nigerian Ports Authority is charged with the responsibility of administering operations within the Nigerian Ports limits:**

One of the major functions of the Nigerian Ports Authority is to administer the operations within Nigerian Ports, and this include administration of water, as well as the land within the Nigeria Ports limits. The Nigerian Ports Authority was empowered to oversee every activity within the ports limits as permitted by the Act that saw to its establishment. Therefore, it was under its power to making sure that its statutory responsibilities and carried out efficiently and effectively with a view to making sure that, the purpose for which they Nigerian Ports Authority was established is actualized.

**Operational Infrastructure in Nigeria Ports are developed and owned by the Nigerian Ports Authority:**

For the purpose of meeting the mandate of the Nigerian Ports Authority, there is need for the operational infrastructure within the Nigeria Ports to be up to date, and possibly upgraded. Therefore, it is incumbent on the part of the Nigerian Ports Authority to ensure that, every operational infrastructure within the ports limits is developed. Besides developing operational infrastructure within the ports, the Nigerian Ports Authority is expected to undertake quality planning of these operational infrastructure within the ports before embarking on developing these infrastructures, because when there is such quality planning, there is bound to be proper development of operational infrastructure thus, the statutory responsibilities of the Nigerian Ports Authority would be made easy.

### **The Nigerian Ports Authority sets benchmark for tariff structure:**

It is the function of the Nigerian Ports Authority to making sure that, benchmark for tariff structure is set. It is true that there is a kind of scheme of duties, a revenue tariff imposed by a federal government agency, such as the Nigerian Ports Authority on goods imported into Nigeria and goods exported out of Nigeria, and a good number of products used in Nigeria particularly, foreign goods are coming through the Nigerian Ports, they are shipped into the country through water, and there are some locally made goods from Nigeria, which have gained market share overseas, and these goods leaved Nigeria shore through Nigeria Ports. Therefore, since the purpose of establishing Nigerian Ports Authority was to administer the operations of the Nigeria Ports, it is therefore, a part of Nigerian Ports Authority (NPA) function to set benchmark for tariff structure imposed on goods.

### **The Nigerian Ports Authority undertakes Nautical and Harbour Operations:**

The major function of the Nigerian Ports Authority revolves around the administration of the operations within the Nigeria Ports limits, and this include the water and the land. Therefore, if water operation is involved, it simply means that, the NPA is responsible for operations, such as nautical operations, which has to do with water navigation and shipping, as well as other operations like hydroelectric survey. This is vital to the operations of the NPA.

### **The Nigerian Ports Authority maintains safety and security within the Nigerian Ports:**

Security of lives and goods of every participants in the Ports is very vital, it is the responsibility of the NPA to ensure that there is safety in the Nigerian seaports. It is the function of the Nigerian Ports Authority to maintain security and ensure safety within the Nigerian Ports limits particularly, where there is heavy duty or the busiest area of the Nigerian Ports. However, whatever the case may be, without the maintenance of order, security and safety in the Ports, the Nigerian Ports Authority perhaps, may not actualize the goal and objective of establishing the Nigerian Ports Authority, therefore, maintenance of security and safety is of utmost important in the Nigerian Ports.

### **The Nigerian Ports Authority guards against marine pollution and other incidents:**

In every organization, accident do occur, sometimes accident happened due to the carelessness of the management of the organization. Since the Nigerian Ports Authority is not exempted from such occurrences, it is expected of the Nigerian Ports Authority to guard against such occurrences within

the Nigeria Ports limits. For instance, it is the responsibility of the Nigerian Ports Authority to discourage or prevent the act of polluting the water, as well as, guard against any other such incident that may be capable to hampering the functions of the Nigerian Ports Authority. This is very vital, and the responsibility is failed upon the shoulders of the Nigerian Ports Authority.

### **The Nigerian Ports Authority enact sports' Regulations and Ports Bye-Laws:**

Huge responsibility on the part of the Nigerian Ports Authority to enable it succeeds, one of such duties is the enactment of laws and regulations with a view to regulate the operations of the operators of the Nigerian Ports. Without such regulations and laws which defined the operations within the Nigerian Ports limits, operators are likely to go out of the way to infringe either the other operators within the Nigerian Ports or the Nigerian Ports Authority. So, since the regulations are necessary and important, it is therefore, expected the NPA to enact regulations that will help it regulates the activities carried out within the Nigerian Ports limits.

One thing is to enact bye laws and regulations, another thing is to follow such regulations up, monitor the operators' compliance to such regulations and laws, possibly these laws and regulations have to be enforced. Despite concession excise, port users still expect the Nigerian Ports Authority, to perform its pre-concession roles, explains the current roles of the NPA in port and cargo operations in Nigeria (Eromosele, 2023). However, the port reform of 2006 helped to reposition and transform Nigerian seaports for competitiveness and efficiency in order to compete favourably with its contemporaries in the African region and indeed the rest of the world.

The concession policy adoption by Federal government was the Landlord model of port concession, which ceded cargo handling operations to private terminal operators while the NPA retains the responsibility of providing marine services. The policy of port concession stemmed from the desire of the federal government to infuse private sector efficiency into the port value chain by embracing Public Private Partnership (PPP) model, which is the global business approach. The port concession era transformed the operational functions of NPA to a more technical regulation with core responsibilities of providing and maintaining common user facilities such port internal roads, illumination, dredging, buoyage, pilotage, towage and another technical enabler of safe navigation, in addition to exercising regulatory oversight on terminal operators (See figure 2).

However, it appears there is limited public understanding of the roles of NPA in the port given the dominant perception that everything ports rest on NPA, when in actual facts there are other

government agencies such as the Nigeria Customs Service and others including security agencies, even the concessionaires whose roles affect port efficiency and operations.

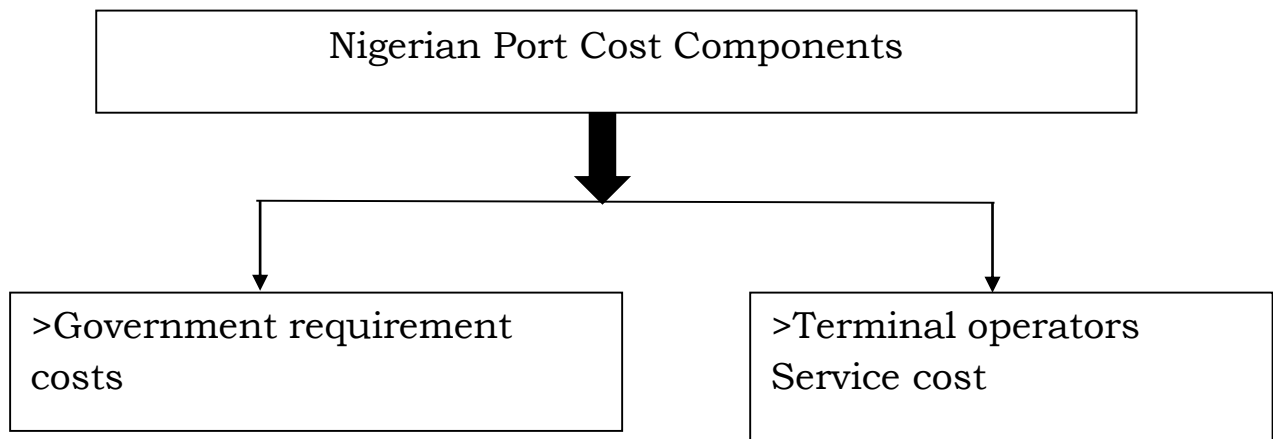
Delay in the port terminal operations is the major cause of port congestion suffered in Nigerian ports. According to Zuesongdham (2012), the advantage of the Landlord port model is to maximize the efficiency in the port operations by private sector because of their accountability and competence in service delivery and investment in superstructure that will boost the functional performance of the port industry and this is the core function of the private concessionaires rather than the public sector when using Landlord port models and subsequently, this will create competitive market dynamics and advance management of all factors towards effective port operations.

While on the other hand, Brouer, Karsten, and Pisinger, (2017), United Nations Conference on Trade and Development UNCTAD, (2021) and Ziaul and Hans (2018) note that seaborne trade constitutes nearly 80% of the world merchandise and as such requires cost efficient modes of transportation. An efficient port as an important interface for transportation of cargoes, it is a port industry that can operate optimally within a specified time. A port that is efficient in administration with adequate manpower supply, container handling equipment and all other necessary port facilities, and most importantly a port void of delays and congestions which could result to additional unbudgeted cost on the parts of the cargo and ship owners (Jafari, 2013). Container transportation via the port industry is estimated to be six times more cost efficient than trains, 15 times more efficient than trucks, and over 200 times more efficient than airplanes (Brouer *et al.*, 2017; Ziaul *et al.*, 2018). A prerequisite to achieve this efficiency lies on optimal port operations which maximizes the use of available capacity and port facilities combined with good managerial expertise to save time and cost while serving a large throughput of ships and cargoes at the port terminals.

### **2.1.2 Port Cost**

Port pricing is an aspect of port administration that is very critical in the operations of the port industry. In Nigerian port this is one of the core roles of the NPA to determine the cost or tariff structure of the port systems as well as to regulate the activities of the private operators at the port pricing of the port operations at the terminals. Port pricing is essentially treated as a major contributor to the overall transportation costs to the potential port user, specially the ship owners. Port charges amounts to fees paid by the users of the port facilities and services provided by the

port industry. Additional charges may be required for any delay and accrued on demurrages which attract extra fees payable by the beneficiary. Cost is essential component which calls for attention and requires considerations in its implementation in the port systems.



**Fig. 2.3: Nigerian Port Cost Structure**

Source: Developed by researcher

The Nigerian port cost structure can be categorized costs into two viz.; Government required costs which are all charges by the NPA and Service costs which on the other hand are charges by the service provided by terminal operators which are the private operators at the port terminals.

➤ **Government requirement cost include the following:**

- i. Port Dues: this are charges levied by the port to all entering ships and is generally calculated on the gross registered tonnage (GRT) of the ship based upon its tonnage certificate. It reflects the provision and maintenance of harbour infrastructure such as entrance channel, breakwaters, and turning basins, maintenance dredging and navigational aids.
- ii. Customs duty, Entrance/clearance, Quarantine, Fumigation and other associated cost are paid to the NPA.
- iii. Custom clearance fee: This charge covers all processes and customs entry documentation to the Customs and Border Protection (CBP).
- iv. Berthing/mooring dues: It is a levy charged on vessel that make fast alongside or casts off from a wharf in a Port or Harbour where boats or boat crew are provided by NPA to run and secure lines, or for every vessel making fast to mooring. The levy is also charge when vessel is made fast to already fasten vessel.
- v. Ship dues: this charge cover all services normally required by a vessel for her movement into and out of the Port including the use of Tug Boats.
- vi. Harbour dues: This charge is applicable to all goods discharged or loaded and to all passengers embarked or disembarked within the harbour. It is also a charge for the facilities put in place to create a secured harbour for the berthing of a vessel to enable save discharge/loading operation of cargo.
- vii. Conservancy: It is a charge that applies for the act of regulating and sustaining required standard of safety for ship in the waterways, through activities of Dredging, Sweeping, and Lighting, Wreck removal, provision of aids to navigational and other activities necessary for safe movement of ships in and out of the ports.
  - a. Pilotage dues: Pilotage is charged calculated in accordance with Pilotage rates and assessed against ship for the services a Pilot rendered or offered on a ship entering, leaving or shifting in a Port. The safe navigation of ship, including piloting in a Compulsory Pilotage District is at all times the paramount duty of a ship's master and the presence of an Authority's Pilot on the bridge shall in no way relieve the master of his duties and responsibilities.

- b. Footage dues: Is a charge assessed against the ship for the assistance offered by a pilot to facilitate safe berthing and sailing of ships in the ports.
- viii. Anchorage charge: A vessel shall be placed on Anchorage Due if she is lying idle or does not attain 40% productivity target. It shall be the duty of the Port Manager in collaboration with the Traffic Manager and Terminal Operator to determine whether or not a vessel is lying idle
- ix. Royalty charges: These are applicable to operations at: (i) Leased/Appropriated Area (ii) Private Jetties (iii) Off-shore Oil Terminals (iv) FPS/FSO/Platforms (v) Royalty on Rent (vi) Royalty on Cargo (vii) Towage Royalty (viii) Stevedoring Royalty (ix) Use of private equipment and machineries in NPA premises
- x. Coastal charges: Are applicable to vessels engaged in trade within Nigerian Territorial Waters, exclusive of Service Boats. Goods previously landed in any Sea Port in Nigeria and subsequently re-exported to another Nigerian Port will rank as coastal traffic and attract coastal Charges.
- xi. Tropical West Africa (T.W.A.) charges: It is applicable to vessels engaged in trade Within West Coast of Africa lying between latitude 15<sup>0</sup> N and 15<sup>0</sup> S.

➤ **Service cost include:**

- i. Bunker Cost: It is charged for the supply of fuel/diesel or refueling of a ship by the use of a truck, barge or another ship in a seaport. It is also referred to as taking of oil or bunkers on board ship. It includes the cost of oil, water and other liquid fuel used by vessels.
- ii. Storage Cost: includes cost paid for Yard Handling, Demurrage, Warehousing, Auto and truck storage, Grain storage, Refrigerated storage, and other related costs.
- iii. Loading and Discharge Cost: Comprises the cost associated with Stevedoring, Clerking and checking, Watching, Clearing and fitting, Equipment rental, Agency fee and other related costs.
- iv. Consolidation Fee: This is a service fee for bringing together and packing several smaller shipments into the same container.
- v. Terminal Handling Charges (THC): The fee collected by terminal operators from shipping lines, who in turn to recover from the shippers the container terminal cost for loading or unloading of the containers and other related costs borne by shipping lines at the ports of shipment or destination.
- vi. Cargo insurance fee: This typically provided by insurance specialist to protect against damages or theft in transit, shippers usually arrange cargo insurance through their forwarder

### **2.1.3 Cost of delays**

Delay is an act of obstructing that slow down a process which affects the rate of flow of the process and possibly affects the outcome of a system. In maritime industry, delay could also be referred to an unforeseen circumstance that causes setback in the planned schedule of a port operations such as bad weather etc., (Noorul, et al., 2019). Delays could result to tasks and milestones not completed within the established deadlines, leading to an overall extension of the operational timeline beyond what was originally scheduled. Delay could result from any force (human or natural phenomena) that impedes the process of achieving organizational set objectives which has to do with deterring the rate of operations or free flow of the entire process of port operations and vessel voyage plan (Noorul, Fitri, Mohammad, Izzat, Aminuddin, and Alisha, 2019). Delays are detrimental to the overall maritime activities.

Cost of delays in terminal operations is a management concept used to quantify the impact of delay in service delivery. It is a measure of financial, operational and customer–related costs associated with a delay in the delivery of services. Cost of delay can be measured based on economic terms, estimating the economic impacts of delays on the success of a system. Cost of delays could help to evaluate and estimate the impact of time on an expected outcome. However, according to Linus (2024), the cost of delay is not just about financial loss on monetary terms, it also pertains to loss of opportunities, customer dissatisfaction and a decline in market share. Cost of delays could portray significant impacts on loss of organizational goodwill in a business (Linus, 2024). Goodwill is a reputation a port has that makes the customers to continue and return to the port as well as the ability of the port industry to attract new customers to increase its profitability over time.

The cost of delay considers the economic impact of the time it takes to deliver port services to a vessel or cargo in a port. It includes factors such as lost opportunity, potential market share loss, reduced customer satisfaction, increased development costs, and decreased team morale (Linus, 2024). Essentially, the cost of delay is a way to measure the impact of delaying the delivery of a port service, and is used to inform decisions about prioritization, resource allocation, and port management (Linus, 2024).

There are two main classifications of cost of delays in organization which include; direct and indirect cost of delays. The direct costs of delays are those that are directly associated with the

delay, such as the cost of additional resources due to delays, lost opportunities, and other factors. For instance, if a port service is delayed, the cost of resources such as berth, labour, materials, and equipment may increase. Additionally, the port may miss out on potential opportunities, such as new customers or markets, that could have been gained if the port operations were completed on time. On the other hand, indirect costs of delays are those costs that are not directly associated with port delays, such as cost of customer dissatisfaction, lost market share, and other factors. For example, if a port service is delayed, customers may become dissatisfied with the port services, leading to a decrease in customer loyalty (goodwill) and a decrease in market share.

#### **2.1.4 Vessel operations in container terminals**

Vessel operations are the determinate factors in the overall port operational performance. Vessel operations involve the handling of vessels, including navigation and maneuvering within the port, berthing and unberthing of vessels, and anchorage management. Terminal operations revolve around the quick and efficient handling of ships and its cargos.

Vessel operations of port system is a core function of the port owners or operators to provide vessel with every necessary support to navigate in and out of the port environment, provide berths, berthing/mooring facilities as well as every compulsory and ancillary services needed by a calling vessel. In Nigeria, where Landlord system of port administration is practiced, the Port Authority has the responsibility to aid visiting vessels to navigate in and out of the port systems by providing tugs and pilotage services through the help of local port pilots, allocation berths, provide berthing and mooring facilities etc. while, on the other hand, port operators render services to enhance the operational performance of the port system through efficient cargo handlings. Efficient vessel and cargo operations would enhance vessel turnaround time of the port by reducing the number of days vessels spend in the port system. The effectiveness of the port systems encourages more vessel traffic; however, the reverse becomes the case when delays occurs at the port terminals, hence, increasing the periods of vessel stay in the port reduces the patronage, which reflects the number of times vessel call to the port industry.

## **2.2 Theoretical Review**

The performance of any port industry to a very large extent depends on the administrative system of the National port. This study reviewed some theories on administrative systems as practiced in some civilized countries which could be applied for effective management of port system to

achieve optimal operational performance and productivity. The study also discussed theoretical models to control delay variables in the port industry.

### **2.2.1 Bureaucratic Management Theory**

Bureaucratic management theory was developed by the German sociologist, Max Weber from 1864 to 1920. The theory was propounded to operate an organization in an efficient way. It contains two critical elements which include; structuring an organization into a hierarchy and having clearly defined rules to help govern an organization and its members. According to Max Weber, the Bureaucratic management approach emphasizes the necessity of organizations to operate in a rational way instead of following the “arbitrary whims” or irrational emotions and corrupt practices.

According to Max Weber, the bureaucratic management theory states that to manage an organization efficiently, it is essential to have a clear line of authority along with proper rules, procedures and regulations for controlling each business operation. Bureaucracy refers to the possessing of control over a group of people or activities through knowledge, power or authority.

The theory further found different characteristics in bureaucracies that would effectively conduct decision making, controlling resources, protecting workers and accomplishment of organizational goals. Bureaucratic management approach developed by Max Weber is best suitable for government establishments rather than private business organizations (Sandro & Carlos, 2019).

However, Daft in 2008 expound on the concept of organizational delays based on Max Weber Bureaucratic management theory. Draft’s study centered on the relationship between formal social organization, the bureaucratic management and the environment of operation (Daft, 2008). The port system is a formal organization which have similar organizational and structural interrelationship with its systems and environment. The organizational theory evolved out of different perspectives and aims at achieving industrial effectiveness and rationalized bureaucracy without delays. Delays in a formal organization may be caused by ineffective rules or by bad management/administration, however, delays may also be attributed to differences in norms and informal behaviour (corrupt practices) or to uncontrollable events as in natural phenomenon such as bad weather as applicable in maritime industry (Bozeman & Feeney, 2011). Furthermore, delays can derive from organizational centralization, or a lack of resources. Most important, the very notion of administrative delay is essentially a social construction (Bozeman & Feeney, 2011).

The organizational theory describes the organizational system as a decision-making process that involves many steps when making choice on producing outputs or rendering services. Shukla (2018) describes decision making process as one whose step provide an occasion to change decision. Organization has formation that are used to make up the working units of the organization, each of these functional structures are set into groups that have defined operations. With this arrangement and dependency of each of them to produce the overall output, issues arise to prevent organization to produce accelerated changes as well as deal with the demand they face (Zetterquist, Mullern and Styhre, 2011) and these could be in form of delays caused by so many factors in the organization. It is for this reason that organization decision making process are ones that need timing and resources to be able to produce solution that have value addition to the organization. Organizations are difficult and making sense out of them may demand the use of multiple perspective and knowledge to be able to bear a wide range of analysis, decision and plan without having to delay its operations. Modern organizations focus on how to increase efficiency, effectiveness and other objective indicators of performance through the governing structure and control (Rodrigues, 2011).

Port industry is a complex system with various units of decision making, administration and operations especially in the era of port privatization. Each unit of port operations requires a functional and proactive system to ensure a continuous flow in the systems without hitches or obstructions in the administrative flow and the operational functioning of the port industry. Inefficiency in the administrative system of local port industry would cause delays in the port operations. Managerial decisions inconsistent with time such as changes in port policy framework, unregulated price changes, strike actions, unannounced shorting down of systems and so on are organizational decisions that can affect the operational performance of port industry, as well as inadequate in manpower supply, equipment unavailability etc. are areas of administrative deficiencies that have great impacts on operational performances and causing delays in the port industry. To a large extent, this affects the efficiency of port industry. Port efficiency is a measure of port performance in the global shipping trade which affect many decisions of potential ship owners and cargo owners in port choice.

The relevance of a seaport cannot be over emphasis. Seaports play vital roles in overall supply chain and the major determinant of total transportation cost for every imported and exported containers. Modern container vessels can handle up to 20,000Twenty-foot Equivalent Units (TEU) and leading shipping companies operate fleet of more than 500vessels and hence, transport more

than 10,000,000 full containers annually, which invariably imply that ports handle over 500 vessels with over 10,000,000 TEUs for each leading shipping companies annually passing through the port industries worldwide. Therefore, the huge pressure to attract shipments to any particular port of a given region lies on competitiveness of the port in terms of its operational efficiency amongst other neighbouring hub ports. The global maritime business environment today is highly competitive, impacting every port organization large or small. According to Qiao and Chris, (2020), the impulsive or spontaneous reaction under the current circumstances is to ensure that local ports provide port users satisfactory port services within their estimated time and costs to attract more customers and in doing this, every aspect of port operations must be carefully structured and evaluated through quality assurance of good managerial expertise to eliminate unnecessary delays and non-value adding costs to retain its competitive service position.

According to Onwuegbuchunam (2018) the concerns about performance and efficiency in port terminals led national governments to embark on port reforms. The Federal government of Nigeria, for example, adopted the Landlord port model which brought about concessioning of port terminals to private operators. Despite high investments in terminal facilities by the private terminal operators, there are still complaints about level of service offered to port users.

Port efficiency analysis is a methodology applied in most port for self-evaluation (Nwolozi, Lateef, Elias, and Ebere, 2021). The efficiency analysis of a port is part of what happens in these three dimensions - maritime, terminal and hinterland operations (Athanasios and Jean-Paul, 2022). These dimensions are interrelated and necessary in efficiency analysis since inefficiencies in one dimension is likely to impact the others. For instance, issues in terminal operations are most likely to negatively impact maritime and hinterland operations with delays. According to Brooks, Knatz, Pallis and Wilmsmeier (2020), the efficiency of port access is a component of port performance, which includes average anchorage time, where ships are waiting for an available berthing allocation and long waiting times at anchorage can be the outcome of a lack of berthing space able to accommodate specific ship classes (e.g., draft and cargo type) as well as terminal productivity issues. The average ship turnaround time (or ship dwell time) represents the time it takes to service the ship once it has docked. Enhancing such a system is clearly to the benefit of maritime shipping companies. Terminal operations represent the most common performance indicator to measure port efficiency. For container terminal operations, this commonly involves several key operations. Crane performance is a common bottleneck in terms of the average number of crane movements per hour. For maritime shipping companies, this is a crucial factor since it is related to the amount

of time their ships will spend at the port. How cargo (in containers) is brought back and forth to the storage yard is also a component of port performance and often related to the number of movements per crane hour. Many container terminals use holsters or straddle carriers for such operations. Container storage yard operations involve stacking and related stacking density, an important variable determining terminal capacity. The average yard dwell time for inbound, outbound, and transshipment cargo is also a common indicator. When trucks enter the terminal to pick up or drop off cargo, space and equipment are required. This is often a critical bottleneck for trucking companies since it dictates the amount of time they will spend at the terminal, reflected in the average truck turnaround time (Brooks, Knatz, Pallis and Wilmsmeier, 2020). Gate performance concerns the efficiency of tasks related to document processing and security inspections. A truck is admitted and cleared to pick up or drop cargo at the facility. Gates used above their capacity are characterized by long truck lines waiting to be processed and enter the terminal for the cargo they are already chartered to handle. Therefore, the average gate waiting time can be used as a performance indicator. For terminals having on-dock rail facilities, the performance of the rail loading/unloading equipment can also be an important component of the terminal's performance (Brooks, *et al.*, 2020). On the part of the hinterland operations, congestion and bottlenecks at street intersections impair the port's performance in many of the supply chain management strategies of the port's customers (Athanasios and Jean-Paul, 2022). In many gateway ports, Trans loading activities that transfer the contents of maritime containers into domestic truckloads (or domestic containers), or vice-versa, are an element of the performance of hinterland operations (Athanasios and Jean-Paul, 2022). Port authorities have an oversight, either directly or indirectly, of port efficiency (Pallis and Syriopoulos, 2007).

Furthermore, Pallis and Syriopoulos (2017) infer that where the terminal operations are concessioned to private operators, port authorities tend to have direct oversight of maritime operations and several elements of hinterland operations, such as local roads directly connected to the port terminals, some of which are on land owned by the port authority. Although cities are not directly involved in port operations and commonly have limited control, if any, jurisdiction on port land, they commonly provide and maintain crucial road infrastructure connecting the port with its hinterland. They also bear many of the externalities of port operations, namely local congestion. Therefore, the port authority and the city are important stakeholders in the port performance evaluation.

Ports measure performance to monitor their activities, check their efficiency, compare present with past performance, and compare current with targeted performance. Based on the outcome of these exercises they adopt any necessary alignments to structures and strategies to improve performance. The performance measurement output can also be used to promote the business of the port. The questions that each port management and terminal operator have to answer are - what to measure, how to measure, and how to use this measurement. In conclusion, Pallis and Syriopoulos, (2017) notes that the list of indicators that ports and terminal operators use to measure their performance includes: production measure; productivity measures, utilization measures; and service measures.

According to Chang and Tongzon, (2018) many ports around the world are very much concerned with measurement reports and feedback on evaluation of their port performances for organizational improvement. Ports are striving to offer competitive services in order to attract a huge market share as well as sustaining patronage of the users and hence remain at the peak in the business of international shipping trade. The result of this intense inter-port competition in the container port sector is the interest in efficiency analysis (in terms of quality, efficiency, productivity and cost advantage) by port users as well as port operators (Wang, Cullinane and Dong-Wook 2015). Efficiency analysis provides port operators or port authorities with a means of making more informed decisions with regards to port planning or operations while it provides port users (especially shippers, carriers or shipping lines and freight forwarders) with a means of assessing the relative competitiveness of ports in order to make informed decisions on port utilization.

Ports in Western-Europe, North- America and East-Asia have, for many years, utilized efficiency analysis to improve operations by minimizing the use of resources for port production and time vessels spend in the ports (Chang and Tongzon, 2018). This implies cutting down costs by adopting cost reduction and cost control mechanisms; this has fueled port growth and massive investment in port related activities. In West Africa (WA), the port industry has seen major growth in recent times. In the last twenty (20) years, a number of West African ports have undergone restructuring and reform processes. These processes have been mainly centered on allowing more private sectors involvement in the port industry to generate investment for port development and to increase capacities and efficiencies of ports. More recently, port development in West Africa has been directed towards attaining hub port status (Van, 2015). This can be seen in vision and mission statements of most West African ports. For instance, Ghana Ports and Harbor Authority (GPHA) has on its vision statement “to be the leading trade and logistics hub of West Africa” and the

mission statement is “to provide efficient port facilities and ensure quality services to port users”; The Togo ports aims “to make Lome into the gateway of choice to other hinterland countries and a prime transshipment platform, operating to the international standards”; Nigerian Ports Authority (NPA) vision is “to be the leading Port in Africa” and the mission is “to deliver efficient port service in a safe, secure and customer-friendly environment”.

Inter-port competition is at its highest level and private sector investment in port facilities continues to rise in the WA ports. At present, ports that play regional role in WA are generally viewed as the leading potential hub port contenders. They include ports in Nigeria, Ghana, Togo, Ivory Coast, Benin and Senegal, which provide transit services for landlocked countries in WA (Nwolozi *et al.*, 2021). Nigeria which is the largest economy in WA and which has some of the largest ports in the region however does not play a significant regional role as the distance between its ports and the landlocked countries in the region is large (Cullinane, and Wang, 2017). In the past, Nigeria’s large domestic demand was the government priority. Recently however, the Nigerian government is looking to play a more regional role in shipping and is directing its port development efforts to that effect (Van, 2015).

There are several examples of port development projects in WA that have regional focus and are directed at attaining regional hub status. In Nigeria for example, the Lekki Port project seeks to create a multi-purpose deep water port in the Lagos free trade zone area with a projected capacity of 2.5 million TEUs (Twenty-foot Equivalent Units) per annum. The port will include container, dry bulk and liquid bulk berths with a 14-metre draught and 670metres turning cycle to accommodate larger ships (Lekki Port, 2014). Similarly, the Ghana Ports and Harbours Authority (GPHA) has secured \$1.5 billion for expansion of the Port of Tema (Van and George, 2015). The project involves the construction of four (4) deep water berths and an access channel to accommodate larger vessels with high capacity equipment. The aim of the project is to create the largest cargo port in West Africa with a capacity of 3.5 million TEU per annum (Port Finance International, 2014). The Port of Lomé has constructed a \$640 million berth in Togo. The new quay has double docking capacity and measures 450metres able to accommodate vessels of more than 7000 TEU capacity (Van and George, 2015). Similarly, port development projects can be found in other West African countries as there is no exclusiveness in the selection of a hub by shipping lines provided there is efficiency in port container terminal operations and comparative cost advantage. The selection of any port by a shipping line to act as a hub depends on a number of factors. According to Van and George, (2015), in a recent survey, major shipping lines calling

at West African ports were required to rank factors influential to the selection of a hub for the region; port efficiency, effectiveness and operational performance were ranked most in the list of 20 factors. West African ports were noted to be highly congested due to delays in ship and container handling operations and inefficient as compared with other ports in Europe and Asia (African Development Bank, AFDB, 2010). These were the reasons for less competitiveness of WA ports which make the ports operate at high cost for the patronage of shipping lines and other port users.

### **2.2.2 Traffic Congestion Theory**

This study considered the traffic congestion theory propounded by Walter's in 1961. Walter states that if the traffic demand on a particular route is high, specially a narrow channel, traffic will be almost standby and the flow achieve with a very high traffic demand may in fact be lower than the flow achieve with a low traffic demand (McDonald, 2013). Walter derived a traffic flow supply curve that relates the time cost of the trip to traffic density which shows an increase in time cost with rise in traffic flow. Also, the study of Choi in 2013 on congestion theory infers that time cost rises at an increasing rate with traffic density (McDonald, 2013). Hence, Walters and Choi both posit a level of traffic density at which the marginal time cost of a trip approaches infinity. This theory can be applicable to a port system with a narrow channel, inadequate berths and berthing facilities, whereby increasing vessel traffic increases time cost of vessels in a congested seaport.

Congestion as a result of delayed operations in ports or shipping industry is a global Philomena. The worse state of delays in port operations or shipping industry as a whole is that it can lead to congestion and thus, increase time cost which affect the overall cost of shipping trade. In fact, the concept of port congestion is primarily on delays as the basis for port congestion. Vessels can arrive at the required time but loading and unloading of containers takes a lot of time causing delays at ports making the shipping industry lost valuable time and incur cost. Delays in handling vessels and containers lead to port congestion. Port congestion is the obstruction in maritime operations, terminal operations and possible hinterland operations as categorized by Theo, Athanasios and Jean-Paul (2022) and witness at anchorage where vessels await berthing allocation; at the port terminals, stacking area, transit sheds, truck traffic, dockyard, boatyard or wharf due to massive anchorage of container ships waiting for loading or offloading of shipments; trucks entering and exiting the port, container awaiting customs clearance etc.

Crucial to the conceptualization of port congestion are terminals and gateway port (Wouter, and Theo, 2010). Therefore, terminals are sections of the Port where ships harbour or bunk for the discharging and loading of their merchandise. The equipment utilized in the terminals for discharging and loading of cargoes are the cranes, forklifts, lighters, etc. While the gateway is the route that connects shipments to the hinterland either by road or rail transportation (Wouter and Theo, 2010).

The inability for ships to berth, load, and unload as early as possible when they arrive at the port is due to the ports incapacity to provide adequate spaces for container ships (Xchange, 2020), whereas, in Nigeria ports Emeghara (2021) examined and described the ugly situation as resulting from managerial ineffectiveness and bottle-neck which is root on corrupt practices in Nigerian ports industry. Therefore, ships have no choice but to queue up and wait their turn literally. Unfortunately, this is dangerous and poses many problems for businesses, as it causes them to increase their operational costs. In addition, it presents a burden on shipping lines, cargo owners, and of course, port management losing its credibility and competitiveness in the global maritime industry. Therefore, port managers need to work towards increasing efficiency when managing ships, enlarging and developing their infrastructure, employing adequate staff strength (Xchange, 2020) and curbing corrupt practices especially in Nigerian ports (Emeghara, 2021). Ports are of utmost importance to international trade and the economy. The United Nations Conference on Trade and Development (NUCTAD) has stated that maritime trade contributes 90% of the world's supply chain, meaning that 90% of the goods transported all over the world is moved by ships, and any delay at the port costs 0.6% to 2% of the value of the goods daily (NUCTAD, 2019).

Sea transportation remains the most common form of transporting goods all over the world, and its efficiency greatly matters. In Germany, ships were delayed for about 45 to 55 hours, although the Covid-19 pandemic has increased delay time to about two weeks (Kaufmann, 2021). In Nigeria, pre Covid-19, ships were delayed for about 20 days, and now the days have gone up to 50 days, sometimes very nearly three months (Safety4sea, 2020). There are several factors that cause port congestion and mitigate against the effectiveness and efficiency of international trade as a whole. There are issues such as extreme demand oversupply of port facilities, the government's inconsistent and unrealistic policies, poor and obsolete port infrastructure, lack of technological infrastructure to help improve the service rendered at the ports to compete globally (Nze & Onyemechi, 2018).

There are several ways in which congestion occurs as posited by (Nze & Onyemechi, 2018), there is ship berth congestion, mainly caused by the fact that several ships have engaged the spaces allotted to the newly arrived ships. Congestion can also occur (ship work congestion) when there are delays attributed to gaps when it comes to loading and unloading ships. This could be drastic in that it lengthens the amount of time a vessel should remain at Port, therefore causing more inconveniences. There is also vehicle gate congestion due to the port management's inability to properly program the way trucks can access the port to pick up and drop cargoes. Once laid out programs are followed through and trucks arrive and leave as they should, the port will run smoothly, and there would be no congestions. Otherwise, there would be port gate congestion. Cargo stack congestion refers to cargo continuously stored at the storage area beyond the allotted time frame. Finally, ship entry/exit route congestion deals with any incidental obstruction on the marine side access route to the port. It could cause queues, bunching and ships overstaying at anchorage and berth as well as cargoes at the stack and trucks on traffic within the ports.

Oyatoye, Adebisi, Okoye and Amole (2011) applied queueing theory to the problem of port congestion in order to enhance sustainable development of Nigeria ports. According to Oyatoye, *et al.*, (2011), Nigeria Ports are characterized with incessant congestion problem in the recent past. This has resulted in diversion of ships scheduled for Nigeria Ports to other neighbouring countries which has caused the country to lose a lot of revenue. The effectiveness of a Port is contingent upon loading and unloading of ships. The traffic movement through a port is a complex phenomenon because of the random nature of the arrival and service time of the ships. This requires a systematic approach in port planning and management. Oyatoye *et al.* (2011) adopted Queueing model to the arrival and services pattern which causes the problems of congestion and proffer solutions to the problem areas. It was also used to predict the average arrival rate of ships to Tin Can Island Port and the average service rate per ship in a month. The study found that the number of berths in Nigerian port was adequate for the traffic intensity of vessels but other factors leading to port congestion were identified through the content analysis of the interview conducted with stakeholders at the port. Policy recommendations that could make Nigerian ports to be cost effective, more attractive and enhance quick turnaround of vessels at the ports were made.

### **2.2.3 Resources Based Theory**

Resources based theory was expounded in the study of Kor and Mahoney in 2004 which aimed at understanding how organization achieve competitive advantage with the application of estimable physical and non-physical resources at the firm's disposal. A firm may have many sources ranging

from human resource (labour), equipment and financial resource viewed from the angle of the inputs. The resources-based theory by Kor and Mahoney is a strategic theory that fundamentally focuses on strategies that can be used to gain and support competitive power in a firm.

Resource-Based Theory (RBT) also was put forward by Penrose in 2009, which proposed a model on the effective management of firms' resources, diversification strategy, and productive opportunities. Penrose's study was the first to introduce conceptualization of a firm as a synchronized bundle of resources to address and tackle the means of achieving its goals and strategic behavior. The emergence of RBT was incidental to the Theory of Growth by Jay Barney in 1980. Today RBT has become the dominant model in strategic management and strategic planning in formal organizations.

Port industry as well adopts the RBT as it experiences labour and infrastructural issues that are principally caused by processes and exercises within the port terminal operations. Planning for port labour and technological applications becomes a very complex task since the extent and outcome of wrong skill task to port terminal operations activities can result to adverse outcomes which could affect performance efficiency. Delays occur due to inadequate manpower and obsolete technology. Having the ability to determine the correct labour and skills required to perform certain operations in the port is necessary (Kor and Mahoney, 2014). Port suffer delays due to inadequate or manpower deficiency, lack of technological knowhow, right scheduling of work, planning and staffing. Resource management is fundamental in organizational efficiency and performance especially the ports industry in the era of industrialization, globalization and technological advancement, making time and cost most priorities in operational efficiency rating of the port industry which gives port comparative advantage.

#### **2.2.4 Queuing Theory**

The origin of queuing theory can be traced to A.K. Erlang in 1909 on his publication on the theory of "Probabilities and Telephone Conversations". Queuing theory is the mathematical study of congestion and delays of waiting in line. Queuing theory examines every component of waiting in line to be served, including the arrival process, service process, and number of servers, number of system places, and the number of customers which might be vessels, containers, trucks and documents (Alberto, Rita, Francesco, and Riccardo, 2010; Canonaco, Legato and Musmanno, 2018). Manitz, (2015) infers that waiting in line is a common occurrence in everyday life because it serves various key functions as a process. When there are limited resources, queues are a fair

and necessary manner of dealing with the flow of clients in service industries (Roy, Gupta and De Koster, 2016).

As a branch of operations research, queuing theory is very useful to make informed business decisions on how to build efficient and cost-effective workflow systems in port industry. According to Julius and Suzanne (2022), queues occur when resources are limited in supply or when the number calling for services outweighs the service units available. In fact, queues make economic sense and where there are no queues simply means there could be costly overcapacity or no good customer inflow (Ulusçu and Altıok, 2019). Queuing theory helps in the design of balanced systems that serve customers quickly and efficiently at optimal cost to enable system remain sustainable. All queuing systems are broken down into queuing units for an activity. At its most elementary level, queuing theory involves the analysis of arrival rate at a facility, such as ports terminals, then the service requirements of that facility, e.g., berthing, load and unloading operations.

In queuing theory, a queue does not refer simply to a one way forward of first come, first served, although, it is the most commonly adopted in service industries. Queue service disciplines include; First-in-First-out (FiFo), or First-come First-served (FcFs); a type of queue that occurs when customers politely lined up, waiting for turns to be attended to. Last-in First-out (LiFo) is the opposite scheme and applicable in some organizations so that whoever has been waiting for the shortest time is served first. This type of queue management is common in asset management, where assets produced or acquired last are the ones used or disposed-off first. This is not really common in-service industry such as the port industry. Priority queue service is where customers are served based on their priority level; these levels could be based on status, task urgency/emergency, or some other criteria. Most times in the port, vessels and cargoes can be treated on the basis of critical considerations and criteria making them to be served on the concept of priority and when such vessels and containers arrive in numbers exceeding the service units, the traditional queuing order of first in first served is obeyed for the priority service units.

In port systems, there may be a single server (narrow channel), where only one vessel can sail off at a time, or parallel servers, where the same line is served by several servers. A tandem queue occurs where each of multiple servers has their own queue or line independently. Balking occurs when a customer decides not to wait for service because the waiting time threatens to be too long. Reneging is similar, but when a customer who has waited already decides to leave because they

have wasted too much time on queue. Jockeying is when a customer switches between queues in a tandem queue system, trying to orchestrate the shortest wait possible. According to Ulusçu and Altıok (2013), queuing in real-life applications is an administrative strategy to handle delays in service/operations and congestions due to influx of customers. It is a method of cost optimization and facility utilization approach which tend to strikes a balance in organizational targets and customer satisfaction to achieve the organizational set objectives (Ulusçu and Altıok, 2013). Queuing theory covers a wide range of applications, such as how to provide faster customer service, improve traffic flow, efficiency in ship and cargo operations, and design of communications and file documentation systems. Queuing theory is primarily a tool for calculating costs or cost optimization technique (Chu and Huang, 2012), as most industries would find it excessively expensive to build facilities to run in such a way that none of their customers or clients ever had to wait in line or symptomatic of a lack of customers in the system. As a result, businesses employ queuing theory information to set up their operations systems in order to strike a balance between the cost of supplying clients and the difficulty caused by having to wait in line for delays and congestions (Chu and Huang, 2012). The customers in line and the performance of the service they are waiting for are the fundamentals of queuing models.

There are standard notations for queuing theory. These standard symbols include:

$\lambda$ : the mean arrival rate of customers to facility

$\mu$ : the mean service rate.

n: the number of customers in the system.

A: the arrival process probability distribution.

B: the service process probability distribution.

C: the number of servers.

D: the maximum number of customers allowed in the system at any given time, waiting or being served (without getting bumped).

E: the maximum number of customers total.

The concept queuing theory is typically based on problems of arrival rate of customers, service rate, queuing and leaving the system which is the last in the order of queuing theory.

Arrival rate explains the average number of customers arriving during a specific time frame, such as hours, days, or months and is one factor to consider when it comes to the arrival of vessels at the queuing location anchorage or berths. Significant variations in the volume of traffic or arrivals that occur at different times of the day, or on different days of the week or month, are considerable factor.

Service rate on the other hand explains the average time it takes to serve each customer or client, the number of servers required for maximum operational output and cost effectiveness, and the rules dictating the order in which clients are served are all elements that have an impact on actually providing service. While most queues work on a first-come, first-served basis, this is not always the best option for some firms. Variables exist in regard to the actual providing of service as well.

Queue is basically the arrangement of the order on any of the queue discipline which is subject to the characteristics of the customers, type of services and competition existing in the industry. Customer may choose to leave the system if the queue is too long and time consuming.

Leaving the queue after service is a basic logistical issue as frequently related to clients leaving a queue area. Businesses having driven-through operations, for example, must consider how customers exit through the queue which may affect incoming traffic to the facility, as mentioned above. These are critical queuing model problems to be determine to ensure operational efficiency in ports industry.

#### **2.2.4.1 Little's Law of Queuing Theory**

Little's Law was developed by John Little a profession in Massachusetts Institute of Technology (MIT) in 1954 in his publication and the law gained recognition and applied in operations research from 1961.

Little's law asserts that the long-term average number  $L$  of customers in a stationary system is equal to the long-term average effective arrival rate  $\lambda$  multiplied by the average time  $W$  that a customer spends in the system in queuing theory (Branislav, 2016). Little's Law is a theorem that determines the average number of items in a stationary queuing system, based on the average

waiting time of an item within the system and the average number of items arriving at the system per unit of time. The law provides a simple and intuitive approach for the assessment of the efficiency of queuing systems. The concept is very significant for business operations because it states that the number of items in the queuing system primarily depends on two key variables and is not affected by other factors, such as the distribution of the service or service order. Almost any queuing system and even any sub-system can be assessed using the law. The theorem can be applied in different fields of studies such as transport and logistics, port operations etc.

Little's law is a mathematical probability stated as.

$$L = \lambda W$$

Where

L is the average number of customers in the system.

$\lambda$  is the average arrival rate into the system.

W is the average amount of time spent in the system.

Although it appears to be a simple result, it is rather surprising because it is unaffected by the arrival process distribution, service distribution, service order, or virtually everything else.

Little's law holds true for every system. The sole requirements are for the system to be stable and non-preemptive (Canonaco *et al.*, 2018); this eliminates transition states like initial setup and shutdown. In some circumstances, not only can the average number in the system be mathematically related to the average wait, but the complete probability distribution of the number in the system can also be mathematically related to the wait (Manitz, 2015).

Many Queuing Models (QM) are developed based on Little's law and are used to analyze complex dynamic and stochastic situations and to understand issues for system decision making. This methodology has been applied successfully to several experimental examples and is shown to deliver competitive results much faster compared to conventional models in a stochastic environment (Roy *et al.*, 2016).

Specific developments in the past years include analytic formulations and formulae, analytic formulations and numerical solutions, simulation models and integration of simulation-optimization framework for the performance evaluation of port systems (Roy, *et al.*, 2016). Potential changes in Queuing Models (QMs) development is the domain of application for QMs and integration with other modelling approaches are very important.

The M/M/1 queue model represents a concept of queue length with only one server where arrivals are determined by a Poisson process and service time have an exponential distribution (Asmussen, 2013). In other words, it is a system with Poisson input, exponential waiting time and Poisson output with single channel.

The concept of Poisson process implies to the occurrence of certain events that appears to happen at a certain rate, but completely at random. It is usually used in scenarios like the seaport where the ship arrival occurs at a certain rate, but completely at random without a certain structure or known pattern of arrival. On the other hand, the exponential distribution deals with the time between occurrences of successive events as time flows by continuously. Queue capacity of such a system is infinite with first in first out mode. The first M in the notation stands for Poisson input, the second M for Poisson output and 1 for the number of servers and infinite capacity of the system.

The assumption of M/M/1 queuing model are as follows:

The number of customers arriving in a time interval  $t$  follows a Poisson Process with parameter  $\lambda$ .

The interval between any two successive arrivals is exponentially distributed with parameter  $\lambda$ .

The time taken to complete a single service is exponentially distributed with parameter  $\mu$ .

The number of servers is one.

Although not explicitly stated both the population and the queue size can be infinity.

The order of service is assumed to be FIFO.

According to Teknomo (2014), the formulation of measurement of effectiveness of M/M/1 queuing system are given below.

Input:

Arrival rate (number of customers/unit time)  $\lambda$

Service rate (number of customers/unit time)  $\mu$

Output:

$U$  = Utilization factor = percentage of the time that all servers are busy,  $U = \rho = \lambda/\mu < 1$

$P_0$  = probability that there are no customers in the system,  $P_0 = 1 - \rho = 1 - \lambda/\mu$

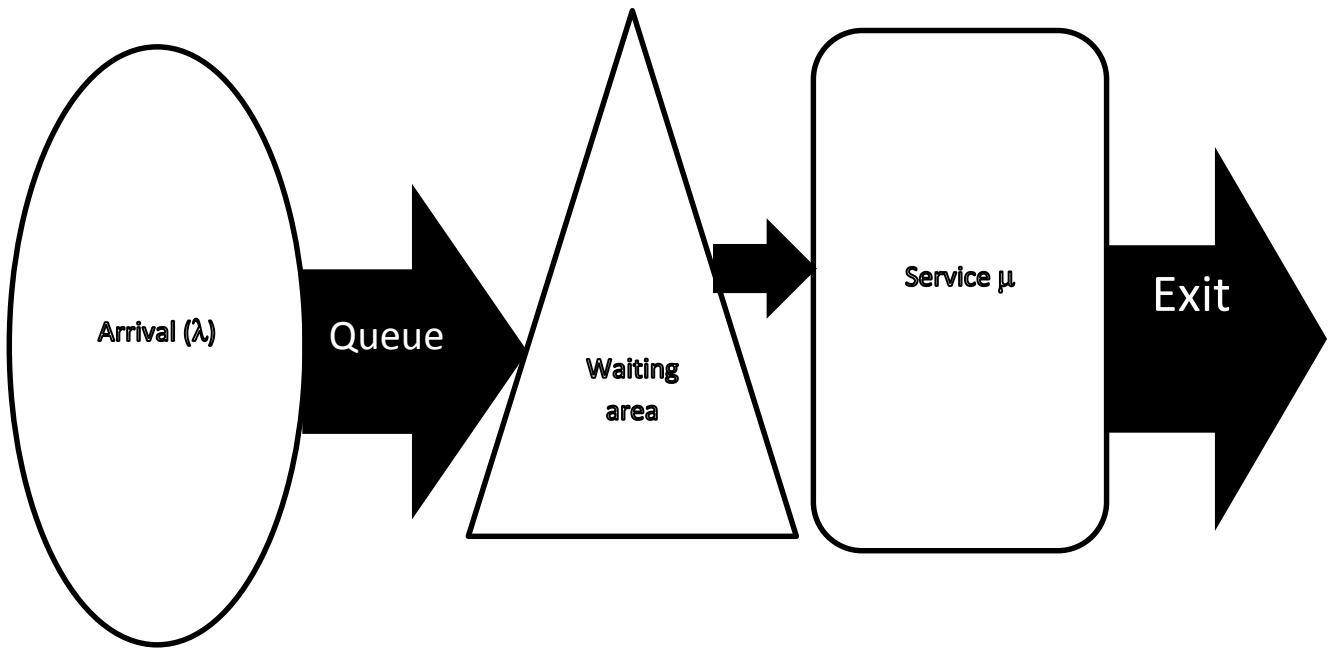
$P_n$  = probability that there are  $n$  customers in the system,  $P_n = \rho^n P_0$ ;  $P_{n+1} = \rho P_n$

$W_q$  = average time a customer spends on queue for service,  $W_q = W - 1/\mu = L_q/\lambda$

$W$  = average time a customer spends in the system (in waiting line and being served),  $W = W_q + 1/\mu$

$L_q$  = average number of customers on queue for service,  $L_q = \lambda W_q$

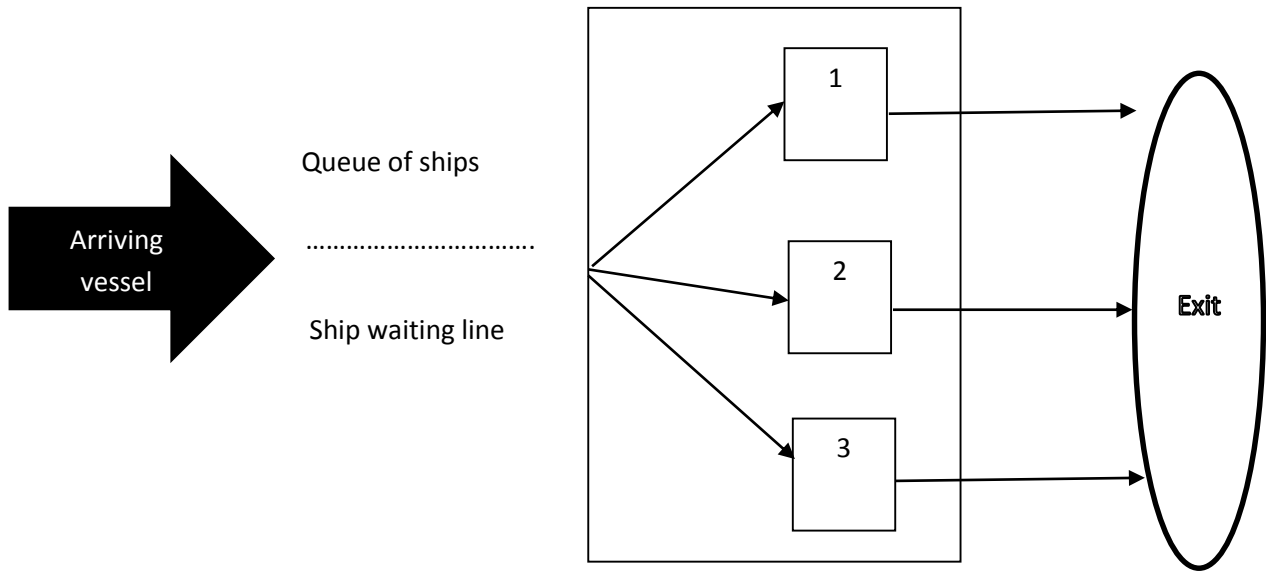
$L$  = average number of customers in the system (in waiting line and being served),  $L = \lambda W$



**Fig. 2.4: A single server M/M/1**

**Source: Developed by Researcher, 2023**

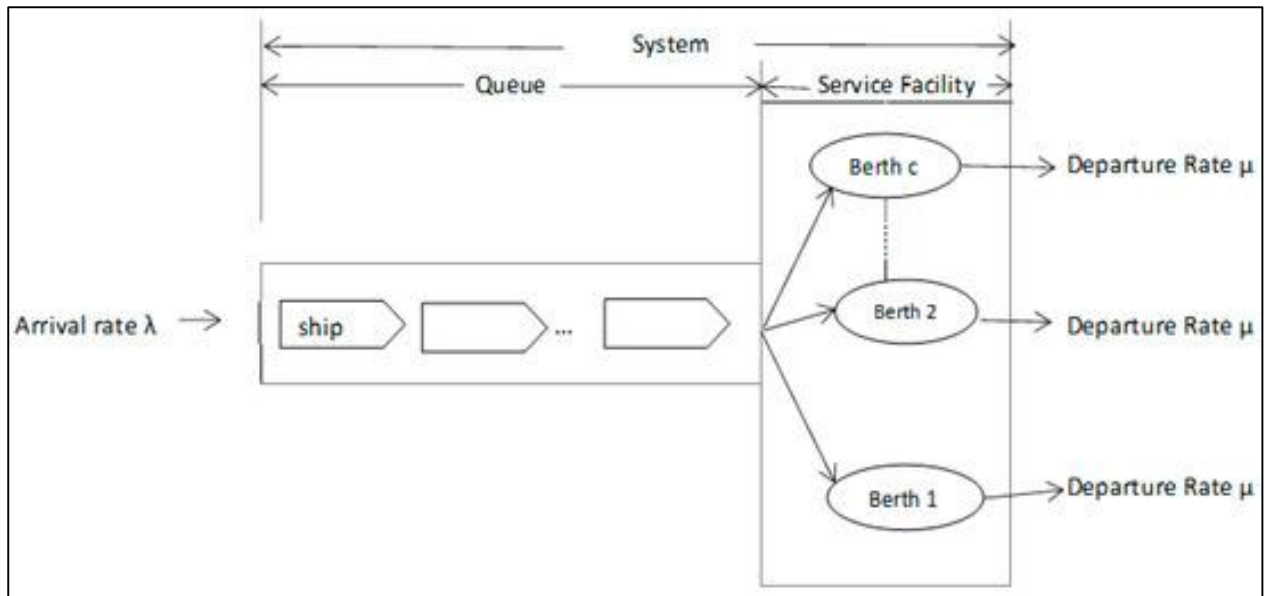
The Concept of (M/M/C) First Come First Serve Queue model (FCFS/8) is Multi server queue which has two or more service facility in parallel providing identical services (Srinivasan, 2014; Gautam, 2012), whereby all the customers in the waiting line can be served by more than one station. An infinite source population with first come first served discipline are observed where both the inter arrival time  $\lambda$  and service time  $\mu$  follow an exponential distribution (Venkatesh, 2015, Shanmugasundaram, and Venkatesh, 2015).



**Fig. 2.5: Multi server queue system (M/M/C)**

**Source: Developed by Researcher, 2023**

The rationale for applying the queuing model in this study is the fact that ship arrival rate and service rate are in Poisson process or random process and queuing model can be used to determine effectively how berths were utilized and to also ascertain the less than optimal changes in ships' turnaround time variation observed in the systems. The application of the queuing model in this study is considered appropriate since a system of berths in a seaport where ships arrive and are served can be described by queuing model. The diagram below further explains arrival rate and service rate of seaport terminal queue system.



**Fig. 2.6: queuing system with parallel servers.**

**Source: Adapted from Taha (2017)**

## **2.3 Empirical Review**

### **2.3.1 Port characteristics and infrastructure effect on port delays**

Port characteristics and infrastructure is essential for the efficiency and effectiveness of the maritime network. Port characteristics and infrastructure endowment can be described by variables such as number of cranes, storage areas, quay length, maximum draught (water depth), and length of berth at origin and destination ports. According to Wilmsmeier and Martínez-Zarzoso (2019) the interaction of these variables is decisive; arguing that high technological applications of equipment in port industry, for example, installing ship-to-shore gantries and development of quay spaces will save time at the port and speed up operations at the container terminals, however, may well lead to higher port charges for a shipping line. However, development of port infrastructure is only worthwhile if the entire transport system benefits and not if bottlenecks are only shifted to another element within the system (Wilmsmeier, Jan Hoffmann and Ricardo, 2016)).

Factors influencing productivity are physical, institutional or organizational. Physical limiting factors include the area, shape and layout of the terminal, the amount and type of equipment available, and the type and characteristics of the vessels using the terminal (Wilmsmeier and Hoffmann, 2018). Lack of cranes, insufficient land, oddly shaped container yards; inadequate berth space, inadequate gate facilities, and difficult road access are all physical limiting factors causing delays. Productivity must be considered in a system perspective for it to be of maximum value to industry. This is important from a policy perspective, thus emphasizing the need for co-modality and multimodal visions in policy recommendations and guidance. All players should have an awareness of the entire system and be cautious of becoming its weak link. Empirical results presented by Wilmsmeier *et al.*, (2016) are quite clear and straightforward to illustrate this. It explains that increase in port efficiency, port infrastructural development, private sector participation and inter-port connectivity - all help to reduce the overall global maritime transport time and costs. In his study, two countries in their sample with the lowest port efficiency improved their efficiency to the level of the other two countries with the highest indexes; the freight on the route between them would be expected to decrease by a given per cent for several reasons which include time saved in port terminal operations. Improvements in port infrastructure and private sector participation have led to reduced maritime transport time and costs.

Hence, improving port efficiency and productivity by introducing technical advances as well as port design characteristics and planning/administrative measures can reduce operational time and costs at the port industry.

### **2.3.2 Review on Vessel Operations in Container Port Terminal**

In the recent time maritime trade has developed so rapidly with drastically effects on the world economic system. Many organizations in the maritime industry – the ship building construction, ship owners, freight forwarders, conference liners, and port operators have moved from traditional approach to modernized system of global technological advancement for economies of scale in ship and port terminal operations. The wind of civilization and recent economic downturn in the world economic system has brought about a conscious management of resource in the maritime sector. Time and cost have become a vital consideration in all maritime operations for all industries or sectors concerned in the shipping business. All actors in the industry seek how and the best mix of resources to minimize cost and maximize profit. However, this has been the order of the day in the history of maritime industry; the stakeholders had always sought through diverse approaches over the years to minimize delays and operating costs in ports since it contributes so much to non-value-added costs in shipping trade.

According to Merk and Li (2013), shipping has been characterized by a continuous search for reducing costs resulting from non-valued added activities such delays, congestion, demurrage at the ports through civilization and technological advances in the industry. The advent and use of standardize containers were a great achievement in shipping industry, which does not only help in cargo handling but also saves shipping costs by reducing shipping time, space and volume. The present-day technology of the shipping industry has introduced various sizes of container vessels such as VLCCs (very large container carriers) and ULCCs (Ultra large container Carriers) which are able to carrying over 10,000 TEUs containers across various ports of a given shipping route. The essence of these technological advancements is to achieve economies of scale in shipping industry and to lower transport cost and gain time in shipping operations.

Looking at the container ports globally, it is obvious that many ports around the world have developed programs in forms of policies and advance technology in container port operations which aims at high productivity, performance, and efficiency. In summary, this is targeted at resources optimization to reduce cost especially from non-value-added activities and delays at ports to maximize profit through effective utilization of resources. The effectiveness of resources

utilization is the function of the administrative system to manage resources to avoid delays and congestions at ports.

In Africa and among other ports of the world, privatization of container port terminals has been a means of container terminal development, to pull resources from the private sectors to invest in port terminal infrastructure. Ports are seeking patronage of shipping lines as well as shipping lines making choice of ports that are effective in operations without delays which would attract extra cost to their budgets, hence, ports operators need adopt good managerial approaches and technologies in container port terminal operations which will yield better efficiency, productivity and performance that port users can have a comparative advantage.

Ports industries like other modern business enterprises see efficiency in port operations as a cost control measure. According to Wayne (2016), port operational efficiency signifies cost effectiveness. However, the following are areas of port operations that need to be managed effectively in port industry.

### **2.3.3 Port Price and Vessel Operations**

In the recent time maritime trade has developed so rapidly with drastically effects on the world economic system. Many organizations in the maritime industry – the ship building construction, ship owners, freight forwarders, conference liners, and port operators have moved from traditional approach to modernized system of global technological advancement for economies of scale in ship and port operations. The wind of civilization and recent economic downturn in the world economic system has brought about a conscious management of resource in the maritime sector. All actors in the industry seek how and the best mix of resources to minimize cost and maximize profit. However, this has been the order of the day in the history of maritime industry; the stakeholders had always sought to minimize operating costs through diverse approaches over time. According to Merk and Li (2013), shipping has been characterized by a continuous search for reducing costs resulting in economies of scale through civilization and technological advances in the industry. The advent and use of containers in shipping industry does not only helped in cargo handling but also saves shipping cost by reducing shipping time, space and volume. In the present time the industry has introduced various sizes of container vessel (These are very large container carriers (VLCCs) and Ultra large container Carriers (ULCCs) which are able to carrying over 10,000 TEUs containers across various ports of a given shipping route. The essence of these

technological advancements is to achieve economies of scale in shipping industry and to lower transport cost.

Talking about the port, it is obvious that many ports around the world have developed programs in forms of policies and advance technology in port operations which aims at high productivity, performance, and efficiency. In summary, this is targeted at cost optimization to maximize profit through effective utilization of resources. In Africa and among other ports of the world, privatizations of port industry have been a means of port development, to pull resources from the private sectors to invest in port infrastructural development. Ports are seeking patronage of shipping lines as well as shipping lines making choice of ports that offer effective cost advantage among other factors. Hence, ports operators invest rapidly at optimal cost which will yield better efficiency, productivity and performance that port users can have a comparative cost advantage.

Ports industries like other modern business enterprises see efficiency operations as a cost control measure. According to Adizes *et al.*, (2019) port operational efficiency signifies cost effectiveness. However, the following are areas of port operations that need to be managed effectively in port industry.

#### **2.3.4 Vessel Handling Operations in Container Port Terminals**

For a container port terminal effectiveness, ports operators should employ the right mix of resources (human and material resources) to ensure that calling vessels are handled promptly at the right time without delays. Vessel handling operations involve pilotage navigation and maneuvering within the port, tug services, berthing, and unberthing of vessels, and anchorage management. Cargo handling operations requires good number of cranes, forklift, skilled manpower, stevedores, space for container stacking, and standard trucks to load-on containers in and out the ports. According to Haralambites and Veenstra (2020), conventional general cargo ship operations involve a very labour intensive process. This has been the genesis of most problems in ports. Consequently, ships have to spend most productive time in ports during loading and unloading operations. A potential user of a port or a liner conference would consider such a port as very expensive and ineffective. But improved cargo handling rate will positively affect turnaround time of ship in ports as well as improve port viability. This of a truth, increase in cargo handling performance will leads to reduced shore and berth costs and henceforth leads to reduction in freight rates and overall maritime transport costs.

### **2.3.5 Consequences of Port Delays and Congestion in container terminal**

According to Nze and Onyemaechi (2018), Port Congestion is a scenario associated with delays, queuing and extra time of voyage and dwell time of ships and cargo at the ports, which always have unpleasant consequences on Logistics and supply chain. These issues often escalate into extra costs, loss of trade and disruption of trade and transport agreements (Nze and Onyemaechi, 2018).

This is the most critical and a chronic problem that many ports around the world face and this contribute to raises the cost of shipping to countries whose ports experience delays. Port delays are as results of many factors ranging from administrative ineffectiveness to inadequate berth spaces, cranes, manpower, and problem of bureaucracy, custom clearance and many other technical challenges. Ports associated with these challenges suffer delays in ship and cargo clearance and would operate at a very high costs and users incurring excess demurrage. Shippers and ship owners must choose ports where their cargoes and ships must be handled rapidly, efficiently and economically (Iaguo, Xinrui & Jihong 2023). Such quality service is not available in congested ports. There must be an improvement in labour and capital productivity with good managerial policy to tackle the problems of port delays. In other words, increase in cargo handling rates at the port will help remove congestion in the ports.

Likewise, in regional ports, to tackle the problem of port delays and congestion in the developing countries ports, Chin and Chih-Wen (2012) suggest the introduction of a hub port that will perform effectively. A hub port is a transshipment centre capable of accommodating larger container carriers. In this hub, full economies of scale in port operations are enjoyed by calling ships. Typical examples of hub city are ports of Singapore, Hong Kong, Rotterdam, Antwerp etc. These ports centre operate a simple system describe as “hub and spoke network/relationship”. The system enables big cellular vessels to call at the hub centre, with the availability of feeder services, the huge surges of containers are forwarded to other regional and local ports and economically efficient. The system has proved advantageous to global shipping as it has dramatically reduced congestion through improved cargo handling rate. Likewise, the cost of shipping to various local and regional ports on the hub network has been reduced (Chin Yuan and Chih-Wen, 2012).

However, prior to the submission of Chin Yuan and Chih-Wen, (2002). Asabe, (2021) studied on economic analysis of the European seaport system and port congestions using the hub-feeder container system and short sea shipping networks of the Mediterranean, it was found that there

was increase from twelve percent to fourteen percent on the rate of port congestions (Asabe, 2021). This corroborating with the findings of the institute of transport and maritime management, on the effects of port congestion on market value, especially in the U.K ports and Baltic ports, realizing nearly a market share that is less than 10% each, less than 3% from Black seaport, and less than 30% from Mediterranean seaport (Asabe, 2021). This report traced the primary cause of port congestion to structural issues like infrastructural and connection obstruction to the borderland through road, rail and inland waterways, and scattered terminus for deep-sea vessels and feeders or barges (Asabe, 2021). This depend highly on the types of goods at the port, superstructures available and administrative system of the port. From the statistics documented on North Western port the congestions affected mostly 8% (40 million TEU) of containers, 7% (269 million tons) of dry bulk, 5% (391 million tons) of liquid bulk, 0% (62million tons) of conventional general cargo, and 8% (82 million tons) of RoRo (Asabe, 2021).

### **2.3.6 Port Delays and Charges**

Time spend at the ports is very necessary as it forms the basis for most charges on the services rendered to ships and container cargoes. Charges in shipping trade can be classified in various forms. It can be classified based on who incurred the charges and activities on which the charges were incurred. According to Ndikom (2011), charges in shipping may be viewed from these perspectives: first, as charges borne by ship operators (Liners) for the services received, and charges borne by the port users (Importers and Exporters) of shipping services. However, the study is focused on evaluation of delays and cost of port container terminal operations (port services) of the shipping industry which majored on ship and cargo handling at the container port terminals. In shipping industry these categories of charges are the determinants of the overall price for shipping services.

Port charges and dues are the cost required by port authority for services rendered, which are distinct from facilities provided in connection with the handling of cargo. Major port charges, which form the main sources of income for a port, are constituted by general port dues, rates and specific tariffs.

Iheanacho (2015) explicitly marked distinction between rates and dues. “Rates are prices required for different services performed, while dues are broadly divided into two main classes – dues on vessels and dues on goods”. Dues on vessels are otherwise known as tonnage dues or duties on tonnage, the usual basis of payment being a certain sum per net register ton of ship. Delays in port

operations add up to port charges and dues at the ports. Port dues on ship are calculated on the basis of the ship's characteristics such as gross registered tonnage (GRT), length overall, draft of the ship etc. The port due is sometimes called the harbour or river due. On the other hand, port dues on cargo, which normally covers the utilization of port infrastructure with respect to cargo is calculated based on the characteristics of goods such as weight, volume, value or a combination of these (Ndikom, 2018), however, time spend at the port affects the overall costs of shipping.

### **2.3.7 Container Port system and Operations**

The term Port Systems (PS) is often used to refer to systems with multiple components that need to cooperate to achieve a common goal, trying to make efficient use of available resources. In general case, PS consists of many interacting sub-systems performing various planning and control functions. Container port terminal design of a PS presents a special challenge for the designers, because it involves more complex systems with various levels of interactions between its components and with mutual influences which could be deterministic or defined by stochastic values (Theo, Athanasios and Jean-Paul, 2022).

The complexity of Port Systems of a container port terminal requires particular methodology or model choice for effective operations. Analytical models which are frequently used (models of queuing theory) for analysis of global solutions could estimate the performances of a port system. However, even with the simplification and decomposition of system, it is not always possible to adequately set the corresponding analytical model.

Many operations research models have been used for the purpose of modeling various operations situations in port industries around the globe. Queuing models (QMs) play an important role in modeling and analysis of port systems, especially, in the era of technological advancement in container port terminal operations and industrial globalization of the shipping industry. In the literature, various QMs from simple queues to a complex queuing network models (QNM) have been suggested and studied for different types of port operations around the world such as analyzing movement of ships in port (El-Naggar, 2010), ship traffic modeling (Branislav and Nam, 2006), mechanism of congestion occurrence (Theo, Athanasios and Jean-Paul, 2022), cost composition and congestion cost with measurement of total cost (Haq, 2014), optimum use of port facilities and equipment by imposing congestion charges (Serdjo, 2017), optimum number and capacity of port berths (Emeghara, 2012), evaluation method for determining the optimum number of berth (Serdjo, 2017), size of port, optimum berth allocation, and crane combination in port

(Cullinane, 2013), average cost per ships served and ship turn-around time at the port (Jammaz, 2010), analysis of time spent at berth, measurement of delay to ships in the queue (Kimani and Kimwele, 2014), distribution of berth occupancy, berth planning by evaluation of congestion and cost (Shehu, Intan and Akintola, 2014), optimum port capacity related to congestion and berth occupancy (Roy *et al.*, 2016), handling equipment assignment and deployment, and so on. There is a rapidly increasing literature in the applications of QMs to port systems and it is the intent to attempt a classification, literature review and identify possible future directions of research.

Container port systems have been long and very often considered as required queuing models and network of queuing in operations. These systems consist of berths with ships waiting to be served in queues. Berth throughput capacity can be estimated based on experience from existing ports without giving much thought to the effect of the size of the port, but, measured by the number of berths (Sirous, Said and Mehrdad, 2017) since, some ships can berth on one or more berths to loaded and discharge its containers in a port. Port Queuing Network Model can be represented by a single-service channel for a single-berth port and by multiple-service channel for a multiple-berth port.

A container terminal port system consists of one or more berths, an arrival process, and a service process, along with some additional assumptions about how the system works. The number of ships in the port system at any given time will equal the number of ships in the queue plus the number of ships at berths. These numbers will vary over time as ships come and go, so they are formally stochastic processes (Shehu *et al.*, 2014). According to Sharma (2018), if there is a limited amount of anchorage area, or for any other reasons ships are prevented from joining a queue once it reaches a certain level, then the queue or port system has finite capacity.

From the viewpoint of design practice in a port system operation, deterministic approach is simpler, but the possibility of its application is limited, while the stochastic approach describes more realistic process and its dynamic character. Knowledge of these behavioral laws, guide to adequate description of material flow, and the data base is used as a source of knowledge in systems modeling (Sharma, 2018). The particular problem presents the selection of the QMs to be deployed or design. Various authors such as Onwumere, (2018), Kalavaty, (2017) and Tom, (2019) among others gave different types of theoretical Queuing Model approaches but there are no indications of adequate use in problem solving and the difference between the theory and practice (Sanijb and Biswa, 2011).

### **2.3.8 Ship Arrival Pattern and Queuing Theory**

The arrival of container ships in a port is often irregular, and when it arrives, it may not be able to move directly onto a berth or has to wait until a berth becomes empty, if all berths are occupied. The berth time needed to serve a ship is also a variable, as it depends on the amount of cargo which the ship carries and the capacity of the present facilities for handling and storing cargo (Gokkup, 2015; Zdenka and Edna, 2015).

The investigation of such random occurrences requires a complex and detailed analysis. The concept of “Queuing theory-waiting line problem” can successfully be applied in a port system operation. Queuing Theory is one of the most useful tools for analyzing the behavior of waiting units (ships in this case), for investigating the components of a multiple operations system behavior (Branislav and Nam, 2016). Thus, queuing theory may be adequate for studying container ship movement in a sea port.

Two basic elements are necessary for the application of queuing theory to a waiting line problem: an arrival function and a service function. These functions should first be modeled. Once the validity of these models is tested, the different characteristics of the theoretical models, which describe the actual system with the accuracy that may be realized in estimating future traffic, can then be determined (Branislav and Nam, 2016).

An important parameter measuring the performance of a seaport is the delays that ships experience while waiting to be processed (Emeghara, 2012). These factors affect delays- the pattern of ships arrival, and the berth time requirement for cargo handling calls for ordered queuing systems of ship waiting line at the container terminals before the beginning of loading/unloading operations or waiting to berth i.e. when there are no ships waiting to be serviced at the terminal.

In order to eliminate waiting at the port container terminal, it is not the best management approach to construct great number of Berths to obviate the need for waiting or many cargo handling facilities which would be permanently employed so that they do not remain unattended. These extreme solutions, of course, are not rational, queuing theory has proved good model in optimization in facility utilization and cost implication, in handling delays and waiting time in a port system (El-Naggar, 2010). Due to random arrivals of container ships at the terminal as well as duration of ship service which is also a random variable, from a queuing theory viewpoint, it is not possible in practice to implement such work organization at the port container terminal so that at any one moment the

berth capacity is 100% employed and at any one moment a ship arriving does not have to wait for beginning of loading/unloading operations. Since in practice the waiting time and berth occupancy cannot be completely avoided (El-Naggar, 2010), hence, each terminal strives to reduce waiting time as much as possible, i.e. costs of both participants in the servicing process at the container terminal carry a minimum amount.

Furthermore, the total waiting costs in a port terminal operation can be observed separately, i.e., costs from the ship owner's viewpoint and from the container terminal operator's viewpoint. A clash of interest exists between these two stakeholders - the ship owner and the container terminal operator. It is in the ship owner's interest to have the ship wait as short a period as possible and in the port container terminal operator's interest to handle as much traffic as possible in an observed time unit with the least number of berth facilities, hence, optimization in operations for the two interests is a major consideration in port operations. Nevertheless, the servicing process at the container terminal should be resolved taking into consideration total waiting costs as the interests of both, ship owner and port terminal operator, are mutually interwoven. The port container terminal is not indifferent to the long waiting time of the ships even though it has high berth utilization, as this waiting is expensive and can divert the ships to other ports; in the event of a short waiting time, the supposition is that the container berths are poorly employed and this may result in an increase of port service costs, which, in turn, is not in the ship owner's interest (Branislav, 2016). If costs are taken as optimization criteria, then the servicing process solution at the container terminal will represent the optimum number of berths for which total expenses of ship waiting time and expenses of berth occupancy are minimum in an observed unit of time (Branislav, 2016).

Onwuegbuchunam (2018) applied key performance indicator metrics and parameters of queuing model in assessing performance of Nigeria's concessioned port terminals. Data for the study were obtained from terminal level records of cargo and ship handling activities for years 2000 to 2015. Major findings indicate that cargo and vessel throughputs improved after the reforms in the six ports examined. However, much variability was observed in trends in ships' turnaround times across all ports after the concession policy implementation. Additional results from the queuing model analysis suggest that the high ships turnaround times observed in some ports are associated to delays in ship operation at the berths. The study recommends that policy interventions be focused on ship operations at the berths as a step-in improving service level in the port terminals.

According to El-Naggar (2010), to analyze the movement of ships in a seaport using the queuing theory, the following conditions are assumed:

- i. Ships arrivals and service times conform to the pattern of random occurrences.
- ii. Ships are processed on the “first-come first-served” queue discipline.
- iii. The queue length is unlimited, that is, if a ship arrives and finds a long queue, it joins the waiting ships and does not leave the port.

El-Naggar (2020) studied the application of queuing theory to the container terminal at Alexandria seaport. He designed a methodology to support decision-making process for a developing seaport infrastructure to meet future demand. In order to determine an optimum number of berths at a seaport, the queuing theory was applied in the light of port facilities and activities. The aim was to avoid in advertent over and under-building. The study analyzed the movements in port, the waiting time of vessels outside the port and in queue were calculated in accordance with the considered queuing model. The theoretical functions representing the actual vessel arrival and service time distributions were determined. For the economic considerations, cost estimate studies including cost of port and waiting vessels were estimated and finally, the optimum number of berths that minimizes the total port costs was calculated, hence, the proposed mathematical and economical models were applied to Alexandria port in Egypt.

### **2.3.9 Vessel Operational Costs and implications in Maritime Industry**

According to Wilmsmeier (2014) advances in technology have led to a continuous reduction in vessel operating costs over time. Improved fuel efficiency, economies of scale, and automation in port operations- all help to reduce environmental and financial costs. However, the drive to invest in lower operating costs may have some negative repercussion on freight rates. For instance, as carriers invest in larger and more energy-efficient vessels in the current market situation to achieve economies of scale or to improve fuel efficiency, they are unintentionally also contributing to a future oversupply of capacity. While the individual carrier may benefit from cost savings from deploying bigger vessels, all carriers bear the burden of the resulting oversupply and lower freight levels to the benefit of importers and exporters. Oversupply of shipping capacity combined with a weak global economy has been a main factor affecting freight rates in recent years (Drewry, 2015). In an effort to deal with low freight rate levels and to leverage some earnings, carriers have looked at measures to improve efficiency and optimize operations in order to reduce unit operating costs. Some of these measures involved operational consolidation, slow steaming, idling, and replacing

smaller and older vessels with newer and more fuel-efficient ones. Although operating costs in shipping have been decreasing, the total costs of the transport system have declined less. First, total costs for the carrier have to consider the costs of investing in new assets. Second, larger ships and the increasing use of hub ports also require ports and port cities to invest in additional capacities for storage, handling and intermodal connections (Drewry, 2015). These additional costs – including external social and environmental costs – are not born by the carrier, but by the ports and local communities.

Lower operating costs as compared to higher fixed costs (that is, the capital costs associated with larger and more fuel-efficient ships) will likely also lead to more volatile freight rates. In the short term, the freight costs will have to cover at least the operating costs of the carrier; put differently, if the price of a transport service does not cover at least the fuel, communications and crewing costs, the carrier will anchor the ship and not offer the transport service.

In the long term, however, the freight charges will have to cover the total average costs, including the fixed costs. As operating (variable) costs are lower today than in previous years, this means that freight rates may also reach lower levels than in the past. Lower unit operating costs in bigger vessels; however, can only be reached if utilization rates are sufficient; if they are not, the carrier might be affected by diseconomies of scale (ECLAC, 2012). The risk of the latter also increases with ship size, particularly if demand and supply do not develop in line with each other. Effectively, freight rates appear to fluctuate more today than in previous years, and the changing structure of operating versus fixed costs is probably one of the reasons for this trend.

#### **2.3.10 Cost Concept and Queue Model applications in container port**

The understanding of cost concept and Queue Model applications is necessary in maritime industry. Vessel owners and port terminal operators are very mindful when it comes to issues of cost. The global maritime business environment today is highly competitive, impacting every port organization large or small. According to Meng *et al.*, (2014), the impulsive or spontaneous reaction under the current circumstances is just to cut all costs to the minimum level to attract more customers and in doing this, every aspect of port cost either from the angle of vessel owner or port operators must be carefully examined to eliminate unnecessary discretionary and non-value adding costs, while yet retaining its competitive position in quality and size.

In maritime industry, investors' main objective is to achieve maximum profit and handsome rewards especially the private sector operators and vessel owners. The investors would want to avoid any non-value adding cost which will increase cost of doing business in the port industry.

Cost generally is the price paid or incurred as part of acquiring, producing, or maintaining a business inflow or outflow, usually measured in monetary terms. According to Wikipedia, cost is the value of money that has been used up to produce something or deliver a service, and hence is not available for use anymore (<https://en.wikipedia.org>). Cost is the value attached to a product, goods or services. However, the cost imply here is simply the cost incurred due to idle time or unproductive time of the vessel and berth inoccupancy. Idle time results when vessels are queued up at the anchorage awaiting berth allocation or at berth awaiting loading and/or unloading operations to commence. In the maritime industry, it is a practice that there is no idle time, implying that the vessel or any maritime/port facilities incurs costs and expected to generate income at every point in time. When such facility lays idle or unproductive, costs are incurred or profit loss as result of idle time.

Queue model is a probabilistic approach that helps to determine the utility cost of a system. It can be used to determine the optimality cost of operations. Queue model could be adopted as a tool for cost control and cost reduction. It is required to achieve maximum profit in competitive market where demand is affected by the cost which the port industry is a typical example. The port industry is a typical scenario of a competitive business environment where the port customers are interested mostly in cost of operations in the port industry. Queue model is a technique for cost control which makes available the necessary information to manage the actual cost or operations/events and align with the budgeted costs and timing. While on the other hand, it is a handy tool for cost reduction technique which is used to save the unit cost without the system being congested or empty thereby compromising service quality output (Asaolu and Nassar, 2017).

Sikka (2013) discusses that cost control system consists of ways and methods that are used to control the operating cost of a system and ensure that cost does not go beyond a certain amount with respect to time, since time is the basis for determining cost of operations and services in the port industry. The process of regulating the cost of operating a business is known as cost control and is involved within acceptable limits. These limits are usually stated as standard cost or target cost limits in a formal operation plan or budget. Cost control is the process of avoiding wasteful use of valuable resources (time) and encouraging efficiency and cost consciousness. Cost reduction

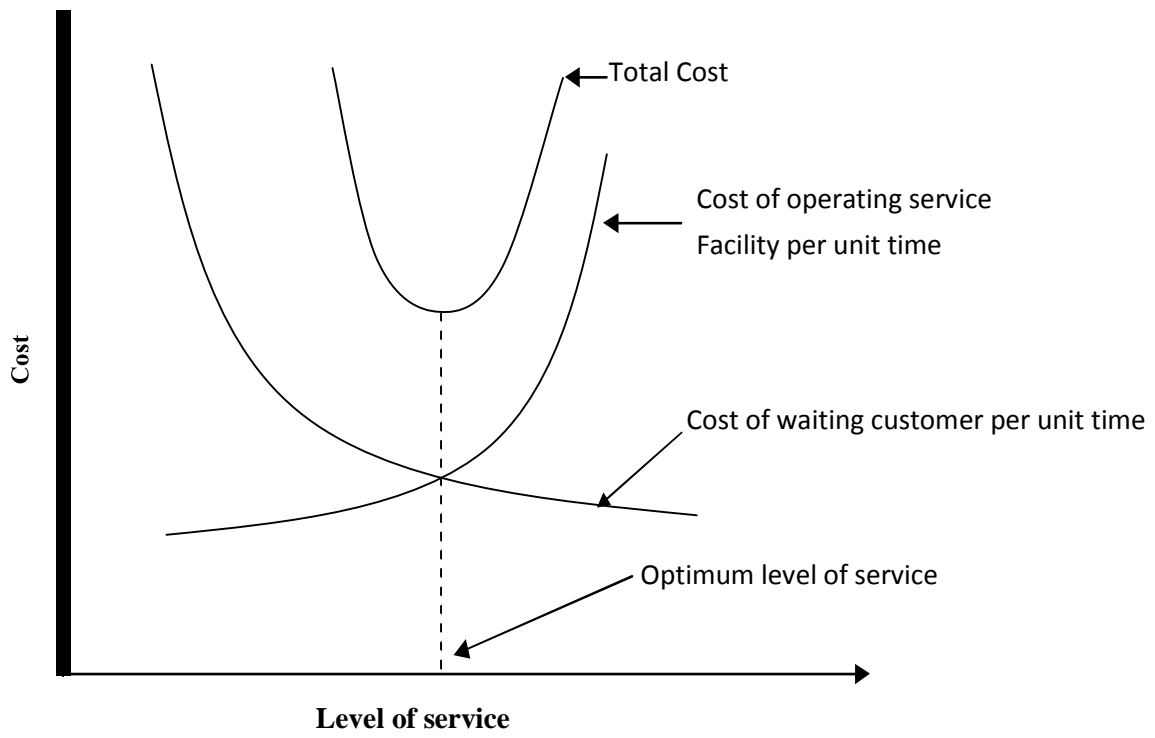
is a planned positive approach to reduce delays or congestions on the vessel which may result to berth inoccupancy when the vessel is diverted to other ports hence, to achieve optimal cost and berth utilization, there should be cost reduction measure through application of queuing model.

In competitive industry like the seaports/maritime industry, there is need to incur reasonable cost, management has to ensure careful and efficient use of resources (time) so as to achieve the set standards. Therefore, the concept of application of queuing model in port container terminal system is for cost optimization. Cost Optimization helps port organization develop strategies aimed at increasing revenue and decreasing costs to enhance productivity and profitability. The concept of cost optimization in the port industry, is not just thought to be purely a cost reduction exercise, but also a cost control technique which is the process of establishing standards and maintaining the performance according to standards to maximize profit by reducing delay time of vessels at berth and/or avoiding cases of berth inoccupancy.

Therefore, cost control and reduction are important cost optimization techniques in a port terminal operation in order to regulate and reduce unwanted delays and time waste, and it also helps to bring about increase in market demand in term of competitive market. The most significance of cost reduction and cost control derive from its function is profit maximization. Any port terminal operator that successfully adopts queuing model in cost control and cost reduction would operate the port terminal system at an optimal cost with the berthing facilities fully utilized without reducing its quality (Lockey, 2012).

The main difficulty encountered by port industries recently is the increase in port demand and high cost of installation of terminal infrastructures and maintenance.

Most of the cost factors in terminal operations are fixed cost and variable cost and similarly, to vessel owners. The cost of operations to the both ends could lead to inevitable cost control and reduction scheme which makes it relevant for ports operators to seek the best cost model to work on efficient frontier. Every port organization that wants to survive and maintain its customers must seek to improve on its products and service quality and ready to deliver at a barest competitive cost. Therefore, in order not to exceed their budget and not to run at loss as well as not to reduce the quality of their products and services, needs to work-out the optimal costs using cost control and cost reduce approaches to a targeted lowest minimum cost (optimal cost) that would give the port a comparative cost advantage over the other ports within the region and the world best practice in terms of service quality.



**Fig. 2.7: Costs Associated with Queuing system**

**Source: Michael and Shaib, (2012)**

The cost diagram above simplifies the cost model for optimal cost for a port terminal operation of the port system. The optimal level of service is reached at the point of intercession where cost of operating service facility per unit time meets with the cost of vessel waiting per unit time (Michael and Shaib, 2012). This assumes a port service rate which does not allow delays or long queuing time as well as berth inoccupancy. The optimal level of service implies that the customers need not to queue for long time awaiting service causing delays thereby increasing cost (vessel idle time), also it implies that the system is busy and no idle berth, where all the service points (berths) are fully utilized and no cost incurred or profit loss on berth inoccupancy.

In all these, Nigeria port industry has the challenge to pass through the processes of development to ensure operational efficiency. Operational efficiency can be defined as the ratio of input to run an operation and output gained from the operations (Timothy *et al.*, 2015). This definition took note of both port users and the port operators. Port is hence said to operate efficiently when the operational efficiency of both the users and operators are optimally achieved at a given cost known as optimal cost. When operational efficiency is improved, the output to input ratio improves.

In the world today, ports industries are faced with challenges of new technology, globalization and competition. To meet customer's desire, port industry must ensure a satisfactory service delivery. A port could only continue to be relevant to customers if it operates with minimum delay, utmost efficiency and at a reasonable cost to users. There are so many factors militating against efficient running of Nigerian ports (Nwokedi *et al.*, 2019).

### **2.3.11 Effect of Cost on Port Efficiency, Performance and Competitiveness of a Container Port**

In port business evaluation, cost is very significant to stakeholder either to the user or the operator. Profit can only be derived where the business earnings are higher than the input costs. In measuring the profit for any business venture, it is simply done as "Selling Price less the Cost Price (i.e. SP-CP)", and where the value of outputs is less than the value of the inputs, the business is running on deficit. No business owner or operator would want to perform below a given profit margin. This is what happens when berths are not fully utilized and/or when vessels waste precious time awaiting service at the ports *verse visa*.

In the recent time, maritime industry operators have experienced high cost of operations due to global economic development and its attendant influences on ports. This is as a result of changing

world in advance technology, shipping development, and preferential choice of shippers and shipping lines which has geared-up ports upgrading and maintaining standards which would attract patronage/customers among other ports. This rising demand in the port industry tends to increase port operational costs; while on the other hand, shippers and shipping lines seek to patronize ports that would offer comparative low cost on port services.

The growth of traffic on the world scale, as a consequence of the globalization of the economies of almost all maritime countries has resulted in more intense competition and adoption of new strategies by all the agents involved in the port activities. Some of these transformations and their consequences have been emphasized in the recent scientific literatures on seaports assessment. In this context, the literature focus is, in particular, on port performance and competitiveness. Barros (2009) defines performance as an investigation of efficiency and effectiveness in the accomplishment of a given activity. The most straightforward and still widely used approach in measuring port efficiency is the calculation of partial productivity. In the last two decades, benchmarking efficiency methods, such as Data Envelopment Analysis and Stochastic Frontier Approach, have been widely used. Another branch of literature has taken a more macro perspective by focusing on port effectiveness and the users' satisfaction. For Barros (2017), "in an environment in which ports have natural hinterlands and are not in competition with one another, a performance evaluation methodology may be appropriate. However, in an environment in which ports are in competition with one another (where shippers and carriers are part of the port-selection process); a port should not only be concerned with whether it can physically handle cargo (port production factors), but also whether it can compete for cargo (port operational cost factors). In a competitive environment, port time-related costs in addition to port charges incurred by shippers and carriers are important determinants in port selection". From this perspective, seaports have to move out of their rather passive position to avert the existing strong bargaining position of shipping lines. When analyzing seaports, as critical nodes in supply chain, several factors for competitiveness have to be considered which cost of operation is mostly considered because it adds up to overall transportation and logistics costs.

Performance may be evaluated from the standpoint of efficiency and effectiveness. Efficiency has been noted as "doing things right" while effectiveness is "doing the right things". Doing things right refers to a full utilization of the available resources and efficient management of operations. However, the improvement of seaport efficiency does not necessarily ensure a good adaptation to the requirements of the users. Brooks *et al.* (2013) indicates that the right things are those that are

important to the customer. Therefore, effectiveness refers to the achievement of seaport objectives. Effectiveness is, then, a wider term that encompasses the term efficiency. In some studies, about organizational effectiveness, efficiency is considered as a criterion for the measurement of the effectiveness of an organization.

Port efficiency/productivity has long been a dominant topic for port performance researchers. There are many ways of measuring port efficiency/productivity relative to cost of port operations which include the following broad categories of activity indicators (cargo throughput, container throughput, vessel traffic volume, berth occupancy rate, vessel tonnage, etc.); partial and total productivity measures include (vessel turnaround time, labour and capital required to load or unload goods, etc.); and economic and financial indicators (rate of return on turnover, operating surplus per ton of cargo handled, etc.). However, the main weakness of multiple indicators lies in the difficulty of examining whether port performance has enhanced or deteriorated over time and between seaports. In the recent time, some particular measures of efficiency, which can involve at the same time various inputs, have gained more attention from port researchers. These measures can be obtained using a parametric method- Stochastic Frontier Approach (SFA) or non-parametric methods- Data Envelopment Analysis (DEA) and Free Disposal Hull (FDH). According to these methods, seaports are assimilated to a “Decision Making Unit” (DMUs). The results provide information on by how much a DMU can decrease the input without decreasing the output; this is targeted on cost control and reduction while maintaining quality standards of products and services. Therefore, technically inefficient DMUs can be brought towards efficiency by cutting down overused inputs. This efficiency is known as “Technical Efficiency” (TE). The analysis can be expanded to “Allocative Efficiency” (AE) defined as the ability of a DMU to minimize costs for a given output. When combined, both measures (TE and AE) are referred to as “Total Economic Efficiency” (TEE).

On the other hand, assessing the effectiveness of the seaport organization is a subject that has not been studied comprehensively in the literature. This is because of the complexity and dynamism of the structure and the environment of a seaport. To evaluate port effectiveness, we first have to identify the port users because they have different functions and objectives. Some studies focus on a group of actors in particular, such as carriers (Itoh, 2012), shippers (Kaisar *et al.*, 2009) or terminal operators (Kaisar, 2019). Others extend the definition of port users to the entire supply chain (Brooks and Schellinck, 2013). According to Park and De (2016), assessing organizational effectiveness of ports should refer, first, to the output quality, second to leadership, stability,

growth and planning and finally to many other important criteria such as customer satisfaction, information management and communication, adaptability/flexibility, efficiency/productivity, professionalism, human resource development and profitability.

One of the main methods used to evaluate the service quality offered to port users is the “SERVQUAL”, a multi-item scale in which the “Service Quality” is defined as the gap between customers’ expectations and perceptions of the service experience. In this model, five dimensions are identified (i.e. tangibles, reliability, responsiveness, assurance and empathy). Studies, like those of Ng and Lee (2017), Pjevcevic *et al.* (2012) and, Min and Park (2015) tested “SERVQUAL” in shipping and in commercial ports. The importance performance analysis is another method used to evaluate both customer satisfaction and service quality (Gi, Vinh, & Saeveon, 2015). It does this by determining the relevance of the evaluation criteria or attributes to customers and their assessments of the organization’s performance on these criteria (Brooks and Schellinck, 2013).

Furthermore, Marlow and Paixao (2012) define competitiveness as the skill or talent resulting from acquired knowledge capable of creating and sustaining superior performance developed by competition. Because port competitiveness strongly affects a country’s growth and development, port operators and authorities located in the same port range and serving approximately the same hinterland have to create a sound competitive strategy. A large number of recent publications in the field of maritime and seaport management have analyzed the fierce competition for market share among ports and developed various methodological approaches to identify the major determinants of seaport competitiveness. Many authors emphasize that location advantages, service cost and maritime accessibility are critical in leading to port's competitive success. Others suggested that port dues, costs and many other elements, such as hinterland accessibility, infrastructure quality and productivity, also perform a vital role in strengthening a port competitive position. There has thus been a considerable discussion on the main determinants of a port international competitiveness. In this context, an overall definition of seaport competitiveness does not exist. Competitiveness is a multidimensional concept which depends on several factors that can make a seaport attractive or not (Gi-Tae, Michael, & John, 2011). As Barros (2019) said, “port competition is a puzzling expression”.

### **2.3.12 Effect of cost of delays on vessel operational performance**

According to Raymond, Tse and Peter (2013), when a delay occurs in a port system, there are basically two options prescribing overtime work (long turnaround time) and injecting additional resources (additional cost), in order to meet the project schedule of certain activities. This is the effects of operational delays which affects the schedules of the vessel and incurring cost to meet the new schedules due to delays at the ports.

Willem (2020) infers that delays have been part of the dynamic shipping world and partially paid back in the chain by way of demurrage. However, demurrage is a visible expense for extra time when the charter party dictates that certain time limits are being exceeded due to shipping delays either the port or other factors, however, not only the shipping lines and carriers bear the costs of delays; all port participants are affected too, because of unreliable vessel's Estimated Time of Arrival (ETA), and service rate at the ports. cost of delays however, has a ripple effect on the overall logistics system. At the port's terminals, berths are not optimally utilized, and the port authority cannot efficiently use its infrastructure.

Congestion in ports is a phenomenon associated with delays, queuing and extra time of voyage and dwell of ships and cargo at the port, which always occur with unpleasant consequences on logistics and supply chain (Usman, 2015). These often translates into extra costs, loss of trade opportunities, discomfort to port users, decline in market shares and disruption of trade and transport agreements (Hasheminia & Jiang, 2017). In a study to identify the consequences of port congestion on logistics and supply chain operations in some African ports by Usman (2015), port congestion scenarios, were examine on the dimensions of various factors that trigger congestion in the ports of Lagos, Durban, Mombasa and the catchment ports of the Suez Canal. The study applied the concept of variations in turn-around time of ships and cargo vis-à-vis the port's capacity and relative efficiency level in order to identify the active factors that cause port congestion in African ports. The results provided some explanations on the consequences arising from these on notable African logistics and supply chain networks. The findings revealed that the bane of congestion in African ports emanates entirely from either planning, Regulation, capacity, efficiency or a combination of the factors. It recommends that African ports should enhance their regulatory mechanisms, then to improve capacity and efficiency level in order to shoulder the ever-increasing challenges of port congestion in years ahead.

## Research Gap

This study is basically an estimation of cost of delays on vessel operations in container terminals of Nigeria seaport industry. The estimated the average turnaround time of vessel in ports container terminals, the arrival rate of vessels in ports container terminals, the average service rate of vessel at berth in ports container terminals, the optimal service rate of ships in ports container terminal, the probability that the system is optimally utilized, the container terminal utilization coefficient, the ship queuing costs in ports container terminal and the cost of idle berth in container terminal of Nigerian seaports by applying queuing models whereas, multiple regression was used to determine the significant effect of cost of delays on vessel operations in container terminal of Nigerian seaports.

The review of literatures on this study has identified gap in this area of research as there has not been any known work done in this area of study as long as Nigeria seaports are concerned. Many studies have been carried out which were premised on seaport congestions such works include Emeghara and Ndikom (2012) which focused on delay factors evaluation of Nigerian seaports, a case study of Apapa Ports Complex, Lagos, using ranking and multi-regression analysis. Nze and Onyemaechi (2018) studied on port congestion determinants and impact on logistics and supply chain on five African ports. The study applied the concept of ranking by inspection using the dwell time of ships in five African ports to evaluate the variations in ship turnaround time and relative efficiency level of the selected African ports. The approach was used to identify the active factors that cause port congestion in African ports. Yusuf, Shekwobagwu, bdulmalik and Damana (2022) studied on assessment of factors causing congestion and nature of cargo clearance in Apapa Port, Lagos using descriptive statistical method. The work of Oyatoye, Adebisi, and Okoye, (2011) was an application of queue theory to port congestion problem in Nigeria. Queue model was applied to the arrival and services pattern which causes the problems of congestion in Tin Can Island port, while Asabe (2021) studied on assessment of factors causing port congestion in Nigeria; a case of Lagos-Apapa Port using analytical hierarchy process (AHP). Aruwei *et al.*, (2022) researched on impact of port congestion on Nigeria economic growth. The study investigated the impact of port congestion on economic growth in Nigeria using the Autoregressive Distributed Lag (ARDL) approach to co-integration and error correction modelling to analyze time series data from 1995 to 2019 in Nigeria Lagos-Apapa Port. Alamutu, (2018) studied the application of Queue Model to ease traveler's flow in Nigerian International Airports. The study examined the application of queuing model to ease travelers' flow in the Nigerian international airports. Muhammadu (2018),

studied the application of queue theory in tackling the problem of port congestion at Apapa port, Lagos. The study demonstrates the applicability of queue theory models in addressing the problem of congestion in Nigerian Ports, by dealing with the application of multi-queue and multi-server queue models with infinite capacity, First-come First-served model in tackling the congestion problem at the Apapa port, Lagos. Nwachukwu, Akpudo, Enyinda and Stephens, (2023) used Queue Modeling Simulation to determine vessel traffic and optimal service rate for Nigerian ports. Therefore, a significant gap exists on the real time quantification of costs to ports and shippers arising from the delays occasioned by highlighted factors in literature. These delays to be quantified would be translated to equivalent cost, which would eventually become a new contribution to the existing body of knowledge in port operations in Nigeria, hence, this study is aimed to evaluate effect of cost of delays on vessel operations in container terminal of Nigeria seaport industry which no research has been carried out in this area in Nigeria seaports.

## **CHAPTER THREE**

### **METHODOLOGY**

#### **3.1 Research Design**

The study used a mixed design method consisting of quantitative research design and survey design approaches. The quantitative research design involved the use of secondary data from the Nigerian ports Authority (NPA) covering a time period of 16 years. The approach was to use the time series quantitative data on the vessel delayed operations in the Nigerian ports and the associated vessel operation costs in the ports to estimate the cost of vessel operations delay in Nigerian ports. The significances of the estimated costs on maritime and port logistics performances were also determined using quantitative tools.

The survey design involved the use of questionnaire and checklist as survey instruments to generate primary data on the ship operators and shippers satisfaction with container terminal operations relative to the extents of delay in vessel operations in each container terminal used in the study.

#### **3.2 Description of Nigeria seaports / the Study Areas**

There are basically six major ports actively engaged in maritime activities in Nigeria and operated by the concessionaires. These are Lagos port complex (Apapa port and Tin-Can Island port); Onne port complex, Port Harcourt port complex. However, the study would focus on three container ports being Apapa port, Port Harcourt, Onne and River Port container ports terminals.

The Lagos Port Complex (Apapa Quays) is a 'Premiere Port', the earliest and largest Port in Nigeria. It is situated in Apapa, Lagos State, geographically located between longitude 6.456991° and latitude 3.370757°. The Port was established in 1913 and construction of the first four deep water berths commenced in 1921. The port complex consists of a number of facilities including Apapa quays, third Apapa wharf extension, Apapa dockyard, Apapa Petroleum wharf, Bulk Vegetable Oil Wharf, Ijora Wharf, Kirikiri Lighter Terminal, and Lily pond inland container terminal. The Nigerian Ports Authority (NPA) owned and managed the operations in Lagos Port Complex from 1956 until 2005 with the exception of stevedoring and manufacturing (Nwolozi and Ndubisi, 2020). In 2005, the port complex was concession and divided into multiple terminals which were sold to private operators to manage for a given period of time as agreed in the

concession terms (Ndikom, 2015). The Port of Apapa Container Terminal covers 44 hectares; 6.4 thousand square meters of storage area and can handle up to 22 thousand TEUs of containerized cargo (NPA News, 2017). It has water depth of 10.5 meters, total quay length of 950 meters of numerous berths ([www.worldportsource.com](http://www.worldportsource.com)). The Terminal Operators are: AP Moller Terminal Ltd. (APMT), ENL Consortium Ltd. (ENL), Apapa Bulk Terminal Ltd. (ABTL), Greenview Development Nigeria Ltd. (GNDL) and Lilypond Inland Container Terminal. The Port also has two (2) Logistics bases- Eko Support Services Ltd. and Lagos Deep Offshore Logistics (LADOL) and eight (8) jetties. Sugar, Salt and Flour are produced in factories belonging to operators within the port. Lagos Port Complex is registered as an ISPS certified Port facility with the International Maritime Organization (IMO).

Tin Can Island Port (TCIP) is located North-West of Lagos Port Complex and has bearing of Latitude 62°N and Longitude 30°23'E. The port was developed in 1975 when the country experienced increase in economic activities of the oil boom which led to high volume of import and export resulting to serious Port congestion at the time. The resultant effect created a situation where it became necessary for the government to initiate an actual means of decongesting the Port; by constructing a new Port on Tin Can Island. In 1976, the construction of the new Port started and was commissioned on 14th October, 1977. Tin Can Island Port Complex today comprise of RoRo and Tin Can Island Ports. This merger came with the concession of the terminals to five (5) Terminal Operators in May, 2006. The Port handles diversified cargoes with each terminal operator specializing in unique forms of cargo (Dry and Wet bulk cargoes, Box- Containerized cargoes, and RORO services). The Port handles vessels ranging from 100m – 260m.

Onne Port Complex is situated on the Bonny River Estuary along Ogu Creek. Onne is the first Nigeria ports to operate the Landlord Port Model, devised to encourage private sector participation in the Port Industry. There are multiple operations that are carried out in the Port in addition to the Oil and Gas operations. Some of such multiple operations are General Cargoes, Bulk Cargoes (Dry & Wet), Oil Well Equipment, Containerized Cargoes and other Logistics Services provided to companies that are customers and tenants. Hence the Port is a multi-purpose Cargo Port. The Port is highly industrialized with modern facilities and equipment that can stand the test of time. There is also adequate land available for development to all customers and prospective investors who desire to partner with the Port in the Maritime Business. The Port covers an area of 2,538.115 hectares. Onne Port has one of the biggest harbour mobile cranes in Africa (Liebherr 600) with a lifting capacity of 208 metric tons and 220 Gmk, 5220 grove twin cranes that has capacity of lifting

single heavy cargo of 300 tons owned by one of the Terminal Operators in the Port. Onne is a relatively major port in the region and has several quays with facilities for cargo ships up to 60,000gt. It is also the main base for the offshore activity in the region. Onne port is nicknamed Oil and Gas Free Zone (OOGFZ) and contains several quays to cater to off shore supply vessels and a shipyard (WAS - West Atlantic Shipyard). OOGFZ also contains Shell Nigeria Exploration & Production Company (SNEPC), one of the largest bases of Shell offshore in Africa including berths leased out to Exxon Mobil, Total S.A. and other oil companies.

The port consists of three regions located adjacent to the Niger delta - Federal lighter terminal, Onne port complex and Federal ocean limited (which consists of facilities for offshore oil and gas supply vessels). It also has a container terminal (WACT - West Africa Container Terminal) with a deep draft of 12 meters and frequented by vessels up to 4000 TEU in size belonging to Maersk lines and PIL and CMA CGM (<http://nigerianports.gov.ng>)

Rivers port also refers to as Port Harcourt port is situated off Gulf of Guinea with quay length of 1,259 metres and a stacking area of 27,497.15 square metres. Port Harcourt port is actually a multipurpose facility and is strategically located in oil producing state of the Niger Delta region of the country. The concessionaires operating in the port include the port and Terminal operators limited (PTOL) and BUA ports and terminal Nigeria limited. The Port is equipped with 16 tanks of 3,048 MT capacity of bulk oil installation and four (4) Arcon sheds with storage capacity 12,486.15 square metres. The Port plays the 'Mother-Port' role to several jetties surrounding her as 'satellites' through the provision of pilotage and towage services, catering for the various markets, relating to Dry, Liquid and General cargo trades.

### **3.3 Sources of Data**

In carrying out this study, the researcher employed both primary and secondary sources of data. The primary data was sourced through survey. Checklist and questionnaire were used as survey instrument to elicit responses from sampled population of ship operators and shippers on their satisfaction with container terminal operations in Nigerian ports relative to the delays in vessel operations at the terminals.

The secondary source of data was majorly from Nigerian Port Authority Annual Reports of 2007-2022 as well as Nigerian Port tariff regulation of 2004 which is also a publication of the Nigerian ports Authority.

### **3.4 Study Population**

The population of the study consist of terminal operators in Nigerian ports, ship agents, ship operators, shipping companies, and shippers. The estimated population of the study was 500 respondents, where 125 respondents were randomly selected from each port of Onne, Rivers, Tin Can and Apapa.

### **3.5 Determination of Sample Size**

The researcher used the Taro Yamane formula to determine the sample size for unknown population in other to arrive at meaningful sample size that would satisfy the objectives of the study as shown below:

$$n = N / 1 + N (e)^2$$

Where

n = the determined sample size

N = the estimated study population;

e = the error limit of 0.01 was used

□ n = 476 respondents.

476 questionnaires were required; hence, 119 were distributed to the respective ports.

### **3.6 Instrument of Data Collection**

The instrument used for primary data collection was a structured questionnaire designed by the researcher. The researcher, however, on a pilot study visited the ports and had opportunity to interact with the staff of port terminal operators, the port traffic workers, ship agents, ship captains, harbours and commercial departments of the NPA to gather information to authenticate the secondary information which were a review of existing documents and published materials such as the NPA Handbook, NPA Annual Statistical Reports, NPA simplified tariff, current publications

in journals and the internet Google scholar. Also, a well-structured questionnaire was deployed to elicit responses from the respondents in a random selection from the respective ports. The questionnaire was designed in 5 Likert scale percentage rating of 20, 40, 60, 80 and 100 of port user's satisfaction Scores with Container Terminal Operations in Nigeria relative to the Extent of Delay experienced at the Terminals in the respectively ports.

The secondary data collected from documented materials comprises of time series data on vessel turnaround time, berth occupancy rate, berth vacancy rate, vessel tonnage and ship traffic of Onne, Rivers, Tin Can Island and Lagos Apapa ports covering sixteen (16) years periods of port concession from 2007 to 2022. Other information was gathered from NPA simplified tariff comprises of berthing and mooring charges, berth rent, pilotage rates and tug charges. The secondary data collected on this study were authenticated as the researcher visited the ports and had brief oral interactions with the workers in harbours department of the ports, ship-owners/Agents, Importers/Exporters, workers at the port container terminals which guided the researcher on the results and decisions on this study. The information from the interactions enabled the researcher build confidence on secondary data collated, organized and evaluated for statistical analysis.

### **3.7 Validity of the Instrument**

The validity of the instrument is the extent to which the instrument measures what it was designed to measure. Validity of an instrument can be criterion-related (predictive) validity, content validity and construct validity. For the purpose of this study content validity was used to ascertain the validity of the instrument. Content validity has to do with the ability of a measuring instrument to adequately measure and cover the scope of the study, which the questionnaire designed for this study was adequately construed and validated by experts to serve the purpose of data collection on this study.

### **3.8 Reliability of Research Instrument**

Reliability is the consistency between independent measurement of the same dependability and predictability of a measuring instrument.

Reliability test is a test carried out to ensure the stability or consistency of a test score or the ability of a particular measuring instrument to yield similar results when applied to the same situation at different times. In testing the reliability of the measuring instrument, test and re test method was employed. A pilot study was first conducted from the same respondents at different times with twenty selected members of the sample population, five (5) from each port. The questionnaires were administered to the same set of respondents at different times. The separate scores were recorded and correlated to determine the test and retest reliability coefficient of the instrument using Pearson Product Moment Correlation Coefficient (PPMCC) and a reliability index of 0.7 calculated indicating correlation and reliability of the instrument.

### **3.9 Method of Data Analysis**

For the purpose of this study, the researcher used tables and charts to represent the data collected and results of the study where necessary. For empirical analysis, the researcher employed queuing models suitable to evaluate the variables on this study. Also, Multiple Regression Analyses (MRA) was employed for the hypothesis testing to determine the effect of cost of delays on vessel operations in container terminal operations of Nigeria ports industry.

The analyses derived using the queue theory models in this scenario include the turnaround time (waiting time of vessel) in the queue, the average time of vessel in the system, the average service time of vessel at berth, the optimal service rate, the coefficient of berth utility, the cost of delays and cost of berth non-occupancy of the selected Nigeria seaports container terminals.

According to Zdenka and Edna, (2021) a port container terminal is defined as a queuing system with the following operational characteristics:

- i. If the entrance units are container ships which form (or not) a queue (depending on the immediate situation) to be serviced (unloading or loading of containers) at the container berths (servicing channels), and leave the system when the service has been performed.

- ii. If it is not possible to anticipate the arrival time of ships at the terminal as it depends on route, speed of ship in knots, weather, organization of maritime transportation processes and other reasons.
- iii. If it is not possible either to accurately predict servicing time of the ship, i.e. duration of transshipment operations, as it depends on number and type of container, capacity and technology of transshipment facilities, weather, organization of port transshipment processes, etc.

The consequence of these facts is the irregular berth usage. If the number of arriving ships is greater than the berth capacity, i.e. the number of ships which can be serviced by the existing berths within an observed time unit, then the ships appear in a queuing line or, conversely, if there are fewer ships, they do not have to wait, however, the berth capacity is not completely utilized and empty at a time. Through statistical data analysis on the number of ship arrivals per year of a chosen port container terminal, it has been established that no significant dependence exists in the sequence of yearly arrivals of container ships, i.e. ship arrivals are statistically random. An analogous conclusion is obtained by a statistical analysis of the service time duration of container ship (Zdenka and Edna, 2021), hence, from observations, it follows that the number of ship arrivals and duration of servicing time in Nigeria ports can be taken as random variables and, in addition, the empirical distributions of those variables approximated with the appropriate probability distributions, and therefore, queuing theory can be applied in such cases for computing indices of port container terminal operations.

Furthermore, from the queuing theory viewpoint, a port container terminal operation should be an open system as the ships are not a component part of the system; a single or multi server system (depending on the number of berth facilities) and, in this connection, ships at anchorage form queues for particular berths (Shanmugasundaramn and Venkatesh, 2015). The number of ship arrivals as well as the duration of servicing time i.e. duration of ship's stay on the berth are allocated according to certain probability distributions (most often according to Poisson's or Erlang's distribution of the  $k$ -order, where  $k$  is a natural number). The servicing time of ship, together with the time spent queuing on the berth, represent the time of the ship's stay at the terminal and is one of the more significant indices of port container terminal operations. Also, as regards queuing discipline, a container terminal is a system where servicing is most often carried out according to the FIFO rule (first come-first served), however, it could also be possible that there are certain ships which have priority in servicing.

At this point, it is necessary to explain the basic parameters of port container terminal operations as applicable on queuing model. These are average number of container ships which arrive at the terminal in an observed time unit and average number of container ships which can be serviced in a time unit at the terminal. On the basis of these parameters, appropriate indices of port container terminal operations can be computed and using the model of total queuing costs, decisions on optimal capacity of a port container terminal can be made.

First of all, the researcher adopted little's theory on basic queuing system which will be used for each of the Nigeria seaports considered in this study.

Queue length = Arrival rate  $\times$  Average time spent in the queue

$$Q_L = \lambda * W_t \tag{3.1}$$

Where,

$Q_L$ : queue length. Average number of vessels in the system (average number of vessel arrival per year in ports container terminal),

$\lambda$ : Arrival rate (the time intervals of vessel arrival at port container terminal),

$W_t$ : Average time ship spends in the system (average ship turnaround time at ports container terminal). Hence,

$$\lambda = Q_L / W_t \tag{3.2}$$

The queue model basic parameters of port container terminal used are the ship arrival rate ( $\lambda$ ) and the service rate ( $\mu$ ). For any chosen container terminal system, the parameter  $\lambda$  represents the average number of container ship or container vessel which arrive at the terminal during an observed time unit (e.g. during a year, month or day). It often happens in real life instance that data on the number of ships within a time unit are not available only the time which elapses between two consecutive ship arrivals. On the basis of these data, an arithmetical mean ( $\Lambda_m$ ) which represents the average interval between two consecutive ship arrivals is computed. This interval is, in fact, the reciprocal value of the ship arrival rate:

$$\Lambda_m = 1/\lambda \quad (3.3)$$

$$\text{Or } \lambda = 1/ \Lambda_m \quad (3.4)$$

The service rate can be explained by the same analogy. For a given container terminal system,  $\mu$  represents the average number of container ships or containers which can be serviced in a time unit at certain berth. If the number of ships which can be serviced during an observed time unit is unknown and only duration of service time per ship is known (ship turnaround time), then the arithmetical mean ( $\Lambda_m$ ) pattern represents the average service time duration per ship and this time is the reciprocal value of the service rate:

$$\Lambda_m = 1/\mu \quad (3.5)$$

$$\text{Or } \mu = 1/ \Lambda_m \quad (3.6)$$

Therefore, to determine optimal service rate ( $\Phi\mu$ ) of Nigeria port, the parameter  $\mu$  the service rate of one berth and multiplicand  $\beta_b$

$$\Phi\mu = \beta_b * \mu \quad (3.7)$$

Where,  $\beta_b$  is the symbol for the number of Berth, accommodative capacity of the container terminal of a port as a whole.

The arrival rate and service rate quotient represent the utilization factor or berth occupancy rate  $\beta_b$

$$\beta_b = \lambda/ \mu \quad (\text{hence, service rate} = \mu = \lambda/ \beta_b) \quad (3.8)$$

Where  $\beta_b$  is number of container berths of a port

Then, if  $\lambda > \mu$  one berth is insufficient as the utilization factor is greater than 100%. On this occurrence, the number of berths should be increased until the service system reaches a stability condition that the utilization coefficient of the system has been satisfied at optimal level  $\beta\phi/\beta_b < 1$ . Where  $\beta\phi$  is berth occupancy rate.

$$\beta\phi/\beta_b < 1 \quad (3.9)$$

In practice, the value of the parameter  $\lambda$  can be determined as ( $\lambda = Q_L / W_t$ ) while ship service rate ( $\mu$ ) for Nigerian ports is expected to take place within 48 hours of ship arrival at the berth.

To model the queuing cost of Nigeria ports container terminal, the researcher formulated model basically focusing on the cost of vessel queuing waiting for berth allocation, service time and cost of berth inoccupancy (idle berth), when there are no ships waiting to be serviced at the terminal. However, in real life instances in port operations, the waiting time and the berth inoccupancy (idle berth) cannot be completely avoided, provided ship arrival is a random process. These costs fall between the ship-owner and the container terminal operator. However, the total queuing or idle cost is relational because ship-owner and port operator are mutually on the same interest to optimize cost of queue/idle time at the ports. The port container terminal time is not indifferent to the long waiting time of the ships even though it has high berth utilization rate, and the reverse of long waiting time of ship could be diversion resulting to berth inoccupancy. Having strike a balance, the total queuing/idle costs  $C_t$  i.e., vessel queuing costs  $C\ddot{u}_q$ , and berth inoccupancy (idle berth) costs  $C\beta\phi$ .

Total ship queuing costs and berth inoccupancy costs are modeled as follows:

$$\text{Vessel queuing costs} \quad C\ddot{u}_q = C\ddot{u}_q * Q_L * t \quad (3.10)$$

$$\text{Berth inoccupancy (idle berth) costs} = C\beta\phi = C\beta\phi * (\beta_b - \beta\phi) * t \quad (3.11)$$

$$\text{Total queuing/idle costs at port } C_t = C\ddot{u}_q * Q_L * t + C\beta\phi * (\beta_b - \beta\phi) * t \quad (3.12)$$

$$C_t = t * [C\ddot{u}_q * Q_L + C\beta\phi (\beta_b - \beta\phi)] \quad (3.13)$$

Where:

$C_t$  = the amount of total costs expressed in currency units in an observed time unit (USD/hour),

$Q_L$  = the average number of container ships in the queue,

$\beta_b$  = the number of container berths,

$\beta\phi$  = the average berth occupancy rate;  $\beta\phi$

$(B_b - \beta\phi)$  = number of idle berths

$t$  = the length of time period for which costs are computed (e.g. day, month, year),

$C\ddot{u}_q$  = the amount of costs during waiting time of ship in the queue, expressed in currency units for an observed time unit (USD/hour/ship),

$C\beta\phi$  = the amount of costs arising from non-occupancy of berth, expressed in currency units for an observed time unit (USD/hour/berth).

The basic parameters for the study include the following on Table3.1below:

**Table 3.1: Study Parameters, Sources of Data and Data Collection Methods**

S/N	Parameters	Data Collection	Method / Source of Data collection
1	$Q_L$ = Average number of vessels in the system (queue length)	Average number of vessel arrival during the year (2007-2022)	Method: Secondary data Source: NPA annual statistics report
2	$W_t$ = Average time ship spends in the system	Average ship turnaround time (2007-2022)	Method: Secondary Source: NPA annual statistics report
3	$\beta_b$	the number of container berths at the port	Method: Secondary Source: NPA annual statistics report
4	$B\phi$	the average berth occupancy rate of the port (2007-2022)	Method: Secondary Source: NPA annual statistics report
4	$C\ddot{u}_q$ = the amount of costs during waiting time of ship in the queue	Port Berth occupancy costs per hour/berth in USD	Method: Secondary Source: NPA simplified tariff
5	$C\beta\phi$ = berth inoccupancy cost (USD/hour/berth).	Port Berth inoccupancy costs per hour/berth in USD	Method: Secondary Source: NPA simplified tariff
6	$t$ = length of time for which costs are computed	The length of time period for which costs are computed (e.g. day, month, year)	Method: Secondary Source: NPA simplified tariff

Source: Researcher desk, 2023

### 3.10 Queue Model Derivation

Model of ship queuing costs and berth non-occupancy costs, or total queuing/idle model costs is applied in such manners that utilize formulae. The amount of ship queuing costs and berth non-occupancy costs for a certain number of container berths can be calculated through a change in the number of berths the service process at the container terminal is programmed and on the basis of the results obtained for various values of berth numbers, the optimal number of berths can be determined, i.e. the number of berths for which the amount of total queuing costs is minimal. The model of total queuing costs can serve as a basis for making appropriate business decisions on employment, facility and yard capacity or planning the development of future port container terminal capacity.

#### **For Onne Port, we have that:**

The average turnaround time of vessel in Onne Ports container terminal =  $W_t^o$

The arrival rate of vessel in Onne Ports container terminal =  $\lambda^o = Q_L^o / W_t^o$

The average service time of vessel at berth in Onne Ports container terminal =  $\mu^o = \lambda^o / \beta_b^o$

The optimal service rate of ships in Onne Ports container terminal =  $\Phi^o \mu = \beta_b^o * \mu^o$

The container terminal utilization coefficient of Onne Port =  $(\lambda^o / \mu^o) * 100$

The ship queuing costs in Onne Ports container terminal =  $C\ddot{u}_q^o * Q_L^o * t^o$

The cost of idle berth in container terminal of Onne Ports =  $C\beta\varphi^o * (\beta_b^o - \beta\varphi^o) * t^o$ .

#### **For Rivers Port, we have that:**

The average turnaround time of vessel in Rivers Ports container terminal =  $W_t^p$

The arrival rate of vessel in Rivers Ports container terminal =  $\lambda^p = Q_L^p / W_t^p$

The average service time of vessel at berth in Rivers Ports container terminal =  $\mu^p = \lambda^p / \beta_b^p$

The optimal service rate of ships in Rivers Ports container terminal =  $\Phi^p \mu = \beta_b^p * \mu^p$

The container terminal utilization coefficient of Rivers Port =  $(\lambda^p / \mu^p) * 100$

The ship queuing costs in Rivers Ports container terminal =  $C\bar{u}_q^p * Q_L^p * t^p$

The cost of idle berth in container terminal of Rivers Ports =  $C\beta\varphi^p * (\beta_b^p - \beta\varphi^p) * t^p$

**Tin Can Island Port, we have that:**

The average turnaround time of vessel in Tin Can Island Ports container terminal =  $W_t^{\hat{c}}$

The arrival rate of vessel in Tin Can Island Ports container terminal =  $\lambda^{\hat{c}} = Q_L^{\hat{c}} / W_t^{\hat{c}}$

The average service time of vessel at berth in Tin Can Island Ports container terminal  
=  $\mu^{\hat{c}} = \lambda^{\hat{c}} / \beta_b^{\hat{c}}$

The optimal service rate of ships in Tin Can Island Ports container terminal =  $\Phi^{\hat{c}} \mu = \beta_b^{\hat{c}} * \mu^{\hat{c}}$

The container terminal utilization coefficient of Tin Can Island Port =  $(\lambda^{\hat{c}} / \mu^{\hat{c}}) * 100$

The ship queuing costs in Tin Can Island Ports container terminal =  $C\bar{u}_q^{\hat{c}} * Q_L^{\hat{c}} * t^{\hat{c}}$

The cost of idle berth in container terminal of Tin Can Island Ports =  $C\beta\varphi^{\hat{c}} * (\beta_b^{\hat{c}} - \beta\varphi^{\hat{c}}) * t^{\hat{c}}$

**For Apapa Port, we have that:**

The average turnaround time of vessel in Apapa Ports container terminal =  $W_t^{\hat{a}}$

The arrival rate of vessel in Apapa Ports container terminal =  $\lambda^{\hat{a}} = Q_L^{\hat{a}} / W_t^{\hat{a}}$

The average service time of vessel at berth in Apapa Ports container terminal =  $\mu^{\hat{a}} = \lambda^{\hat{a}} / \beta_b^{\hat{a}}$

The optimal service rate of ships in Apapa Ports container terminal =  $\Phi^{\hat{a}} \mu = \beta_b^{\hat{a}} * \mu^{\hat{a}}$

The container terminal utilization coefficient of Apapa Port =  $(\lambda^{\hat{a}} / \mu^{\hat{a}}) * 100$

The ship queuing costs in Apapa Ports container terminal =  $C\bar{u}_q^{\hat{a}} * Q_L^{\hat{a}} * t^{\hat{a}}$

The cost of idle berth in container terminal of Apapa Ports =  $C\beta\varphi^{\hat{a}} * (\beta_b^{\hat{a}} - \beta\varphi^{\hat{a}}) * t^{\hat{a}}$

### 3.11 Multiple Regression Analysis (MRA)

Multiple Regression Analysis was used to achieve the 6<sup>th</sup>, 7<sup>th</sup> and 8<sup>th</sup> objectives of the study. The data was transformed using the natural log tool to be able to get all the variables in the same log units. It is a statistical investigation of the relationship between dependent variable Y and two or more independent variables X; and it is use to predict relationship, control or optimize the value of the dependent variable Y (Ugwu, 2013). The relationship is formulated in an equation to express the value of Y in terms of the corresponding values of X and to enable future values of Y to be predicted in terms of the observed values of X to be controlled or optimized by manipulating the values of X. The independent variables X are called explanatory variables or controlled variables while the dependent variables Y is also called response variable.

This can be expressed mathematically as follows:

$$\text{Log } Y_{\text{delay}} = \beta_0 + \beta_1 \text{LogSHP}_{\text{trf}} + \beta_2 \text{LogGRT}_{\text{ships}} + \beta_3 \text{LogCONT}_{\text{trf}} + \dots + \beta_n X_n + \mathcal{E}$$

Where

t = number of years/ periods/observations

n = number of the independent variables

$Y_{\text{delay}}$  = average delay in vessel operations in Nigerian ports/

$\text{SHP}_{\text{trf}}$  = ship calls/traffic to Nigerian ports relative to delays

$\text{GRT}_{\text{ships}}$  = Gross Registered tonnage of vessels that called at the ports

$\text{CONT}_{\text{trf}}$  = seaborne Container trade traffic handled by the terminals relative to delays.

$\beta_0$  = constant or the intercept of the graph

$\beta_1$  = slope of the graph

$\mathcal{E}_t$  = random error term.

Similarly, the effects of cost of delay in vessel operations in Nigerian container terminals on shipping and port operations were estimated using the models below. For container shipping operations we have:

$$\text{LogCONT}_{trade} = \beta_0 + \beta_1 \text{LogD}_{costAPAPA} + \beta_2 \text{LogD}_{COSTONNE} + \beta_3 \text{LogD}_{COSTRIVERS} + \beta_4 \text{LogD}_{COSTTIN} \dots + \beta_n X_n + \mathcal{E}$$

For effects of delay costs on ship traffic calls we have:

$$\text{LogSHP}_{trade} = \beta_0 + \beta_1 \text{LogD}_{costAPAPA} + \beta_2 \text{LogD}_{COSTONNE} + \beta_3 \text{LogD}_{COSTRIVERS} + \beta_4 \text{LogD}_{COSTTIN} \dots + \beta_n X_n + \mathcal{E}$$

For effects of delay costs on GRT of vessels that called to port we have:

$$\text{LogGRT}_{trade} = \beta_0 + \beta_1 \text{LogD}_{costAPAPA} + \beta_2 \text{LogD}_{COSTONNE} + \beta_3 \text{LogD}_{COSTRIVERS} + \beta_4 \text{LogD}_{COSTTIN} \dots + \beta_n X_n + \mathcal{E}$$

Where:

$D_{costAPAPA}$  = cost of delay in vessel operations in Apapa port terminal

$D_{COSTRIVERS}$  = cost of delay in vessel operations in Rivers port terminal

$D_{COSTONNE}$  = cost of delay in vessel operations in Onne port terminal

$D_{COSTTIN}$  = cost of delay in vessel operations in Tin Can Island port terminal

### 3.12 Descriptive Statistics

Descriptive statistics was employed to analyze the responses from the questionnaires collated from various respondents on their satisfaction with port operations in the terminals relative the extent of delay in the ports. Descriptive statistics entails describing the main features of a collection of information quantitatively. It aims at summarizing a sample, rather than use the data to learn about the population that sample of data is thought to present.

The goal of descriptive statistics is to describe the data being presented. In this case, data is being described in terms of different variables. For this analysis, the descriptive statistics being considered are the mean, minimum, maximum and standard deviation of the data sets.

Furthermore, descriptive statistics consist of the following Probability Distribution Functions:

- Measurement of central tendency using mean, median and mode to determine the average values in the study distribution
- Measurement of dispersion using Range, Mean Deviation, Variance, Standard Deviation and Semi Inter Quartile Range.
- Measure of Skewed to describe the shape of the distribution if it is normal, positive or negative.

### **3.13 Test of Model Significance – ANOVA**

To tested hypotheses, it is necessary to subject the data set to evaluation using the analysis of variance (ANOVA) and determine the coefficient through deterministic approach. These two forms the regression model.

The analysis of variance approach seeks to split the variations of the dependent variable with its component parts. Variations in the dependent variables that are accounted for by the explanatory variables are called the explained variable.

The  $R^2$  is calculated from the regression table which gives the proportion of the total variation in the dependent variables. It explains the extent of variable in the data set or the population.

#### **Decision Rule**

For the purpose of this study the researcher chose 95% confidence interval or 5% level of significance (0.05). This implies that for a variable to be significant P-value must be less than 0.05 ( $P\text{-value} < 0.05$ ), hence, a  $P\text{-value} < 0.05$ , we reject the null hypothesis and accept the alternative; whereas  $P\text{-value} > 0.05$ , we accept the null hypothesis and reject the alternative. If the null hypothesis is rejected, it means the effect is significant. Also, a value greater than 1 for F-ratio yield efficient model. That is, if f-ratio (calculated) is greater than f-ratio (tabulated) at Alpha  $\infty$  - level of significance (k-1) (n-k). degrees of freedom, then we reject  $H_0$  and accept  $H_1$  and state there is some truth in the estimated model, hence,  $F\text{-ratio (calculated)} = (R^2)/(K-1) (1- R^2)/(N-K)$

Where:

$R^2$  = R square of the model

K = No of variables (independent and dependent)

N = No of observations

## CHAPTER FOUR

### RESULTS AND DISCUSSION

#### 4.1 Data presentation

In this section, the data collected for the purpose of carrying out the study is presented and explained. Each dataset was analyzed in line with the objectives of the study in answer to the research questions.

**Table 4.1: Average Annual Turnaround Time (days) of Nigerian ports**

<b>Year</b>	<b>Tin Can Island</b>	<b>APAPA</b>	<b>Rivers</b>	<b>Onne</b>
2007	3.77	8.7	9.99	1.8
2008	7	9.6	11.71	2.8
2009	6.6	9.5	8.02	3.42
2010	5.07	10.15	10.55	4.84
2011	4.97	7.59	9.75	2.85
2012	5.04	7.96	8.71	2.5
2013	4.46	5.31	7.7	2.42
2014	3.95	3.91	9.58	2.71
2015	4.13	3.8	9	2.6
2016	3.51	4.7	6.4	2.4
2017	3.99	5.1	6.8	2.5
2018	4.12	4.7	5.34	2.76
2019	5.12	5.59	6.14	2.7
2020	5.13	3.7	9.6	3.06
2021	5.45	5.65	10.2	3
2022	4.59	5.75	10.7	2.65
<b>Average</b>	<b>4.80625</b>	<b>6.356875</b>	<b>8.761875</b>	<b>2.813125</b>

**Source: NPA annual report 2007-2022**

Table 4.1 represents ship turnaround time prevailing in container terminals in Nigeria ports between 2007 and 2022. The ship turnaround time is the amount of time it takes to complete all processes of berthing, discharging or loading of cargo and exiting the berth. It indicates the amount of time in days that shipping and port operations are carried out and completed on a given vessels. Vessel. In maritime industry, turnaround time refers to the duration it takes a ship to complete a round trip from one point to another and return to its original location. At the port terminal, the turnaround time represents the time required for a ship to unload its cargoes or load new cargoes or perform all necessary operations and be ready to sail. However, annual ship turnaround time of Nigerian ports is the average time vessels spend in the port from the time it enters to the time it leaves the port system which is measured in days. In global shipping industry the standard turnaround time for container port terminals for a container ship is 2days. Exceeding the standard of two days means delays (Hasheminia & Jiang 2017).

Table 4.1 shows the average annual turnaround time in days of the selected container ports (Tin Can Island, Apapa, Rivers and Onne). The Table measured the average turnaround time in days for the periods (2007-2022) presenting 16years of port concession. The average annual turnaround time calculated in the Table across the periods gave that Tin Can Island has 4.80625days which is approximately ( $\approx$  5days), Apapa 6.356875days ( $\approx$  6days), Rivers 8.761875days ( $\approx$  9days), and Onne 2.813125days ( $\approx$ 3days). This shows that none of Nigerian port operates within the global specified duration for a container ship at ports container terminal. This dataset was used in subsequent sections in determining the delay in vessel operations in container terminals in Nigeria ports by benchmarking against the global ship turnaround benchmark.

**Table 4.2: Average Annual Vessel Calls (Ship Traffic Count) and TEU Throughput Trade in Nigerian ports**

<b>Year</b>	<b>Tin Can Island</b>	<b>APAPA</b>	<b>Rivers</b>	<b>Onne</b>	<b>Aggregate</b>	<b>TEU throughput trade</b>
2007	1185	1359	455	407	3406	431950
2008	1367	1452	481	417	3717	612982
2009	1583	1545	459	435	4022	653,584
2010	1666	1556	482	414	4118	685,937
2011	1628	1594	584	855	4661	839977
2012	1508	1445	499	859	4311	880597
2013	1615	1510	439	823	4387	992666
2014	1692	1503	435	418	4048	1060460
2015	1656	1410	373	339	3778	1567898
2016	1559	1194	319	291	3363	810730
2017	1307	1154	309	276	3046	1289576
2018	1101	1105	314	662	3182	1000967
2019	1198	1034	321	722	3275	1032253
2020	1180	1345	329	695	3549	1073807
2021	1229	1465	345	721	3760	2029823
2022	1230	1554	356	732	3872	2065794
<b>Average</b>	<b>1419</b>	<b>1389.0625</b>	<b>406.25</b>	<b>566.625</b>		<b>2003411.882</b>

**Source: NPA annual report 2007-2022**

Table 4.2 represents the average annual number of vessels calls to the ports (Tin Can Island, Apapa, Rivers and Onne) from 2007 to 2022. It also shows the Twenty Foot Equivalent (TEU) throughput trade handled in all the container terminals in all the four ports used in the study over the 16 years period covered in the study. The average ship traffic volume of the ports was calculated as 1419; 1389; 406 and 567 for Tin Can Island, Apapa, Rivers and Onne ports respectively. This implies that among the Nigerian ports, Tin Can Island ports has the highest vessel calls between 2007-2002 followed by Apapa, Onne and Rivers port being the least. The average annual number of vessels calls to the ports (Tin Can Island, Apapa, Rivers and Onne) from 2007 to 2022. The average ship traffic volume of the ports was calculated as 1419; 1389; 406 and 567 for Tin Can Island, Apapa, Rivers and Onne ports respectively. This implies that among the Nigerian ports, Tin Can Island ports has the highest vessel calls between 2007-2002 followed by Apapa, Onne and Rivers port being the least. The mean TEU throughput trade handled in the container terminals over the period is 2003411.882TEUs. The dataset is table4.2 above was used in carrying out further analysis in order to actualize the objectives of the study.

**Table 4.3: Average Annual Container Ship Berth Occupancy Rate (%)**

<b>Year</b>	<b>Tin Can Island</b>	<b>APAPA</b>	<b>Rivers</b>	<b>Onne</b>
2007	86	60.21	54.22	71
2008	61	64.19	55.86	34
2009	72	62.37	65.58	35
2010	73	68.22	60.31	35
2011	69	64.14	65.25	31.61
2012	69.91	65.25	68.91	31.09
2013	65.9	56.9	52	26.7
2014	71.27	57.58	72.43	44.25
2015	54.1	69.7	55.7	36.1
2016	46.4	55.5	41.8	28.5
2017	43.92	55.76	37.67	18.4
2018	43	55.1	43.12	21.05
2019	51	54.2	51.41	24.24
2020	50	56.35	63.3	24.36
2021	61	65.42	72.38	26.65
2022	64	68.32	61.12	27.16
<b>Average</b>	<b>61.34375</b>	<b>61.20063</b>	<b>57.56625</b>	<b>32.19438</b>

**Source: NPA annual report 2007-2022**

Table 4.3 showed the average annual berth occupancy rates of Tin Can Island, Apapa, Rivers and Onne ports from 2007 to 2022. Berth occupancy is expressed in percentage. It is the number of days a berth is occupied by a vessel to the total number of berth-days available. It shows the utilization rate of a berth in a given year. In Table 4.5, the average berth occupancy rate of Tin Can Island, Apapa, Rivers and Onne ports from 2007 to 2022 was calculated as 61.34375, 61.20063, 57.56625 and 32.19438 respectively which smoothed the annual berth occupancy of Tin Can Island, Apapa, Rivers and Onne ports from 2007 to 2022 as proximately 61.3%, 61.2%, 57.6% and 32.2% annually for the period under review 2007 to 2022.

**Table 4.4: The Average annual vacancy rates of Container Berth (%)**

Year	Tin Can Island	APAPA	Rivers	Onne
2007	14	39.79	45.78	29
2008	39	35.81	44.14	66
2009	28	37.63	34.42	65
2010	27	31.78	39.69	65
2011	31	35.86	34.75	68.39
2012	30.09	34.75	31.09	68.91
2013	34.1	43.14	48	73.3
2014	28.73	42.42	27.57	55.75
2015	45.9	30.3	44.3	63.9
2016	53.6	44.5	58.3	71.5
2017	56.08	44.24	62.33	81.6
2018	57	45.5	56.88	78.95
2019	49	45.8	48.59	75.76
2020	50	43.65	36.7	75.64
2021	39	34.55	27.62	73.25
2022	36	31.68	38.88	72.84
<b>Average</b>	<b>38.65625</b>	<b>38.8375</b>	<b>42.44</b>	<b>67.79938</b>

**Source: NPA annual report 2007-2022**

Table 4.4 is the average annual vacancy rates of the ports representing the percentage of berth not utilized or occupied. This explains the percentage of the berth not working or idle within the year at the respective ports. The Table 4.6 shows berth vacancy rate (non-occupancy rate) of Tin Can Island, Apapa, Rivers and Onne ports measured in percentage for the periods 2007-2022. The Table provided the average percent vacancy rate for each port is given as 38.7%, 38.8%, 42.4% and 67.8% for Tin Can Island, Apapa, Rivers and Onne ports respectively. It also explains the number of days a berth is unoccupied by a vessel to the total number of berth-days available. It shows the vacancy rate of ports berths in a given year. In more details, the data informs that out of 100% of days of berth work days the berth were vacant, idle and unutilized for 38.7%, 38.8%, 42.4% and 67.8% at Tin Can Island, Apapa, Rivers and Onne ports respectively.

**Table 4.5: Gross Registered Tonnage (GRT) of Vessels handled at the Terminals**

<b>Year</b>	<b>Tin Can Island</b>	<b>APAPA</b>	<b>Rivers</b>	<b>Onne</b>	<b>Aggregate</b>
2007	30502604	3325168	6839182	4806012	45472966
2008	34556886	3463642	6952371	4839572	49812471
2009	39076852	3109638	62387526	5396277	1.1E+08
2010	3976893	3098532	7186531	5353788	19615744
2011	32702604	32869251	8289093	4273545	78134493
2012	32636886	32072798	7210520	4291026	76211230
2013	40096754	34189172	6207092	3861299	84354317
2014	47231548	37041879	6761057	8926192	99960676
2015	45864565	36290502	5423002	7296978	94875047
2016	45229402	33612421	4951913	7564109	91357845
2017	40694756	31614347	5405540	7396251	85110894
2018	4205685	3021634	4927297	3674827	15829443
2019	4658031	3207361	5061662	4372567	17299621
2020	4380642	3710732	5725902	4747214	18564490
2021	4907524	3509372	6490843	3870523	18778262
2022	4958326	3401578	6405437	4362186	19127527
<b>Average</b>	<b>25979997.38</b>	<b>16721126.69</b>	<b>9764060.5</b>	<b>5314522.875</b>	<b>57781564.13</b>

**Source: NPA annual report 2007-2022**

Table 4.5 is the average annual Gross Registered Tonnage (GRT) of vessels handled in the container terminals in Nigerian ports between 2007 and 2022. This explains the total number of registered tonnage of vessels that visited the ports during these periods of port concession. The Table 4.5 shows the average annual tonnage for vessel calls of Tin Can Island, Apapa, Rivers and Onne ports measured in tons for the periods 2007-2022. The Table provided the average annual tonnage for vessel calls for each port given as 25979997.38, 16721126.69, 9764060.5 and 5314522.875 for Tin Can Island, Apapa, Rivers and Onne ports respectively. The national average GRT of vessels handled in the container terminals over the 16 years period is 57781564.13GRT per annum.

**Table 4.6: Provisional Data on Tariff and Charges for Vessel Pilotage, Mooring and Berthing Operations in Nigerian Port Container Terminals.**

S/N	Items	Tin Can	Apapa	Rivers	Onne
1	No. of Container berths	13	20	8	7
2	Tug Charge (201-250 LOA)	USD 2500	USD 2500	USD 2500	USD 2500
3	Berths Rent (2days)	USD2.00/LOA	USD2.00/LOA	USD2.00/LOA	USD2.00/LOA
4	Berthing/Mooring	USD 1176	USD1176	USD1176	USD1176
5	Pilotage rate	USD 0.112	USD 0.112	USD 0.240	USD 0.240

**Source: Nigerian Ports Authority Tariff: Dues & Rates Regulations (2005, 2014 and 2021)**

The table4.6 shows the NPA tariff and charges for vessel calls at the container terminals over the years. It indicates the amounts of charges paid per period as tug charge, berth rent, mooring and pilotage services. The estimation of the cost of delay in vessel operation was based upon the NPA rates.

**Table 4.7: Port Users Satisfaction Score(s) with Container Terminal Operations in Nigeria relative to the Extent of Delay experienced at the Terminals on a 5 Linkert Scale**

Satisfaction scores (%)	20	40	60	80	100
Frequency	40	125	98	65	21

**Source: Field survey**

Table 4.7 above shows that out of 476 questionnaires distributed to respondents from various ports on the port users satisfaction scores with the services of the container terminals relative to the delays associated with vessel operations in container terminals in Nigerian ports, only 349 respondents representing about 73.3% of the total population sampled in the study returned the ratings on perceived satisfaction with services of the container terminals relative to the extent of delay experienced in the terminals. The table 4.7 was used to estimate the extent of port user's satisfaction with the operations of the port terminals given the delays witnessed in vessel operations in the terminals.

## 4.2 Results and Discussion of Findings

In this section, the results of the analysis executed on the dataset in order to actualize the objectives of the study were presented as shown in the various tables below.

**Table 4.8: Extent of Delay in Vessel Operations in Nigerian Container Terminals**

<b>Year</b>	<b>Tin Can Island (days)</b>	<b>APAPA (days)</b>	<b>Rivers (days)</b>	<b>Onne(days)</b>	<b>Aggregate delay (days)</b>
2007	1.77	6.7	7.99	0	16.46
2008	5	7.6	9.71	0.8	23.11
2009	4.6	7.5	6.02	1.42	19.54
2010	3.07	8.15	8.55	2.84	22.61
2011	2.97	5.59	7.75	0.85	17.16
2012	3.04	5.96	6.71	0.5	16.21
2013	2.46	3.31	5.7	0.42	11.89
2014	1.95	1.91	7.58	0.71	12.15
2015	2.13	1.8	7.00	0.6	11.53
2016	1.51	2.7	4.4	0.4	9.01
2017	1.99	3.1	4.8	0.5	10.39
2018	2.12	2.7	3.34	0.76	8.92
2019	3.12	3.59	4.14	0.7	11.55
2020	3.13	1.7	7.6	1.06	13.49
2021	3.45	3.65	8.2	1.00	16.3
2022	2.59	3.75	8.7	0.65	15.69

Source: Author's calculation

The result of the study shown in Table 4.8 indicates the extent of delays in vessels operations that ship operators experienced in the container terminals in Nigerian ports between 2007 and 2022. The delays were determined by benchmarking the ship turnaround time in Nigerian port container terminals against the global standard benchmark of 2days average turnaround time for container ports (Victor *et al.*, 2016; UNCTAD, 2021). The delays represent the excess days spent at the container terminals in the Nigerian port sector.

By implication, vessel operators incur more port cost and charges for these extra days (delay period) spent beyond the 2day global port sector benchmark. The days outside the 2days attract extra fees as result of delay factors which could have affected the service rate in delivery of cargos with the stipulated time allowed for container vessel at the port terminals. The average delay per annum in vessel operations affecting ship operators in container terminals in Nigerian port is shown in table4.9 below.

**Table 4.9: Average Delay in Vessel Operations in Nigerian Container Terminals**

<i>Stat</i>	<i>Tin Can Island</i>	<i>Apapa</i>	<i>Rivers</i>	<i>Onne</i>	<i>Aggregate</i>
Mean	2.80625	4.356875	6.761875	0.825625	14.75063
Standard Error	0.24193	0.553669	0.462412	0.156154	1.102733
Median	2.78	3.62	7.29	0.705	14.59
Mode	#N/A	2.7	#N/A	0.5	#N/A
Standard Deviation	0.967718	2.214674	1.849649	0.624617	4.410933
Sample Variance	0.936478	4.904783	3.421203	0.390146	19.45633
Kurtosis	0.735497	-1.21469	-0.81295	7.513528	-0.49535
Skewness	0.971006	0.527588	-0.41973	2.377864	0.556291
Range	3.49	6.45	6.37	2.84	14.19
Minimum	1.51	1.7	3.34	0	8.92
Maximum	5	8.15	9.71	2.84	23.11
Sum	44.9	69.71	108.19	13.21	236.01
Count	16	16	16	16	16
Confidence Level (95.0%)	0.515661	1.180117	0.985609	0.332835	2.35042

Source: Author's calculation

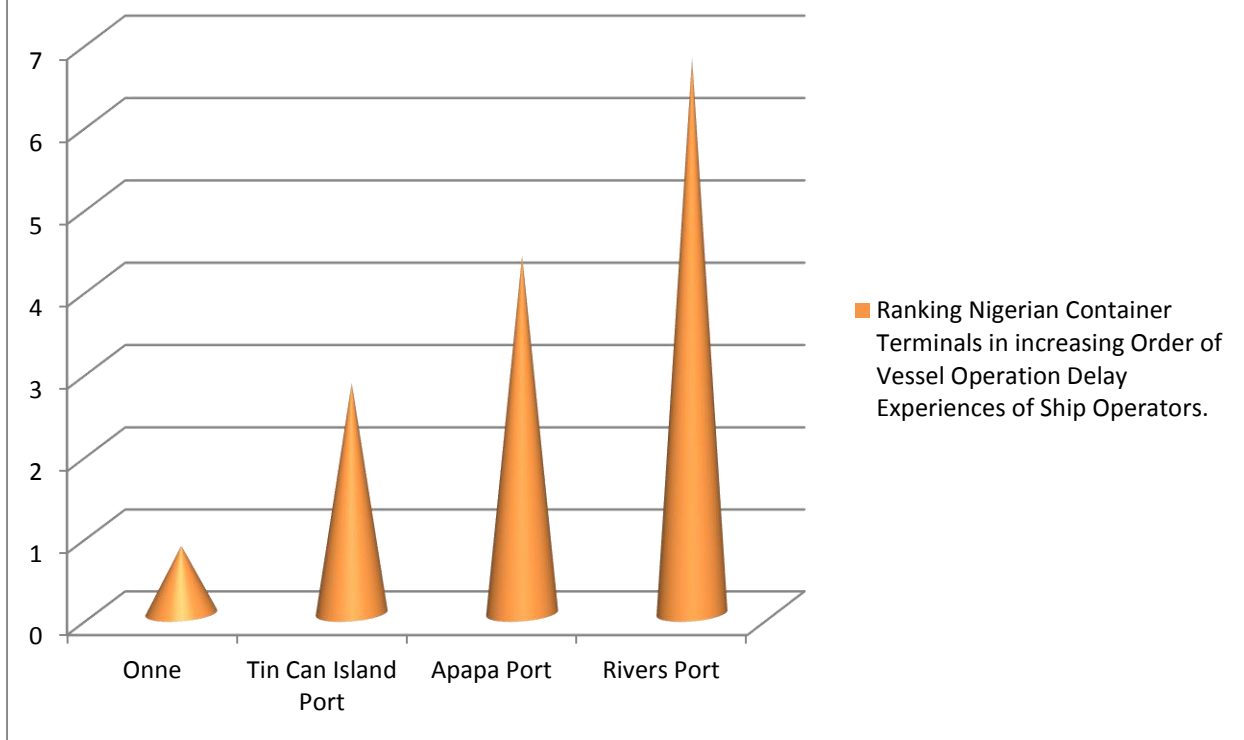
The result of the study presented in table4.9 above indicates that the mean delay in vessel operations that ship operators experienced in Tin Can Island container terminal per annum between 2007 and 2022 is 2.81 days delay with a standard deviation of 0.968. The maximum delay experienced by ship operators in Tin can port over the 16 years period was in 2008 when there occurred an average of 5 days delay in vessel operations in the port.

In a similar way, in Apapa container terminal, the average delay experienced by ship operators in vessel operations per over the period is 4.357 days of delay with standard deviation of 2.215. The maximum delay suffered by ship operators in vessel operation is 8.15 delays which occurred in 2010 while the minimum delay recorded in Apapa container terminal is 1.7 days delay which occurred in 2020.

The Rivers port recorded an average delay in vessel operation of 6.762 with a standard deviation of 1.85. The minimum and maximum delays in vessel operations experienced by ship operators in the Rivers port was in 2018 and 2008 respectively which had respective delay periods of 3.34 days and 9.71 days. In Onne port, the average delay in vessel operation experienced by ship operators over the 16 years period is 0.826 days (1day) with standard deviation of 0.624617. The minimum delay experienced by ship operators in onne port over the period was in 2007 when there was a zero delay (no delay) in vessel operations in the port. The maximum delay experienced in Onne port was in 2010 with an average delay of 2.84 days.

These delays in vessel operations in the container terminals have implications on port cost and charges that the ship operators and shippers pay in order to secure their seaborne trade. Thus, increasing delay in vessel operations may translate to increasing port cost to ship operators and shippers who may be discouraged from patronizing such ports where delays in vessel operations is rampant and uncontrolled. Figure4.1 below presents the ranking of Nigerian Container Terminals in increasing order of vessel operations delay experiences of ship operators.

### Ranking Nigerian Container Terminals in increasing Order of Vessel Operation Delay Experiences of Ship Operators.



**Figure 4.1: Ranking Nigerian Container Terminals in increasing Order of Vessel Operation Delay Experiences of Ship Operators.**

**Source: Prepared by the author.**

Tables 4.10 below shows the result of cost of delay for each year covered in the study based on the delays experienced by ship operators in the various port terminals as shown in table4.9 above

**Table 4.10: Estimated Cost of Delay in Vessel Operations in Nigerian Container Terminals**

<b>Year</b>	<b>Tin Can Island (\$)</b>	<b>APAPA(\$)</b>	<b>Rivers(\$)</b>	<b>Onne(\$)</b>	<b>Aggregate cost of delay in vessel operations (\$)</b>
2007	4194.9	18210.6	7270.9	0	29676.4
2008	13670	22070.4	9341.0	667.2	45748.6
2009	14563.6	23175	5526.4	1235.4	44500.4
2010	10229.2	25362.8	8242.2	2351.5	46185.7
2011	9670.3	17820.9	9052	1453.5	37996.7
2012	9168.6	17224.4	6696.6	859	33948.6
2013	7945.8	9996.2	5004.6	691.3	23637.9
2014	6598.8	5741.5	6594.6	593.6	19528.5
2015	7054.6	5076	5222	406.8	17759.4
2016	4708.2	6447.6	2807.2	232.8	14195.8
2017	5201.9	7154.8	2966.4	276	15599.1
2018	4668.2	5967	2097.5	1006.2	13738.9
2019	7475.5	7424.1	2657.9	1010.8	18568.3
2020	7386.8	4573	5000.8	1473.4	18434
2021	8480.1	10694.5	5658	1442	26274.6
2022	6371.4	11655	6194.4	951.6	25172.4

Source: Computed by Researcher Computed by Researcher from Nigerian Ports Authority Tariff: Dues & Rates Regulations (2021) and Annual Report (2007-2022)

The result of the study shown table 4.10 above presents estimates of the cost and economic implications of delay in vessel operations in Nigerian ports container terminals. Given the extents of delay in vessel operations in each terminal, Table4.10 show the yearly economic cost implications of delay in vessel operations in the ports between 2007 and 2022.

The result indicates that the Apapa port tend to impose the highest cost of delay given that it handled the highest vessel calls over the 16 years period covered in the study. This is followed by Tin Can Island port being the second port with highest delay cost and thirdly, the Rivers port. Onne port seems to have imposed the cost of delay on ship operators and the economy over the period. The aggregate port sector delay cost in Nigeria was also determined as shown in the table. Table4.11 below present a summary of the average cost delay imposed on the ship operators and the Nigerian economy in the individual ports container terminals in Nigeria.

**Table 4.11: Average Cost of Delay in Vessel Operations in Nigerian Container Terminals**

<i>Stat</i>	<i>Delay cost Tin can port</i>	<i>Delay cost Apapa</i>	<i>Delay cost Rivers</i>	<i>Delay cost Onne</i>	<i>Delay cost aggregate</i>
Mean	7961.744	12412.11	5645.781	915.6938	26935.33
Standard Error	749.9172	1781.432	557.9736	147.9249	2867.06
Median	7431.15	10345.35	5592.2	905.3	24405.15
Mode	#N/A	#N/A	#N/A	#N/A	#N/A
Std Deviation	2999.669	7125.728	2231.895	591.6997	11468.24
Sample Variance	8998014	50775997	4981353	350108.5	1.32E+08
Kurtosis	0.596108	-1.16431	-0.77503	0.916112	-1.00869
Skewness	0.959861	0.598494	-0.00078	0.709475	0.640899
Range	10368.7	20789.8	7243.5	2351.5	32446.8
Minimum	4194.9	4573	2097.5	0	13738.9
Maximum	14563.6	25362.8	9341	2351.5	46185.7
Sum	127387.9	198593.8	90332.5	14651.1	430965.3
Count	16	16	16	16	16
Confidence Level (95.0%)	1598.411	3797.032	1189.293	315.2945	6110.995

**Source: Author's calculation**

The result of the study presented in table4.11 above indicates that the mean cost and economic implications of delay in vessel operations that ship operators imposed on ship operators in Tin Can Island container terminal per annum between 2007 and 2022 is USD 7961.744 with a standard deviation of 2999.669. The highest cost of delay borne by ship operators in Tin can port over the 16 years period was in 2009 when there occurred an average of USD 14563.6 cost of delay in vessel operations in the port.

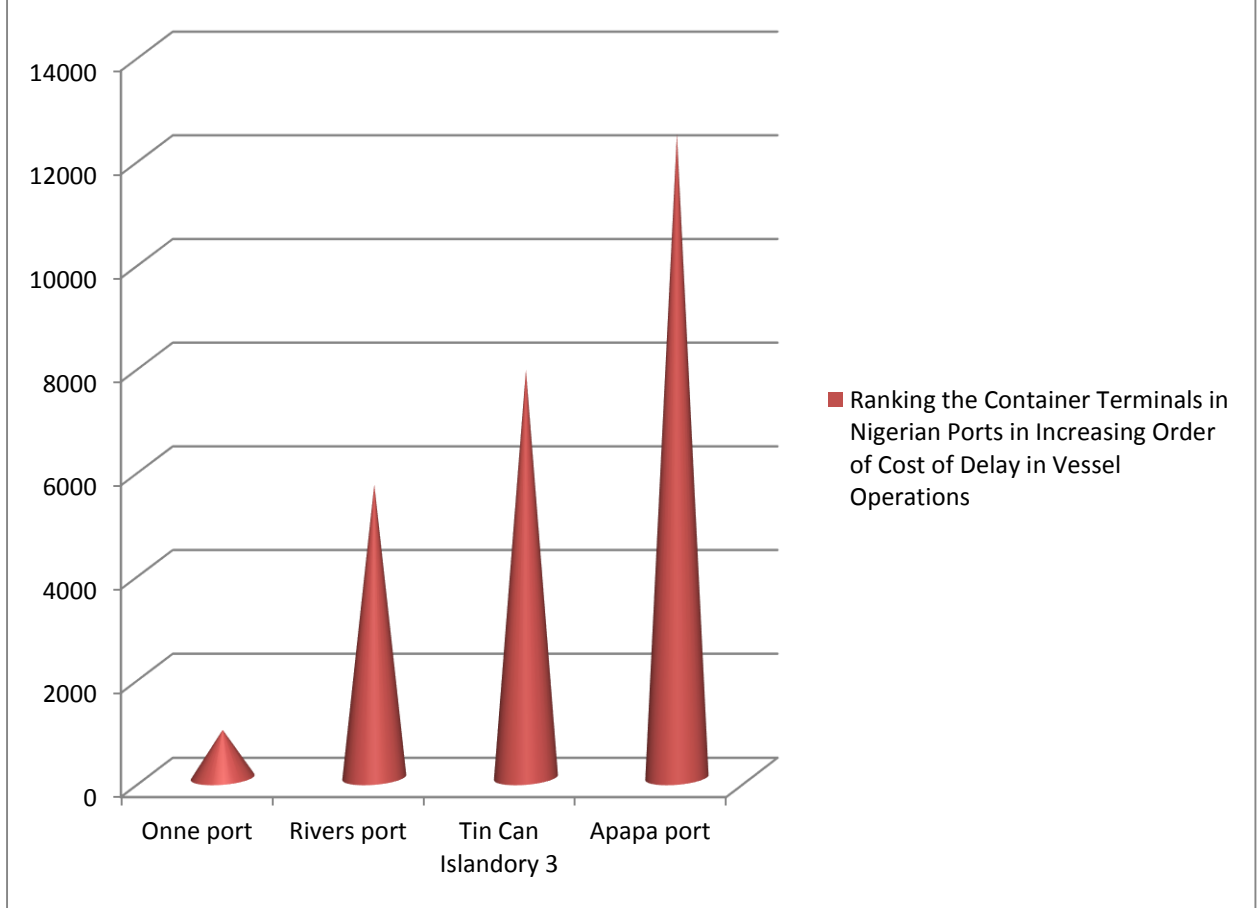
In a similar way, in Apapa container terminal, the average cost and economic implications of delay affecting ship operators in vessel operations per annum over the period is USD 12412.11 with standard deviation of 7125.728. The highest cost of delay borne by ship operators in Apapa port is USD 25362.88 which occurred in 2010 while the least cost of delay recorded in Apapa container terminal is USD 4573 which occurred in 2020.

The Rivers port recorded an average cost of delay in vessel operation of USD 5645.781 with a standard deviation of 2231.815. The minimum and maximum delays in vessel operations experienced by ship operators in the Rivers port was in 2018 and 2008 respectively which had respective costs of delay of USD 2097.5 and USD 9341. In Onne port, the average cost of delay in vessel operation experienced by ship operators over the 16 years period is USD 915.6938 with standard deviation of 591.6997. The minimum cost of delay experienced by ship operators in onne port over the period was in 2007 when there was a zero cost of delay (no cost) in vessel operations in the port.

The Nigerian economy lost an average of USD 26935.33 per annum between 2007 and 2022 in the port sector with standard deviation of 11468.24, as result of delay in vessel operations in the container terminals in Tin Can Island port, Apapa port, Rivers port and Onne port.

These costs of delays in vessel operations in the container terminals have implications development of the port sector and cost of shipping operations in the Nigerian maritime sector. Figure4.2 below presents the ranking of Nigerian Container Terminals in increasing order of cost of delay in vessel operations experiences of ship operators.

## Ranking the Container Terminals in Nigerian Ports in Increasing Order of Cost of Delay in Vessel Operations



**Figure 4.2: Ranking the Container Terminals in Nigerian Ports in Increasing Order of Cost of Delay in Vessel Operations**

**Source: Prepared by the author.**

**Table 4.12: Estimated Annual Cost of Vessel Operations at the Terminals borne by Ship Operators**

<b>Year</b>	<b>Tin Can Island (\$)</b>	<b>APAPA (\$)</b>	<b>Rivers (&amp;)</b>	<b>Onne (\$)</b>	<b>Aggregate cost (\$)</b>
2007	1692312.7	1940804.2	649849.2	581293.7	4864260
2008	1952229.1	2073618.6	686983.4	595576.1	5308407
2009	2260701.3	2206433.0	655562.2	621284.4	5743981
2010	2379234.6	2222142.3	688411.68	591291.4	5881080
2011	2324966.3	2276410.5	834092.2	1221145.2	6656614
2012	2153592.9	2063621.8	712691.8	1226858.2	6156765
2013	2306400.9	2156449.1	626997.4	1175441.5	6265289
2014	2416365.5	2146452.3	621284.4	597004.3	5781107
2015	2364953.5	2013637.9	532733.5	484173.4	5395498
2016	2226426.6	1705165.7	455608.6	415617.8	4802819
2017	1866542.4	1648041.2	441326.2	394194.2	4350104
2018	1572351.3	1578063.8	448467.4	945494.9	4544377
2019	1710878.2	1476667.8	458465.0	1031189.3	4677200
2020	1685172.2	1920810.6	469891	992626.8	5068501
2021	1755149.6	2092184.1	492742.8	1029761.0	5369838
2022	1756577.8	2219286.0	508453.4	1045471.7	5529789
<b>Average</b>	<b>2026491</b>	<b>1983737</b>	<b>580222.5</b>	<b>809276.5</b>	<b>5399727</b>

Source: Computed by Researcher from Nigerian Ports Authority Tariff: Dues & Rates Regulations (2021) and Annual Report (2007-2022)

Table 4.12 shows the annual cost of vessel operations at the terminals borne by ship-owners and ship operators. The estimation of cost of handling vessel at the container terminals represent charges and dues which the ship operators paid to the ports and terminal operators per annum between 2007 and 2022 estimated based on the NPA provisional data on tug charges, berth rent, berth/mooring, pilotage rate and annual vessel traffic of the ports. These services are provided in USD. The averages of these estimates are presented in table 4.13 below.

**Table 4.13: Average Annual Cost of Vessel Operations at the Terminals borne by Ship Operators**

<i>Stat</i>	<i>Tin can Island</i>	<i>Apapa</i>	<i>Rivers</i>	<i>Onne</i>	<i>Aggregate cost</i>
Mean	2026491	1983737	580222.5	809276.5	5399727
Standard Error	75856.59	62874.85	29842.33	74789.18	164974.9
Median	2052911	2068620	577009	783389.7	5382668
Mode	#N/A	#N/A	#N/A	#N/A	#N/A
Std Deviation	303426.4	251499.4	119369.3	299156.7	659899.4
Sample Variance	9.21E+10	6.33E+10	1.42E+10	8.95E+10	4.35E+11
Kurtosis	-1.82144	-0.47444	-0.68359	-1.69692	-0.70483
Skewness	-0.08997	-0.87257	0.488713	0.057587	0.189633
Range	844014.2	799742.7	392766	832664	2306510
Minimum	1572351	1476668	441326.2	394194.2	4350104
Maximum	2416366	2276411	834092.2	1226858	6656614
Sum	32423855	31739789	9283560	12948424	86395628
Count	16	16	16	16	16
Confidence Level (95.0%)	161684.5	134014.6	63607.42	159409.4	351635.6

Source: Authors calculation

The result on table4.13 shows the average cost of vessel operation at the container terminals in Nigerian ports borne by the ship-owners and operators between 2007 and 2022. The result indicates that between 2007 and 2022, ship operators spent an average of USD2026491 as cost of vessel husbandry in Tin can Island port per annum with a standard deviation of 303426.4. In Apapa port container terminal, ship operators spent an average of USD1983737 per annum between 2007 and 2022 as the cost of vessel husbandry at the terminals with a standard deviation of 251499.4.

Similarly, in the Rivers port, an average of USD580222.5 was spend as cost of vessel husbandry by ship operators in the port between 2007 and 2022 while in Onne port, an average of USD809276.5 was spent as cost of vessel operations by ship operators in the port with a standard deviation of 299156.7. The port sector average cost of vessel operations in Nigerian port container terminals per annum between 2007 and 2022 is USD5399727 with standard deviation of 659899.4. Figure4.3 below is a pie chart comparing the annual cost of vessel operations in the Nigerian port container terminals borne by ship operators per annum between 2007 and 2022.



**Figure 4.3: cost of vessel operations in the Nigerian port container terminals borne by ship operators per annum between 2007 and 2022**

**Source: Prepared by the author.**

**Table 4.14: The average service rate and arrival rate of vessel at berth in Nigerian ports container terminals**

Container terminals	Tin can Island	Apapa	Rivers	Onne	Aggregate	Average
Average vessel service rate(s) = $(\mu^o)$ (vessels/berth)	<b>22.69</b>	<b>10.95</b>	<b>5.75</b>	<b>28.8</b>	<b>68.19</b>	<b>17.048</b>
Arrival rate(s) = $\lambda^o$ (vessels/days)	<b>295.3</b>	<b>219</b>	<b>46.3656</b>	<b>201</b>	<b>761.666</b>	<b>190.416</b>

Source: Author's calculation

In Onne port, the average turnaround time of vessel is approximately 2.8 days or 33.6hours as shown in table 4.1 indicating that vessels in Onne port spend an average time of 2.8 days or 33.6hours. The arrival rate of vessel in Onne Ports container terminal ( $\lambda^o = Q_L^o / W_t^o$ ) is 201vessels/day as shown in table4.14 above. In relation to the annual ship traffic calls to the port, it implies is that which signifies that the port receives on average about 567 vessels annually or approximately an average of 47vessel calls on monthly basis from 2007-2022 with a prevailing average turnaround time of vessels estimated at 2.8 days from 2007-2022. This is with respect to a berth, hence, the arrival rate of vessel in Onne Ports is a Poisson process and service time have an exponential distribution, therefore, the arrival rate of vessel in Onne Ports is calculated as 201vessels/day on the average turnaround time of 2.8days of Onne port. The arrival rate is smoothed across the period of study which is in a random arrival rate of ship calls to the port between the periods 2007-2022. It is important to note that the days are referred to berth working days in a year. This gives an average service rate of vessel at berth in Onne Ports container terminal ( $\mu^o$ ) is  $28.7 \approx 29$ vessels/berth

The average service rate of vessel emphasizes on the number of ships handled in a single berth over a given period relative to the number of operational berths in the port. This informs that a berth can handle an average of twenty-nine (29) vessels on a random arrival rate and average of three (3) days turnaround time estimate of Onne port. Then, if  $\lambda > \mu$  (i.e. **201** > **29**) seven berth is insufficient as the utilization factor is greater than 100%. On this occurrence, the number of berths should be increased until the service system reaches a stability condition that the utilization coefficient of the system has been satisfied at optimal level  $\beta\phi/\beta_b < 1$ . Therefore, Onne port has only seven (7) berths which implies that the utilization coefficient of the system is not satisfied at optimal level  $\beta\phi/\beta_b < 1$ . (i.e.  $32.19438/7 = 4.599$ ), hence, seven (7) berths are not optimal for Onne port. More berth facilities are need to handle vessel call at Onne port.

In Rivers port, The average turnaround time of vessel in Rivers Ports container terminal **8.761875**. Therefore, turnaround time of vessels in Rivers Ports is approximately 9 days. This informs that the time elapse during which vessel enters and leaves the port facility is on average of 9days in Rivers port over the periods of 2007-2022. However, the arrival rate of vessel in Rivers Ports container terminal ( $\lambda^p = 406.25 / 8.761875 = 46.3656$  which is approximately 46vessels/day. With a ship traffic of 406.25 per annum, the port receives on average about 406 vessels annual or approximately 34 vessel calls on monthly basis from 2007-2022. The arrival rate of vessels in Rivers Ports is computed as 46vessels/day on a random arrival and turnaround time of 8.761875day.

Relative to the ship traffic call, arrival rate and average turnaround time of vessels in Rivers port; The average service rate of vessel at berth in Rivers Ports container terminal =  $\mu^p = \lambda^p / \beta_b^p = 5.75 \approx 6$  vessel/berth. The average service rate of vessel per berth emphasis on the number of ships handled in a berth. This informs that a berth can handle an average of six (6) vessels on a random arrival rate and average of nine (9) days turnaround time estimated of Rivers port. Then, if  $\lambda > \mu$  (i.e. **46 > 6**) eight berths are insufficient as the utilization factor is greater than 100%. On this occurrence, the number of berths should be increased until the service system reaches a stability condition that the utilization coefficient of the system has been satisfied at optimal level  $\beta\phi / \beta_b < 1$ . Therefore, Rivers port has only eight (8) berths which implies that the utilization coefficient of the system is not satisfied at optimal level  $\beta\phi / \beta_b < 1$ . (i.e.  $57.57/8 = 7.20$ ), hence, eight (8) berths are not optimal for Rivers port. More berth facilities are needed to handle vessel call at Rivers port.

In Tin Can Island Port, the arrival rate of vessel in Tin Can Island Ports container terminal ( $\lambda^{\hat{c}} = Q_L^{\hat{c}} / W_t^{\hat{c}}$ ) is **295.3 vessel/day**. Therefore, the arrival rate of vessel in Tin Can Island Ports is calculated as 295 ships daily on the average turnaround time of 4.806days from 2007-2022.

The average service time of vessel at berth in Tin Can Island Ports container terminal ( $\mu^{\hat{c}} = \lambda^{\hat{c}} / \beta_b^{\hat{c}}$ ) is 22.69 which is approximately 23vessels/berth.

The average service rate of vessel per berth emphasis on the number of ships handled in a single berth over the period relative to the number of berths, ship turnaround time and vessel call rates at the port terminal. This informs that a berth can handle an average of 23 vessels on a random arrival rate and average of five (5) days turnaround time estimated of Tin Can Island port. Then, if  $\lambda > \mu$  (i.e. **295 > 23**) 13 berths are insufficient as the utilization factor is greater than 100%. On this

occurrence, the number of berths should be increased until the service system reaches a stability condition that the utilization coefficient of the system has been satisfied at optimal level  $\beta\phi/\beta_b < 1$ .

Therefore, Tin Can Island port has only 13 berths which implies that the utilization coefficient of the system is not satisfied at optimal level  $\beta\phi/\beta_b < 1$ . (i.e.  $61.34/13 = 4.71$ ), hence, 13 berths are not optimal for Tin Can Island port. More berth facilities are needed to handle vessel call at Tin Can Island port.

Lastly in Apapa port container terminal, the average turnaround time of vessel in Apapa Ports 6.36 days while the arrival rate of vessel in Apapa Ports container terminal ( $\lambda^{\ddot{a}} = Q_L^{\ddot{a}} / W_t^{\ddot{a}}$ ) is 219 vessels/day. The average annual ship traffic volume of Apapa port to be approximately 1389 vessels between the periods 2007 to 2022, which signify that Lagos Apapa port receives on average over 1389 vessels annually or approximately 116 vessel calls on monthly basis between the periods 2007 to 2022. Since the vessel arrival rate follows a Poisson distribution or process and service time rate follow an exponential distribution (Asmussen, (2013); the average vessel service rate ( $\mu^{\ddot{a}} = \lambda^{\ddot{a}} / \beta_b^{\ddot{a}}$ ) at the terminals was estimated relative to the arrival rate, ship traffic and ship turnaround time as 10.95 which is approximately 11 vessels/berth. The average service rate of vessel per berth is the number of ships handled in a berth over the period. This informs that a berth can handle an average of 11 vessels on a random arrival rate and average of six (6) days turnaround time estimated of Apapa port. Then, if  $\lambda > \mu$  (i.e. **219** > **11**) 20 berths are insufficient as the utilization factor would be greater than 100%. On this occurrence, the number of berths should be increased until the service system reaches a stability condition that the utilization coefficient of the system has been satisfied at optimal level  $\beta\phi/\beta_b < 1$ . However, Apapa port has only 20 berths which implies that the utilization coefficient of the system is not satisfied at optimal level  $\beta\phi/\beta_b < 1$ . (i.e.  $61.20/20 = 3.06$ ), hence, 20 berths are not optimal for Apapa port. More berth facilities are required to handle vessel call at Apapa port.

**Table 4.15: The optimal service rate and container terminal utilization coefficient in Nigerian ports container terminals**

Container terminals	Tin can Island	Apapa	Rivers	Onne	Aggregate	Average
Optimal service rate of ships = $\Phi^o \mu$ (vessels/ berth)	299	220	48	203	<b>770</b>	<b>192.5</b>
Container terminal utilization coefficient = $\lambda^o / \mu^o$ (%)	99%	99.5%	96%.	99%	<b>393.5</b>	<b>98.38%</b>

**Source: calculated by the author**

The result of the study shown in table4.15 above shows the optimal service rate of the port terminals and the container terminal utilization coefficients of the port terminals over the period covered in the study. As observed in the table4.15 above, the optimal service rate of ships in Onne Port container terminal ( $\Phi^o \mu = \beta^o_b * \mu^o$ ) is 203vessels. This implies that the with an average service rate of Onne port terminal as 29 vessels per berth on random arrival and average of 3 days turnaround time; the seven (7) berths, can only accommodate approximately 203vessels annually each on random arrival and 3days average turnaround time. More vessels arriving will face delay at the port. This means that for Onne port container terminal to perform effective and optimally average of 203vessels can comfortably be handled by 7 berths. More vessels calling would definitely form a queue at the port.

The container terminal utilization coefficient of Onne Port ( $\lambda^o / \mu^o$ ) \*100) is **99%**. This calculation shows that the utilization factor of Onne port is 99%. if  $\lambda > \mu$  the berths would have been insufficient as the utilization factor would be greater than 100%. However, there are seven (7) berths in Onne container terminal in which each berth can handles 29 vessels efficiently, and 7 berths would have the capacity of handling 203vessels annually ( $29*7=203$ ) for optimality. Whereby there is excess flow of vessels at the port more facilities would be required otherwise, this would cause congestions at the port terminal. This finding informs that for Onne port to function optimally 7berths can only handle 203vessels and other inflow of vessel would have to queue up.

The ship queuing costs in Onne Ports container terminal ( $C_{\bar{u}_q}^o * Q_L^o * t^o$ ) is **\$3402LOA**. The ship queuing cost or waiting cost of vessels in Onne port is calculated as **\$3402LOA** annually. This implies that the average annual queuing cost or waiting cost of vessels at Onne port from 2007-2022 is given as **\$3402LOA** annually. Simplifying, means that vessel at Onne port spent average

turnaround time of 3days, with average rate of vessel calls of 567 annually and berth rent of \$2\*LOA (Length Overall). The cost of idle berth in container terminal of Onne Ports ( $C\beta\phi^\circ * (\beta_b^\circ - \beta\phi^\circ) * t^\circ$ ) is **\$20\*LOA**. From the analysis and calculation, it examined the average berth vacancy rate of Onne port which is **67.80%** vacancy from 2007-2022. This implies that out of 7berths in Onne port only 2berths (**32.2% occupancy rate**) were working and fully utilized while 5berths were more or less idle or not efficiently utilized resulting to 67.80% inoccupancy rate. The cost of idle berth in Onne Port amounts to **\$20 \*LOA** annually. This is calculated based on standard 2days of berth rent (i.e. 48hrs) global duration of vessel turnaround time of ports.

In Rivers Ports the optimal service rate of ships in Rivers Ports container terminal ( $\Phi^p \mu = \beta_b^p * \mu^p$ ) is 48vessels. Having noted that the average service rate of Rivers port is given as six (6) vessels per berth on random arrival and average of 9 days turnaround time estimated of Rivers port. eight (8) berths, can only accommodate approximately 48vessels annually on random arrival and 9days average turnaround time operated in Rivers port. Excess vessels arriving were delayed at the port and form queue. This informs that for Rivers port container terminal to perform effective and optimally average of 48vessels can comfortably be handled by 8berths on 9days average turnaround time operated in Rivers port. Otherwise, more vessels calling would form a queue.

The container terminal utilization coefficient of Rivers Port ( $\lambda^p / \mu^p$ ) \*100) is **96%**.

The terminal utilization coefficient of Rivers Port is given as **(46/6\*8)100 = 96%**. This result shows that the utilization factor of Rivers port is 96%. If  $\lambda > \mu$  the berths would have been insufficient as the utilization factor would be greater than 100%. However, there are eight (8) berths in Rivers port container terminal in which each berth handles 6vessels, and 8berths would have the capacity of handling 46vessels annually (6\*8=46) for optimality on the average turnaround time of 9days. Whereby there is excess flow of vessels at the port more facilities would be required otherwise, this would cause congestions at the port terminal. This finding informs that for Rivers port to function optimally 8berths can only handle 46vessels on the average turnaround time of 9days otherwise, more inflow of vessels would have to queue up.

The ship queuing costs in River Ports container terminal ( $C\ddot{u}_q^p * Q_L^p * t^p$ ) is \$7308LOA. The ship queuing cost or waiting cost of vessels in Rivers port is calculated as \$7308\*LOA annually. This implies that the average annual queuing cost or waiting cost of vessels at Rivers port from 2007-2022 is given as \$7308\*LOA annually. Simplifying, means that vessel at Rivers port spent average

turnaround time of 9days, with average rate of vessel calls of **406** per annum and berth rent given as  $\$2 * LOA$  (Length Overall). The cost of idle berth in container terminal of Rivers Port ( $C\beta\phi^p * (\beta_b^p - \beta\phi^p) * t^p$ ) is  $\$12 * LOA$ . From the results, the average berth vacancy rate of Rivers port which is **42.4%** vacancy from 2007-2022. This implies that out of 8 berths in Rivers port only 5berths (**57.6%**) were working and fully utilized while 3berths (42.4%) were more or less idle or not working in full capacity. The cost of idle berth in Rivers Port amounts to **\\$12\*LOA** annually. This is calculated based on standard 2days of berth rent (i.e. 48hrs) global duration of vessel turnaround time of ports.

In Tin Can Island Port port terminals, the optimal service rate of ships in Tin Can Island Ports container terminal ( $\Phi^c \mu = \beta_b^c * \mu^c$ ) is 299vessels. With an average service rate of 23vessels per berth on random arrival rate of 5 days; the 13berths can only accommodate approximately 299vessels per berth annually. More vessels arriving would be delayed at the port and form queue. This finding informs that for Tin Can Island port container terminal to perform effectively and optimally average of 299vessels can comfortably be handled by 13berths on 5 days turnaround time of Tin Can Island port. Otherwise, vessels calling would form a queue.

The container terminal utilization coefficient of Tin Can Island Port ( $\lambda^c / \mu^c$ ) \*100) is 99%. This indicates that the utilization factor of Tin Can Island port is 99%. If  $\lambda > \mu$  the berths would have been insufficient as the utilization factor would be greater than 100%. However, there are 13berths in Tin Can Island port container terminal in which each berth handles 23vessels, and 13berths would have the capacity of handling 299vessels annually ( $23 * 13 = 299$ ) for optimality. Whereby there are excess flow of vessels at the port more facilities would be required otherwise, this would cause congestions at the port terminal. This finding informs that for Tin Can Island port to function optimally 13berths can only handle 299vessels on 5day turnaround time otherwise, more inflow of vessels would have to queue up.

The ship queuing costs in Tin Can Island Ports container terminal ( $C\bar{u}_q^c * Q_L^c * t^c$ ) is  $\$14190LOA$ . The ship queuing cost or waiting cost of vessels in Tin Can Island port is calculated as  $\$14190 * LOA$  annually. This implies that the average annual queuing cost or waiting cost of vessels at Tin Can Island port from 2007-2022 is given as  $\$14190 * LOA$  annually. To simplify, means that vessel at Tin Can Island port spend the average turnaround time of 5days, with average rate of vessel calls of 1419 per annum and berth rent given as  $\$2 * LOA$  (Length Overall). The cost of idle berth in container terminal of Tin Can Island Ports ( $C\beta\phi^c * (\beta_b^c - \beta\phi^c) * t^c$ ) is  $\$20 * LOA$ . The result also

indicate that the average berth vacancy rate of Tin Can Island port which is **38.66%** vacancy from 2007-2022. This implies that out of 13 berths in Tin Can Island port about 8 berths (**61.34%**) were working and fully utilized while 5 berths (**38.66%**) were more or less not working or idle. The cost of idle berth in Tin Can Island Port amounts to **\$20\*LOA** annually. The calculation was based on 2 days standard of berth rent (i.e. 48hrs) global duration of vessel turnaround time of ports.

In Apapa Port, the optimal service rate of ships in Apapa ports container terminal ( $\Phi^a \mu = \beta_b^a * \mu^a$ ) is 220 vessels. Having noted that the average service rate of Apapa port is given as 11 vessels per berth on random arrival and average of 6 days turnaround time estimated of Apapa port. 20 berths, can only accommodate approximately 220 vessels annually on random arrival and on 6 days average turnaround time operated in Apapa port. More vessels arriving were delayed at the port which form congestion and queue. This informs that for Apapa port container terminal to perform effectively and optimally, average of 220 vessels would comfortably be handled by 20 berths on average of 6 days turnaround time of Apapa port. Otherwise, more vessels calling would form a queue.

The container terminal utilization coefficient of Apapa Port =  $(\lambda^a / \mu^a) * 100$  is 99.5%. This implies that the utilization factor of Apapa port is 99.5%. If  $\lambda > \mu$  the berths would have been insufficient as the utilization factor would be greater than 100%. However, there are 20 berths in Apapa port container terminal in which each berth handles 11 vessels, and 20 berths would have the capacity of handling 220 vessels annually ( $20 * 11 = 220$ ) for optimality. Whereby there are excess flow of vessels at the port more facilities would be required otherwise, this would cause congestions at the port terminal. This finding informs that for Apapa port to function optimally 20 berths can only handle 220 vessels on 6 days turnaround time of Apapa port otherwise, more inflow of vessel would have to queue up.

The ship queuing costs in Apapa Ports container terminal ( $C\bar{u}_q^a * Q_L^a * t^a$ ) is **\$16668LOA**. The ship queuing cost or waiting cost of vessels in Apapa port is calculated as **\$16668\*LOA** annually. This implies that the average annual queuing cost or waiting cost of vessels at Apapa port from 2007-2022 is given as \$16668\*LOA annually. To simplify, means that vessel at Apapa port spend the average turnaround time of 6 days, with average rate of vessel calls of 1389 per annum and berth rent given as \$2\*LOA (Length Overall). The cost of idle berth in container terminal of Apapa Ports ( $C\beta\phi^a * (\beta_b^a - \beta\phi^a) * t^a$ ) is \$32\*LOA. The result indicates that the average berth vacancy rate of Apapa port which is 38.8% vacancy (see Table 4.5) from 2007-2022. This implies that out of

20berths in Apapa port approximately 12berths (61.2%) were working and fully utilized while 8berths (38.8%) were more or less not working and idle. The cost of idle berth in Apapa port amounts to \$32\*LOA annually. The calculation was based on 2days standard duration for berth rent (i.e. 48hrs) of Nigerian ports.

**Table 4.16: Relationship between Delay in Vessels Operations and Trend of Shipping Operations in Nigerian Container Terminals**

<i>Regression Statistics</i>	
Multiple R	0.839527
R Square	0.7046901
Adjusted R Square	0.433626
Standard Error	3.319571
Observations	16

ANOVA					
	<i>Df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>Significance F</i>
Regression	3	159.6102	53.20341	4.828091	0.019826
Residual	12	132.2347	11.01955		
Total	15	291.8449			

	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>	<i>Lower 95%</i>	<i>Upper 95%</i>
Intercept	6.412233	8.124583	0.789238	0.445287	-11.2897	24.11418
GRT	1.2E-04	4.81E-08	2.49229	0.028313	2.2E-07	1.5E-08
SHPTR	2.3E-06	2.65E-08	0.85895	0.407199	8.1E-08	3.5E-08
CONTTR	0.004786	0.001972	2.427597	0.031872	0.000491	0.009082

Source: Authors calculation

Table 4.16 shows the result of the relationship between delay in vessel operations in container terminals and the trend of shipping operation in the terminals. The result was used to actualize the 6<sup>th</sup> objective of the study. The result of the study shows a correlation coefficient of correlation of 0.84. This implies that there exist 84% positive correlation between delay in vessel operations in Nigerian port container terminals and the Gross Registered Tonnage (GRT) of vessels handled in the terminals, the Ship Traffic calls (SHPTR) to the port terminals and the TEU container throughput trade (CONTTR) handled at the terminals, which are used as proxies for shipping operations in the port terminals.

The model equation showing the relationship between delay in vessel operations in the port terminals and shipping operations in the terminals is given as:

$$\mathbf{Log Y_{delay} = 6.41223 + 0.0000023LogSHP_{trf} + 0.00012LogGRT_{shps} + 0.0048LogCONT_{trf}} \quad (4.1)$$

This means that when the ship traffic calls handled in the terminals for example increased by 1%, the delay that will be experienced in vessel husbandry operations in the port terminals will equally increase by 0.0000023% of its mean value over the period. Similarly, when the GRT of vessel handled in the port terminals increased by 1%, delay in vessel husbandry operations will equally increase by 0.00012% of its mean value while for a 1% increase in the TEU container throughput trade handled in the port terminals, the delay experienced by ship-owners and ship operators in vessel operations in the terminals will increase by 0.0048% of its mean value over the period.

These have implications in the development of port terminal policies for the provision of port infrastructure and equipment at the container terminals. Since the result shows that increasing trend in shipping operations is leading to increasing delay in vessel operations in Nigerian port terminals, investment in port infrastructure should be increased in tandem with the extent of increase in shipping operations in order to solve the problems and challenges of delay in vessel operations in Nigerian container terminals.

The coefficient of determination which gives the extent to which the independent variables (shipping operations can predict the dependent variable (delay in vessel operations in container terminals) is 0.7047. This implies that ship traffic calls to the terminals, GRT of ships handled at the terminals and TEU container throughput trade handled at the terminals explain about 71% of variations in delay in vessel operations in Nigerian container terminals.

In order to determine the effect of cost of delays in vessel operations on trend of shipping operations in Nigerian container terminals we examined the effects of cost of delays in vessel operations on the three components variables of shipping operations listed in chapter three of this report which include ship traffic to the port, GRT of vessels that called to the ports and TEU container throughput trade handled over the period. These are shown in table4.17 to table4.19 below.

**Table 4.17: Effect of Cost of Delay in Vessels Operations on Trend of Container Shipping Operations in Nigerian Container Terminals**

<i>Regression Statistics</i>						
Multiple R	0.764598					
R Square	0.584581					
Adjusted R Square	0.305181					
Standard Error	367496.6					
Observations	16					
<i>ANOVA</i>						
	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>Significance F</i>	
Regression	4	1.06E+12	2.66E+11	4.968058	0.0169194	
Residual	11	1.49E+12	1.35E+11			
Total	15	2.55E+12				
	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>	<i>Lower 95%</i>	<i>Upper 95%</i>
Intercept	1139580	313991.9	3.629329	0.003961	448488.4	1830671
Tin Can	-1.9567	47.27584	-0.403083	0.694611	-84.9974	123.1095
Apapa	-5.0592	22.89472	-2.27385	0.044009	-102.45	-1.66824
Rivers	-3.7338	61.83162	-0.593602	0.564785	-99.3871	172.7939
Onne	9.7892	183	1.079176	0.303604	-205.291	600.2696

Source: Authors calculation

Table 4.17 shows the result of the effects of cost of delay in vessel operations in container terminals on the trend of TEU container shipping trade in the terminals over the period covered in the study. The result was used to actualize the 7<sup>th</sup> objective of the study. The result of the study shows a correlation coefficient of 0.765. This implies that there exist 77% positive correlation between the cost of delay in vessel operations in Nigerian port container terminals and the TEU container shipping trade (CONTTR) handled in the terminals.

The model showing the effects of cost implications of delay in vessel operations in the port terminals on the TEU container throughput trade handled by the port terminals over the period is given as:

$$\text{LogCONT}_{trade} = 1139580 - 5.0592\text{LogD}_{costAPAPA} + 9.7892\text{LogD}_{COSTONNE} - 3.7338\text{LogD}_{COSTRIVERS} - 1.9567\text{LogD}_{COSTTIN} \quad (4.2)$$

This means that when the cost of delay in vessel operations in Apapa port container terminal for example is increased by 1%, it will lead to about 5.0592% decline in the TEU container throughput trade handled in the port sector in Nigeria. Similarly, when the cost of delay in Onne port terminal is increased by 1%, it will lead to a 9.7892% increase in the container throughput trade transiting through the port sector in. If the cost of delay in vessel operations in Rivers port is increased by 1%, the TEU throughput trade of the port sector in Nigeria decreased by 3.7338%. The TEU container throughput trade handled in the port sector in Nigeria decreases by 1.9567%, for a 1% increase in delay cost, in the Tin Can Island port terminal. The result indicate that, in Onne port, increasing cost of delay in vessel husbandry operations has not led to increasing trend in TEU container throughput trade handled in the port sector. This is possibly because the port has the least period of delay in vessel operation in Nigeria port sector as shown in previous sections.

These have implications in the development of port terminal policies for the provision of port infrastructure and equipment at the container terminals. Since the result shows that increasing cost of delay for most ports leads to decreasing trend in TEU shipping trade transited through the ports, investment in port infrastructure should be increased in tandem with the extent of increase in shipping operations in order to solve the problems and challenges of delay in vessel operations in Nigerian container terminals.

The coefficient of determination which gives the extent to which the independent variables (cost of delay) influence the dependent (TEU Trade handled) is 0.585. This implies that the cost of delay in vessel operations at the terminals explain about 59% variations TEU container throughput trade handled at the terminals over the period of 16 years covered in the study.

**Table 4.18: Effect of Cost of Delay in Vessels Operations on Ship Calls in Nigerian Container**

**Terminals**

<i>Regression Statistics</i>						
Multiple R	0.732767					
R Square	0.536947					
Adjusted R Square	0.368564					
Std Error	367.169					
Observations	16					
<i>ANOVA</i>						
	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>Significance F</i>	
Regression	4	1719593	429898.2	3.881846	0.045269	
Residual		11	1482944	134813.1		
Total		15	3202537			
	<i>Coefficients</i>	<i>Std Error</i>	<i>t Stat</i>	<i>P-value</i>	<i>Lower 95%</i>	<i>Upper 95%</i>
Intercept	2766.173	313.712	8.817555	2.56E-06	2075.698	3456.649
Tin Can	0.038114	0.047234	0.806918	0.436813	-0.06585	0.142074
Apapa	-0.01854	0.022874	-0.81046	0.434859	-0.06888	0.031807
Rivers	0.141973	0.061777	2.298167	0.042168	0.006004	0.277942
Onne	0.152748	0.182837	0.835435	0.421249	-0.24967	0.55517

**Source: Author's calculation**

Table 4.18 shows the result of the effects of cost of delay on ship calls in the container terminals over the period covered in the study. The result was used to actualize the 7<sup>th</sup> objective of the study. The result of the study shows a correlation coefficient of 0.733. This implies that there exist 73% positive correlation between the cost of delay in vessel operations in Nigerian port container terminals and ship traffic handled in the terminals.

The model showing the effects of cost of delay in vessel operations in the port terminals on the ship traffic at the terminals over the period is:

$$\begin{aligned} \mathbf{LogSHP}_{trade} = \mathbf{2766.173} - \mathbf{0.01854LogD}_{costAPAPA} + \mathbf{0.152748LogD}_{COSTONNE} + \\ \mathbf{0.141973LogD}_{COSTRIVERS} + \mathbf{0.038114LogD}_{COSTTIN} \end{aligned} \quad \mathbf{(4.3)}$$

The means that when the cost of delay in vessel operations in Apapa port container terminal for example is increased by 1%, it will lead to about 0.01854% decline in the in ship calls to Nigerian ports while a 1% increase in delay cost in Onne port will lead to a 0.1527% increase in ship calls to Nigeria. A 1% increase in the cost of delay in vessel operations in Rivers port witnessed a 0.141973% increased ship calls to Nigerian ports while a 1% increase in delay cost in Tin Can Island port will see a 0.038114% increase in ship calls to Nigerian ports over the period.

The coefficient of determination which gives the extent to which the independent variables (cost of delay) influence the dependent (ship calls) is 0.5369. This implies that the cost of delay in vessel operations at the terminals explain about 54% of variations in ship calls to the container terminals over the period of 16 years covered in the study.

**Table 4.19: Effect of Cost of Delay in Vessels Operations on GRT of Ships of handled in Nigerian Container Terminals**

<i>Regression Statistics</i>	
Multiple R	0.644546
R Square	0.41544
Adjusted R Square	0.202872
Std Error	31641468
Observations	16

<i>ANOVA</i>					<i>Significance</i>
	<i>Df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>F</i>
Regression	4	7.83E+15	1.96E+15	1.95439	0.17143
Residual	11	1.1E+16	1E+15		
Total	15	1.88E+16			

	<i>Coefficients</i>	<i>Std Error</i>	<i>t Stat</i>	<i>P-value</i>	<i>Lower 95%</i>	<i>Upper 95%</i>
Intercept	46984714	27034713	1.73794	0.110097	-1.3E+07	1.06E+08
Tin Can	7.0116	4070.452	1.722561	0.112927	-1947.4	15970.61
Apapa	-8.5791	1971.236	-0.43522	0.671821	-5196.58	3480.745
Rivers	6.0411	5323.705	0.113477	0.911697	-11113.3	12321.51
Onne	-4.1269	15756.31	-2.61922	0.023862	-75948.6	-6589.76

**Source: Authors calculation**

The result of the study shown on table 4.19 indicates that the coefficient of correlation between the GRT of vessels handled in the port terminals and the cost of delay in vessel operations at the terminals is 0.6446. This reveals the existence of about 65% positive correlation between the GRT of vessels handled and the cost of delay to ship operators, in the ports, over the period covered in the study.

The model equation depicting the effects of cost of delay in vessel operations on GRT handled over the period is:

$$\mathbf{LogGRT_{trade} = 46984714 - 8.5791LogD_{costAPAPA} - 4.1269LogDCOSTONNE + 6.0411LogDCOSTRIVERS + 7.0116LogDCOSTTIN} \quad \mathbf{(4.4)}$$

The means that when the cost of delay in vessel operations in Apapa port container terminal for example is increased by 1%, it will lead to about 8.5971% decline in the GRT of vessels handled in the port sector in Nigeria container terminals. Similarly, when the cost of delay in Onne port terminal is increased by 1%, it will lead to a 4.1269% decrease in the GRT of vessels handled in

the Nigerian port sector. When the cost of delay in vessel operations in Rivers port is increased by 1%, the GRT of vessels handled in the port sector in Nigeria will increase by 6.0411%. Lastly with a 1% increase in the cost of delay in Tin Can Island port container terminal, the GRT of vessels handled in the port sector in Nigeria increased by 7.0116%.

These have implications in the development of port terminal policies for the provision of port infrastructure and equipment at the container terminals. Since the result shows that increasing cost of delay for most ports leads to decreasing trend in TEU shipping trade transited through the ports, investment in port infrastructure should be increased in tandem with the extent of increase in shipping operations in order to solve the problems and challenges of delay in vessel operations in Nigerian container terminals.

The coefficient of determination which gives the extent to which the independent variables (cost of delay) influence the dependent (GRT of vessels handled) is 0.415. This implies that the cost of delay in vessel operations at the terminals explain only about 41% variations GRT of vessels handled at the terminals over the period of 16 years covered in the study.

**Table 4.20: Port Users Satisfaction with Container Terminal Operations in Nigeria relative to the Extent of Delay experienced at the Terminals**

Satisfaction scores (%)	Average Satisfaction score (%)	Std. deviation	Min.	Max.	Range	N	Standard Error
Frequency	54.38	31.62278	20	100	80.0	349	14.14214

Source: author's calculation

The result of table4.20 shows the satisfaction score of the port users in the use of port services at the container terminals relative to the extent of delay in vessel operations in the container terminals. The result shows an average port users satisfaction score of 54.38% with standard deviation of 31.623. The range 80% indicates the difference between maximum and minimum port user's satisfaction score; indicating that, few operators are completely satisfied with the services at the container terminals, while majority of the ship operators are not completely satisfied. This is supported by the average satisfaction score of 54.38%. The implication is that port terminal operators should drive towards improving the services at the container terminals in order to reduce the delay in vessel operations at the ports.

### 4.3 Test of Hypotheses

In this section, the various hypotheses proposed in the study were tested as shown in the tables below:

**Table 4.21:  $H_{01}$ : There is no delay in vessel operations in Nigerian ports container terminals.**

Hypothesis	Tin Can	Apapa	Rivers	Onne	National Average Delay (NAD)	Decision
$H_{01}$	2.80625	4.35687	6.761875	0.825625	14.75063	$AVD > 0$ ; Reject $H_{01}$

Source: Author's calculation. *If national average delay  $AVD \leq 0$ ; accept  $H_{01}$ ; if  $AVD > 0$ , reject  $H_{01}$*   
 the test of hypothesis  $H_{01}$  reveal that the average delay in vessel operations in the port terminals is approximately 2.81 days, 4.36 days, 6.76 days and 0.82 days respectively for Tin Can Island, Apapa, Rivers and Onne ports. Since in each case, the average delay is greater than 0, we reject null hypothesis  $H_{01}$  and conclude that there is delay in vessel operations in Nigeria port container terminals.

**Table 4.22:  $H_{02}$ : The economic cost implications of delay in vessel operations in Nigeria container terminals is zero.**

Hypothesis	Tin Can	Apapa	Rivers	Onne	National average delay cost (NADC)	Decision
$H_{02}$	7961.744	12412.11	5645.781	915.6938	26935.33	$ADC > 0$ ; Reject $H_{02}$

Source: Author's calculation. *If national average delay  $ADC \leq 0$ ; accept  $H_{02}$ ; if  $ADC > 0$ , reject  $H_{02}$*

The test of hypothesis  $H_{02}$  reveal that for all the terminals, the average cost of delay in vessel operations is greater than zero. Therefore, we reject null hypothesis  $H_{02}$  and conclude that the economic cost implications of delay in vessel operations in Nigeria container terminals is greater than zero.

**Table 4.23 H<sub>03</sub>: The coefficient of the average service rate of vessel at berth in Nigerian ports container terminal is zero.**

Hypothesis	Tin Can port (W <sub>t</sub> <sup>o</sup> )	Apap (W <sub>t</sub> <sup>o</sup> )	River (W <sub>t</sub> <sup>o</sup> )	Onne (W <sub>t</sub> <sup>o</sup> )	National average Service Rate (NASR)	Decision
H <sub>03</sub>	22.69	10.95	5.75	28.8	17.048	W <sub>t</sub> <sup>o</sup> >0, Reject

Source: Author's calculation. *If national average service rate  $W_t^o \leq 0$ ; accept  $H_{03}$ ; if  $W_t^o > 0$ , reject  $H_{03}$*

The test of H<sub>03</sub> reveals that for each port terminal, the average service rate of vessels at berth in Nigerian port terminals is greater than zero. Therefore, we reject null hypothesis H<sub>03</sub> and accept the alternate that the coefficient of the average service rate of vessel at berth in Nigerian ports container terminal is determinable as shown in table4.23 above.

**Table 4.24 H<sub>04</sub>: The optimal service rate of ships in Nigerian ports container terminal is zero.**

Hypothesis	Tin Can (Φ <sup>o</sup> μ)	Apapa (Φ <sup>o</sup> μ)	Rivers (Φ <sup>o</sup> μ)	Onne (Φ <sup>o</sup> μ)	National average (Φ <sup>o</sup> μ)	Decision
H <sub>04</sub>	299	220	48	203	192.5	Φ <sup>o</sup> μ >0, Reject H <sub>04</sub>

Source: Author's calculation. *If national average optimal service rate  $\Phi^o\mu \leq 0$ ; accept  $H_{04}$ ; if  $\Phi^o\mu > 0$ , reject  $H_{04}$*

The test of H<sub>04</sub> reveals that for each port terminal, the optimal service rate of ships in Nigerian ports container terminal is greater than zero. Therefore we reject null hypothesis H<sub>04</sub> and accept the alternate that the optimal service rate of ships in Nigerian ports container terminal is not zero. The coefficient of the optimal service rate of ships in Nigerian ports container terminal is as shown in table4.24 above.

**Table 4.25-H<sub>05</sub>: The container terminal utilization coefficient of Nigerian container ports is zero.**

Hypothesis	Tin Can	Apapa	Rivers	Onne	National average ( $\lambda^\circ/\mu^\circ$ )	Decision
H <sub>05</sub>	99%	99.5%	96%.	99%	98/38%	$\lambda^\circ/\mu^\circ > 0$ ; Reject H <sub>05</sub>

Source: Author's calculation. *If national average container terminal utilization factor  $\lambda^\circ/\mu^\circ \leq 0$ ; accept H<sub>05</sub>; if  $\lambda^\circ/\mu^\circ > 0$ , reject H<sub>05</sub>*

The test of H<sub>05</sub> reveals that for each port terminal, the container terminal utilization coefficient of Nigerian container ports is greater than zero. Therefore, we reject null hypothesis H<sub>05</sub> and accept the alternate that the container terminal utilization coefficient of Nigerian container ports is greater than zero as shown in table 4.25 above.

**Table 4.26: H<sub>06</sub>: There is no significant relationship between delay in vessels operations and trend of shipping operations in Nigeria container terminals**

Hypotheses	F-cal.	F-critical	p-value/sig.	Decision
H <sub>06</sub>	4.828091	3.50	0.019826	Reject H <sub>06</sub>
Variable	t-cal.	t-critical	p-value/sig.	Decision
GRT	2.49229	1.75	0.028313	Significant
SHPTR	0.85895	1.75	0.407199	Not Significant
CONTTR	2.427597	1.75	0.031872	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<sub>06</sub> shows that the F-cal. is 4.82 and f-critical is 3.50 while the p-value is 0.01883 at 0.05 alpha values. Since 4.82 > 3.50 and the p-value is also less than the alpha value, we reject null hypothesis H<sub>06</sub> and conclude that there is significant relationship between delay in vessels operations and trend of shipping operations in Nigeria container terminals.

The test of the individual effects of the explanatory variables also shows that the GRT handled by the ports have t-score of 2.49, t-tabulated value of 1.75, alpha value of 0.02831. We conclude that the GRT of vessel handled in the port terminals over the period have significant effects on the extent of delay in the port terminals. Similarly, the TEU container throughput trade handled have t-score of 2.42 and t-tabulated value of 1.75, we also conclude that the TEU container throughput

trade handled in the port terminals over the period have significant effects on the extent of delay in vessels operations in the ports.

However, ship traffic counts with a p-value of 0.4072 which is greater than the alpha value of 0.05 has no significant effects on the extent of delay in vessel operations in the port terminals. This implies that the extent of delay in vessel operations in the port is more a function of the GRT of the vessels and the quantum of TEU container trade carried.

**Hypothesis-H<sub>07</sub>:** There is no significant effect of cost of delays on trend of shipping operations in Nigerian container terminals.

**Hypothesis H<sub>07</sub>** was divided into three sub-hypotheses as shown in the tables below:

**Table 4.27- H<sub>07a</sub>: There is no significant effect of cost of delays in Vessels Operations on Trend of Container Shipping Operations in Nigerian Container Terminals**

Hypotheses	F-cal.	F-critical	p-value/sig.	Decision
H <sub>06</sub>	4.968058	3.50	0.0169194	Reject H <sub>06</sub>
Variable	t-cal.	t-critical	p-value/sig.	Decision
Delay cost in Tin Can	0.403083	1.75	0.694611	Not significant
Delay cost in Apapa	-2.27385	1.75	0.044009	Significant
Delay cost in Rivers	0.593602	1.75	0.564785	Not significant
Delay cost in Onne	1.079176	1.75	0.303604	Not Significant

Source: Authors calculation. Reject null hypotheses if  $F\text{-cal} > f\text{-critical}$ ; Accept null hypotheses if  $F\text{-cal} < F\text{-critical}$

The test of hypothesis H<sub>07a</sub> shows that the F-cal. is 4.968 and f-critical is 3.50 while the p-value is 0.0169194 at 0.05 alpha values. Since  $4.968 > 3.50$  and the p-value is also less than the alpha value, we reject null hypothesis H<sub>07a</sub> and conclude that there is significant effect of cost of delays in Vessels Operations on Trend of Container Shipping Operations in Nigerian Container Terminals

The test of the individual effects of the explanatory variables also shows that the cost of delay in Apapa port has t-score of 2.27, t-tabulated value of 1.75, alpha value of 0.044. We conclude that the cost of delay in Apapa port have significant effects on the TEU throughput trade handled in the Nigeria port sector over the years. The cost of delay in the other port terminals at Tin Can

Island, Rivers and Onne have no significant effects on the TEU container shipping trade handled by the port sector over the years covered in the study.

**Table 4.28-H<sub>07b</sub>: There is no significant effect of cost of delays in Vessels Operations on Ship Calls in Nigerian Container Terminals**

Hypotheses	F-cal.	F-critical	p-value/sig.	Decision
H <sub>06</sub>	3.881846	3.50	0.045269	Reject H <sub>06</sub>
Variable	t-cal.	t-critical	p-value/sig.	Decision
Delay cost in Tin Can	0.806918	1.75	0.436813	Not significant
Delay cost in Apapa	-0.81046	1.75	0.434859	Not Significant
Delay cost in Rivers	2.298167	1.75	0.042168	Significant
Delay cost in Onne	0.835435	1.75	0.421249	Not Significant

Source: Authors calculation. Reject null hypotheses if  $F\text{-cal} > f\text{-critical}$ ; Accept null hypotheses if  $F\text{-cal} < F\text{-critical}$

The test of hypothesis H<sub>07b</sub> shows that the F-cal. is 3.882 and f-critical is 3.50 while the p-value is 0.0452 at 0.05 alpha values. Since  $4.968 > 3.50$  and the p-value is also less than the alpha value, we reject null hypothesis H<sub>07a</sub> and conclude that there is no significant effect of cost of delays in Vessels Operations on Ship Calls in Nigerian Container Terminals

The test of the individual effects of the explanatory variables also shows that the cost of delay in Rivers port has t-score of 2.29, t-tabulated value of 1.75, alpha value of 0.0421. We conclude that the cost of delay in Rivers port has significant effects on the ship traffic calls to the Nigeria port sector over the years. The cost of delay in the other port terminals at Tin Can Island, Apapa and Onne have no significant effects on the ship traffic calls handled by the port sector over the years covered in the study.

**Table 4.29-H<sub>07c</sub>: There is no significant effect of cost of delays in Vessels Operations on GRT of Ships of handled in Nigerian Container Terminals**

Hypotheses	F-cal.	F-critical	p-value/sig.	Decision
H <sub>06</sub>	1.95439	3.50	0.17143	Reject H <sub>06</sub>
Variable	t-cal.	t-critical	p-value/sig.	Decision

Delay cost in Tin Can	1.722561	1.75	0.112927	Not significant
Delay cost in Apapa	-0.43522	1.75	0.671821	Not Significant
Delay cost in Rivers	0.113477	1.75	0.911697	Not Significant
Delay cost in Onne	-2.61922	1.75	0.023862	Significant

Source: Authors calculation. Reject null hypotheses if  $F\text{-cal} > f\text{-critical}$ ; Accept null hypotheses if  $F\text{-cal} < F\text{-critical}$

The test of hypothesis  $H_{07c}$  shows that the  $F\text{-cal.}$  is 1.954 and  $f\text{-critical}$  is 3.50 while the  $p\text{-value}$  is 0.1714 at 0.05 alpha values. Since  $1.95439 < 3.50$  and the  $p\text{-value}$  is greater than the alpha value, we accept the null hypothesis  $H_{07c}$  that there is no significant effect of cost of delays in Vessels Operations on GRT of Ships of handled in Nigerian Container Terminal

The test of the individual effects of the explanatory variables also shows that the cost of delay in Tin Can Island port and Onne port each has significant effects on the GRT of ships handled in the Nigeria port sector over the years. The cost of delay in the other port terminals at Apapa and Rivers port each has no significant effects on the GRT of vessels handled by the port sector over the years covered in the study. The implications of these findings is that the extent of effects of cost of delay in vessel operation on the individual components of shipping operations (GRT, ship traffic and TEU container trade) examined is a function of the port in question and the extent of delay experienced by ship operators.

**Table 4.30- $H_{08}$ : The extent of port user satisfaction with the operations of the ports relative to the extent of delay in vessel operations in the port is less than 40%.**

Hypothesis	Average port user's satisfaction (APUS) score (%)	Decision
$H_{08}$	54.38	$54.38\% > 40\%$ ; Reject $H_{08}$

Source: Author's calculation. *If  $APUS \leq 40\%$ ; accept  $H_{08}$ ; if  $APUS > 40\%$ , Reject  $H_{08}$*

The test of hypothesis  $H_{08}$  reveals an average port user satisfaction score of 54.38%. Since the average port user satisfaction score is greater than 40%, we reject null hypothesis  $H_{08}$  and accept that alternate hypothesis that the extent of port user satisfaction with the operations of the ports relative to the extent of delay in vessel operations in the port is greater than 40% as shown in table 4.30 above.

## CHAPTER FIVE

### CONCLUSION AND RECOMMENDATIONS

#### 5.1 Conclusion

In conclusion, the study has been able to address the research questions and actualized the aim and objectives of the study. The study concludes as follows:

- (i) Vessel operators in the Nigerian port system incur more port cost and charges for extra days (delay period) spent beyond the 2 days global port sector benchmark. The ship operators experienced annual average of between 2.8 days and 14 days delay in vessel operations in the Nigerian port sector between 2007 and 2022.
- (ii) The Nigerian economy lost an average of USD 26935.33 per annum between 2007 and 2022 in the port sector with standard deviation of 11468.24, as result of delay in vessel operations in the container terminals in Tin Can Island port, Apapa port, Rivers port and Onne port.
- (iii) The average service rate of vessel at berth in Onne Ports container terminal ( $\mu^{\circ}$ ) is 29vessels/berth. The average service rate of vessel emphasizes on the number of ships handled in a single berth over a given period relative to the number of operational berths in the port while the average service time of vessel at berth in Tin Can Island Ports container terminal is 23vessels/berth, 10.95 vessels/berth at Apapa and 5.75vessels/berth at Rivers port.
- (iv) The container terminal utilization coefficient of the Onne, Tin Can Island, Apapa and Rivers are 99%, 99%, 99.5% and 96% respectively.
- (v) The relationship between delay in vessel operations and shipping operations in the port terminals over the period indicates that when the ship traffic calls handled in the terminals for example increased by 1%, the delay that will be experienced in vessel husbandry operations in the port terminals will equally increase by 0.0000023% of its mean value over the period. Similarly, when the GRT of vessel handled in the port terminals increased by 1%, delay in vessel husbandry operations will equally increase by 0.00012% of its mean value while for a 1% increase in the TEU container throughput trade handled in the port terminals, the delay experienced by ship-owners and ship

operators in vessel operations in the terminals will increase by 0.0048% of its mean value over the period.

- (vi) The findings of the study also indicate an average port user's satisfaction score of 54.38% with standard deviation of 31.623 relative to the extents of delay in vessel operations in Nigerian port sector.
- (vii) There is significant effect of cost of delays in Vessels Operations on Trend of Container Shipping Operations in Nigerian Container Terminals.

## **5.2 Recommendations**

The study recommends as follows:

- i. The Nigerian Ports Authority (NPA) as the regulator of the terminal operators should develop and implement policies and strategies to achieve a reduction in the extent of delay in vessel operations in Nigerian port sector.
- ii. The terminal operators and port management should comply with the 2 days ship turnaround benchmarks operational in global ports in order to reduce the economic cost of delay imposed by vessel operations delay in the Nigerian port sector.
- iii. The significant relationship between delay in vessels operations in Nigerian port sector and shipping operations requires that the number of berthing infrastructure in Nigerian container terminals be increased, in order that more vessels can be discharged at the same time.
- iv. Challenges related to vessel documentation which adds to increasing delay in vessels operations in Nigerian port terminals should be addressed.
- v. Port automation encouraging the use of efficient work information and communication technology systems should be employed in order to improve on vessel turnaround time among others port performance indicators. This a factor in considering port selection by shipowner to serve as a hub port (Abdel-malak, 2017; Abdul and Ahmad, 2017).

### 5.3 Contribution to knowledge

The study made the following contributions to knowledge for the first time:

- (i) Vessel operators in the Nigerian port system incur more port cost and charges for extra days (delay period) spent beyond the 2 days global port sector benchmark. The ship operators experienced annual average of 2.8 days to 14 days delay in vessel operations in the Nigerian port sector from 2007 to 2022.
- (ii) The Nigerian economy lost an average of USD 26935.33 per annum between 2007 and 2022 in the port sector with standard deviation of 11468.24, as result of delay in vessel operations in the container terminals in Tin Can Island port, Apapa port, Rivers port and Onne port.
- (iii) The model equation informs that when the ship traffic calls handled in the terminals increases by 1%, the delay experience in vessel husbandry operations in the port terminals will equally increase by 0.0000023% of its mean value over the period. Similarly, when the GRT of vessel handled in the port terminals increases by 1%, delay in vessel husbandry operations will equally increase by 0.00012% of its mean value while for a 1% increase in the TEU container throughput trade handled in the port terminals, the delay experienced by ship-owners and ship operators in vessel operations in the terminals will increase by 0.0048% of its mean value over the period.
- (iv) The model shows that the means when the cost of delay in vessel operations in Apapa port container terminal is increases by 1%, it leads to about 8.5971% decline in the GRT of vessels handled in the port sector in Nigeria container terminals. Similarly, when the cost of delay in Onne port terminal is increases by 1%, it will lead to a 4.1269% decrease in the GRT of vessels handled in the Nigerian port sector. When the cost of delay in vessel operations in Rivers port is increases by 1%, the GRT of vessels handled in the port sector in Nigeria will increase by 6.0411%. Lastly with a 1% increase in the cost of delay in Tin Can Island port container terminal, the GRT of vessels handled in the port sector in Nigeria increases by 7.0116%.
- (v) The model iforms that means when the cost of delay in vessel operations in Apapa port container terminal increases by 1%, it will lead to about 0.01854% decline in the in-ship calls to Nigerian ports while a 1% increase in delay cost in Onne port will lead to a 0.1527% increase in ship calls to Nigeria. A 1% increase in the cost of delay in vessel operations in Rivers port witnessed a 0.141973% increased ship calls to Nigerian ports while a 1% increase in delay cost in Tin Can Island port will see a 0.038114% increase in ship calls to Nigerian ports over the period.

## References

- Abbas A. & Hala A. (2022). Optimal berth scheduling and sequencing under unexpected events, *Journal of the Operational Research Society*, 73:2, 430-444, <https://doi.org/10.1080/01605682.2020.1843981>
- Abdel-malak, P. (2017). Applying Decision-Making Techniques to Civil Engineering Projects” *Beni-Suef University Journal of Basic and Applied Sciences*, 6 (4), 326-33
- Abdul, R. (2012). Selection of the Most Beneficial Shipping Business Strategy for Containerships” *European Journal of Business and Management*, 4 (17), 153-167
- Abdul, R. and Ahmad N., (2017). Selection of the Most Practical Malaysian Port for Enhancing the Malaysia-China Kuantan Industrial Park Business Trade” *International Journal of Shipping and Transport Logistics*, 9 (4), 500-525
- AFDB (2010). Reforms and the Regulatory Framework of African Ports. Available online @ [https://www.afdb.org/fileadmin/uploads/afdb/Documents/Publications/African%20Development%20Report%202010\\_CH%203.pdf](https://www.afdb.org/fileadmin/uploads/afdb/Documents/Publications/African%20Development%20Report%202010_CH%203.pdf)
- Alamutu, S.A. (2018). Application of Queuing Model to Ease Traveler’s flow in Nigerian International Airports. *IOSR Journal of Business and Management (IOSR-JBM)* 20 (8). 17-28
- Alberto R., Rita G., Francesco L., and Riccardo M., (2010). Designing production and service systems using queuing theory: Principles and application to an airport passenger security screening system. *International Journal of Services and Operations Management* January 2010. 6(2) DOI: <https://doi.org/10.1504/IJSOM.2010.030636>
- Al-Refaie A, Abedalqader H. (2021). Optimal berth allocation under regular and emergent vessel arrivals. *Proceedings of the Institution of Mechanical Engineers, Part M: Journal of Engineering for the Maritime Environment*.;235(2):642-656. Doi: <https://doi.org/10.1177/1475090220937888>

- Amsterdam, W. G and Martínez-Z. I. (2010): Determinants of maritime transport costs – a panel data analysis. *Transportation Planning and Technology*, 33(1):117–136.
- Anas, S. A., Olcer, A. I. & Fabio, B. (2022). Port maritime transport and industry: the immediate impact of COVID-19 and the way forward. 4(1). DOI: <https://dx.10.33175/mtr.2022.250092>
- Aruwei, P., and Eko-Raphaels, Melvin U. (2022). Impact of Port Congestion on Nigeria Economic Growth: An Ardl Approach. *International Journal of Innovative Finance and Economics Research* 10(1):29-35.
- Asabe M. O. (2021). Studied on An Assessment of Factors Causing Port Congestion in Nigeria: A Case of Lagos-Apapa Port. World Maritime University library. [https://commons.wmu.se/cgi/viewcontent.cgi?article=2730&context=all\\_dissertations](https://commons.wmu.se/cgi/viewcontent.cgi?article=2730&context=all_dissertations)
- Asmussen, S. R. (2013). "Queueing Theory at the Markovian Level". *Applied Probability and Queues*. *Stochastic Modelling and Applied Probability*. 51(1), 60–31. DOI: [https://dx.10.1007/0-387-21525-5\\_3](https://dx.10.1007/0-387-21525-5_3). ISBN 978-0-387-00211-8.
- Bozeman, B., & Feeney, M. K. (2011). *Rules and red tape: A prism for public administration theory and research*, Armonk, NY: M.E. Sharpe.
- Branislav, D. and Nam KP (2016). Modeling of ship-Berth-Yard Link Performance and Throuput Optimizatin, IAME 2006 Conference, Melbourne, Australia,
- Brooks, M.R., Knatz G., Pallis A.A. and Wilmsmeier G. (2020). Transparency in Port Governance: Seaport Practices. PortReport No 5. PortEconomics.eu.
- Brouer, B. D., Karsten, C. V., & Pisinger, D. (2017). Optimization in liner shipping. *4 O R*, 15(1), 1-35. DOI: <https://dx.10.1007/s10288-017-0342-6>
- Canonaco, P., Legato, P., and Musmanno, R. (2018). A queuing network model for the management of berth crane operations, *Computers & Operations Research*, 2008, 35, 2432-2446.

- Christian, C. O. & Chuka U. I. (2022). The influence of service quality on customers satisfaction in Port Harcourt port. *Global scientific journal*. 9(7). 34-46
- Chu, C. Y., Huang, W. C., (2012). Aggregates cranes handling capacity of container terminals: the port of Kaohsiung, *Maritime Policy and Management*, 2002, 29(4), 341-350.
- Cullinane, K. and Wang, T.-F. (2017) Devolution, Port Governance and Port Performance. *Research in Transportation Economics*, 17, 517-566. [https://dx.doi.org/10.1016/S0739-8859\(06\)17023-7](https://dx.doi.org/10.1016/S0739-8859(06)17023-7)
- Cullinane, K., Wang, T.F., Song, D.W. Ji, P., (2016). The technical efficiency of container ports: comparing data envelopment analysis and stochastic frontier analysis. *Transportation Research Part A: Policy and Practice* 40(4), 354-374.
- El-Naggar, M. E. (2020). Application of queuing theory to the container terminal at Alexandria seaport. *Journal of Soil Science and Environmental Management*. 1 (4), 77-85. Available online at <http://www.academicjournals.org/JSSEM>
- Emeghara, G. C. and Ndikom, O. B. (2012). Delay Factors Evaluation of Nigerian Seaports (A Case Study of Apapa Ports Complex, Lagos) *Greener Journal of Physical Sciences* ISSN: 2276-7851 Vol. 2 (3), 97-106
- Emeka O. (2016). "Nigeria Ports Concessioning Policy and Legal Implications." Tuesday, 7 Mar. 2006. Retrieved April 4, 2016
- Eromosele A. (2023). NPA's Role in Port Operations. *This Day*, Wednesday, August 16, 2023. Available @ <https://www.thisdaylive.com/index.php/2023/08/11/npas-role-in-port-operations>
- Gautam, Natarajan (2012). *Analysis of Queues: Methods and Applications*. CRC Press. [ISBN 9781439806586](https://doi.org/10.1080/9781439806586).
- Gi, T. Y., Vinh, V. T. & Saeveon, R. (2015). An analysis of port service quality and customer satisfaction: The case of Korean container port. 31(4); 437-447. DOI 10.1016/j.ajsl.2016.01.002

- Gi-Tae, Y, Michael, R. and John, D. (2011). Measuring the competitiveness of container ports: Logisticians' perspective. *European Journal of Marketing* 45(3):455-470. DOI:[10.1108/03090561111107276](https://doi.org/10.1108/03090561111107276)
- Hashemina, H., and Jiang, C. (2017). Strategic Trade-Off between Vessel Delay and Schedule Recovery: An Empirical Analysis of Container Liner Shipping". *Maritime Policy & Management*, 44 (4), 458-473
- Henry, M. (2016). Dock Expansion Outlay Keeps Pace with Demand." *Financial Times* [London, England] 30 Sept. 1980: XXXVII. *Financial Times*. Web. 3 Apr. 2016
- Iaguo L, Xinrui W, Jihong C, (2023). Port congestion under the COVID-19 pandemic: The simulation-based countermeasures, *Computers & Industrial Engineering*. 183(109474), <https://doi.org/10.1016/j.cie.2023.109474>
- Jafari, H. (2013). "Identification and Prioritization of Causes of Halt and Lag in Container Handling Operation". *International Journal of Basic Sciences & Applied Research*, 2(3), 345-353.
- Jafari, H. (2013). "Measuring the Performance of Dry Bulk Cargo Loading and Unloading Operation: Latakia. Case study", *Journal of Business and Management Sciences*, 1 (5), 77-82
- Jovanović, S. Olivella J. & Radmilović, Z. (2015). Ship waiting time in a river port with priority servicing and limited anchorage area, 79(1) 23-45
- Julius, M. and Suzanne (2022). *Queuing Theory Definition, Elements, and Example* <https://www.investopedia.com/terms/q/queuing-theory.asp>
- Kalavaty, S (2017). *Operations research; second edition*, Vikas Publishing house PVT Ltd, New Dephi. India
- Kareem, W.A (2010). *An Assessment of Nigeria's Port Reforms*, The Fronteira Post Economic Policy & Financial Markets, Value Fronteira Limited; Occasional Paper Series, May 27, 2010

- Manitz, M. (2015), "Analysis of assembly/disassembly queueing networks with blocking after service and general service times", *Annals of Operations Research*. 226(1), 417-441.
- McDonald, J. (2013). "Pigou, Knight, Diminishing Returns and Optimal Pigouvian Congestion Tolls." *Journal of the History of Economic Thought*, 35(3): 353-371.
- Merk, O., Busquet, B., Aronietis, R., (2015). *The Impact of Mega Ships*. International Transport Forum/OECD, Paris. 108pp.
- Michael, A. J. and Shaib, A. S. (2012). Initial optimization of end product loading at Obajana Cement Company Plc. *Research Journal in Engineering and Applied Sciences* 1(6) 383-388
- Mogbojuri, O. (2020). ANALYSIS OF THE PERFORMANCE OF CONTAINER TERMINAL OPERATIONS IN TINCAN ISLAND PORT, LAGOS, NIGERIA. *International Journal of Economics, Commerce and Management*. VIII (10) 73-85
- Monday, E. I. Emenike, G. C. and Ibe C. C. (2019) Assessment of Vessel Turnaround Time in Eastern Nigerian Ports. *International Journal of Research and Innovation in Social Science (IJRISS)*, v(vi) p71-74
- Muhammadu, U. (2018). Application of Queueing Theory in Tackling the Problem of Port Congestion at Apapa Port, Lagos, Nigeria. Available at <https://kubanni-backend.abu.edu.ng/server/api/core/bitstreams/840e9c11-e207-40b7-ab60-8427ba96e550/content>
- Ndikom, O.B.C. (2011). A critical assessment of delay factors and effects on productivity in Nigerian Ports Authority: a case study of rivers ports complex", *greener Journal of business and management studies*, 3 (2), 78-90
- Ndikom, O.B.C. (2018). *Maritime transport management and administration in Nigeria*. Lagos: bunmico publishers, isbn: 9784890526 (2008), 89

- Nikghadam, S., Molkenboer, K.F., Tavasszy, L. (2021). Information sharing to mitigate delays in port: the case of the Port of Rotterdam. *Marit Econ Logist* **25**, 576–601 (2023). <https://doi.org/10.1057/s41278-021-00203-9>
- Noorul S., Fitri A. R., Mohammad K. O., Izzat A. S., Aminuddin M. A., Alisha I., (2019). Evaluation of Delay Factors on Dry Bulk Cargo Operation in Malaysia: A Case Study of Kemaman Port. *The Asian Journal of Shipping and Logistics*, 35(3), 127-137. <https://doi.org/10.1016/j.ajsl.2019.09.001>.
- Nwachukwu, T.C. Akpudo, C.U. Enyinda, C.A. Stephens, M.S. (2023) Queue Modeling Simulation for Vessel Traffic in Nigeria Sea Ports. 10(2) 27-32,
- Nwokedi T.C., Emeghara G.C., Ikeogu C. (2015), Trend Analysis of Impacts of Cargo Pilferage Risk on Post Concession Cargo Throughput Performance of Nigerian Seaport Terminals. *International Journal of Research Commercial and Management*. 5 (7): 11-15.
- Nze, I, C. and Onyemечи, C (2018) Port congestion determinants and impacts on logistics and supply chain network of five African ports. *Journal of sustainable development in transport and logistics* 3(1) 2018. DOI: 10.14254/jsdtl.2018.3-1.7
- Onwumere, (2018). Handout on Maritime Transport, Operations and Management, Certified Institute of Shipping, Lagos.
- Osuji, J. N., Nwokedi, T. C., Mbachu J C, Nwachukwu J. O (2022). Ship Turnaround Time and Vessel Traffic in Nigerian Ports: A Correlation Analysis. *European Journal of Maritime research*. 1(1), 19-24
- Onwuegbuchunam D. E. (2018). Assessing Port Governance, Devolution and Terminal Performance in Nigeria. *Logistics* 2018, 2(1),6. Available @ <https://doi.org/10.3390/logistics2010006>. <https://www.mdpi.com/2305-6290/2/1/6>
- Othman, B. J., Al-Kake, F., Diah, M. L. M., Othman, B., & Hasan, N. M. (2019). This study examines the antecedents and the effects of knowledge management and information

technology in the manufacturing industry. *International Journal of Psychosocial Rehabilitation*, 23(02).

Oyatoye E.O., Okoye J. C, Amole B. B. (2011). Application of Queueing theory to port congestion problem in Nigeria. 2(7) 24-36

Oyatoye, E., Adebisi, S., and Okoye, J. (2011). Application of queueing theory to port congestion problem in Nigeria. *European Journal of Business and Management*, 3(8), 24-38.

Pallis A. A. and Syriopoulos, T. (2017). Port Governance Models: A Financial Evaluation of Greek Port Restructuring. *Transport Policy*, 14(2), 232-246.

Paul, B. & Coatas P. (2024). Importers Face Surging Shipping Costs, Delays as Red Sea Diversions Pile Up. *The wall street journal*. Available online @ <https://www.wsj.com/articles/importers-face-surging-shipping-costs-delays-as-red-sea-diversions-pile-up-7638ed64>

Qiao, L & Chris Bachmann, (2020). "Assessing the role of port efficiency as a determinant of maritime transport costs: evidence from Canada," *Maritime Economics & Logistics*, Palgrave Macmillan; International Association of Maritime Economists (IAME), 22(4), 562-584.

Roy, D., Gupta, A. and de Koster, R. (2016), "A non-linear traffic flow-based queuing model to estimate container terminal throughput with AGVs", *International Journal of Production Research*. 54(2) 1-21.

Sandro, S. and Carlos, M. F. (2019). The Concept of Bureaucracy by Max Weber. *International Journal of Social Science Studies*. 7(2). 12-18. <https://doi.org/10.11114/ijsss.v7i2.3979>

Sanijb. A and Biswa S.K (2011). Analysis of container Handling system of Chittagong Port. *Mgt Science*. 34 (5), 124-129

- Serdjo, K. (2017) Queueing System in Optimization Function of Port's Bulk Unloading Terminal. *Promet-Traffic & Transportation* · November 2007. DOI: 10.7307/pttv19i2.936. Available at <https://www.researchgate.net/publication/236667748>
- Shanmugasundaram, S and Venkatesh B. B, (2015). Fuzzy Multi Server Queueing Model through DSW algorithm, *International Journal of Latest Trends in Engineering and Technology* 5(3),452-457
- Sharma, J.K. (2018). *Operations Research; Theory and Applications*, third edition, Macmillan Indian Ltd, Indian
- Shehu, Z., Intan R. Endut, Akintola Akintoye (2014). Factors contributing to project time and hence cost overrun in the Malaysian construction industry. *Journal of Financial Management of Property and Construction*. 19(1). Available online @<https://www.emerald.com/insight/content/doi/10.1108/JFMPC-04-2013-0009/full/html>
- Sinay, R. (2021) Port Efficiency and Vessel Turnaround Time. Available online @<https://sinay.ai/en/port-efficiency-and-vessel-turnaround-time/>
- Sirous, Z., Said M., Mehrdad G. (2017). Introducing a Method for More Precise Prediction of Berth Occupancy Ratio in Bulk Liquid Terminals. *International Journal of Coastal & Offshore Engineering, IJCOE* 2(2), 21-26
- Slack, B., Comtois, C., Wiegman, B., Witte, P.A., (2018). Ships Time in Port. *International Journal of Shipping and Transport Logistics*, 10(1), 45-62.
- Srinivasan, R, (2014), Fuzzy Queueing Model using DSW algorithm, *International Journal of Advanced research in Mathematics and Application*.1(1), 57-62.
- Statista Research Department, (2023). Median time spent in port by container ships worldwide in 2021. *Transportation & Logistics*. Available online @ <https://www.statista.com/statistics/1101596/port-turnaround-times-by-country>

- Taha, H.A. (2017). Operations Research, an Introduction, 8th ed.; Prentice Hall, Inc: Upper Saddle River, NJ, USA, 2017.
- Teknomo, K. (2014) Queuing Theory Tutorial <http://people.revoledu.com/kardi/tutorial/Queuing/>
- Theo N., Athanasios P. and Jean-Paul R. (2022). Port Economics, Management and Policy, New York: Routledge, Chp3. ISBN 9780367331559.
- Timothy, J. Coelli D. S., Prasada Rao, Christopher J, O'Donnell, George e. Battese (2015). An Introduction to Efficiency and Productivity Analysis. Springerlink journals 12(05), 24. Available online @ <https://link.springer.com/book/10.1007/b136381>
- Tom, K (2019). Reoccurrence of congestion in Nigeria ports, Port News, 15(6), 2-10
- Ugboma, C. Ibe, I.C. and Ogwude (2014). Service Quality Measurements in Developing Economy: Nigerian Port Survey". Managing Service Quality, 14 (16), 487-495
- Ulusçu, Ö.S. and Altiok, T. (2013), "Waiting time approximation in multi-class queuing systems with multiple types of class-dependent interruptions", Annals of Operations Research, 202(1), 185-195.
- Ulusçu, Ö.S. and Altiok, T. (2019), "Waiting time approximation in single-class queuing systems with multiple types of interruptions: modeling congestion at waterways entrances", Annals of Operations Research. 172(1), 291-313.
- Umoh, G. T. (2019). Port Reforms and Concession: A Study of Apapa And Tin Can Island Seaports. Aksu Journal of Administration and Corporate Governance. 10(12). 43-54
- UNCTAD, (2021). Review of Maritime Transport 2021. Available online @ <https://unctad.org/publication/review-maritime-transport-2021>
- Usman, G. (2015). Consequences of Port Congestion on Logistics and Supply Chain in African Ports. Developing Country Studies 5(6), 23-32. Available @ <http://www.iiste.org>

- Van, D. and George K. (2015) Assessment of Port Efficiency in West Africa Using Data Envelopment Analysis. *American Journal of Industrial and Business Management* 05 (04) (2015),10 [10.4236/ajibm.2015.54023](https://doi.org/10.4236/ajibm.2015.54023)
- Victor, *et al.*, (2016). Analysis of Cargo Handling Operations in Apapa and Tinian Island Ports". *Academia Journal of Scientific Research*, 4 (6), 159-165
- Vukić, L., Lai, K. H. (2022). Acute port congestion and emissions exceedances as an impact of COVID-19 outcome: the case of San Pedro Bay ports. *Journal of shipping and trade*. 7(25). 34-42. <https://doi.org/10.1186/s41072-022-00126-5>
- Yavuz, B. Türkoğulları <sup>a</sup>, Z. Caner Taşkın <sup>b</sup>, Necati A <sup>b</sup>, İ. Kuban Altinel (2014). Optimal berth allocation and time-invariant quay crane assignment in container terminals, Volume 235, Issue 1. 88-101
- Wang, T. Cullinane K. Dong-Wook S (2015). Container Port Production and Economic Efficiency. Publisher: Palgrave-Macmillan September 2005. ISBN: 978-1-4039-4772-7. DOI: <https://dx.10.1057/9780230505971>
- Wayne, K. Talley (2016). Port Performance: An Economics Perspective. *Research in Transportation Economics* 17(1):499-516. Published December 2006. DOI: [https://dx.10.1016/S0739-8859\(06\)17022-5](https://dx.10.1016/S0739-8859(06)17022-5)
- Wouter, J. and Theo N., (2010). "[A theory on the co-evolution of seaports with application to container terminal development in the Rhine-Scheldt Delta,](#)" *Papers in Evolutionary Economic Geography (PEEG)* 1003, Utrecht University, Department of Human Geography and Spatial Planning, Group Economic Geography, revised Feb 2010.
- Willem, V. E. (2020). Vessel delays at port. Available @ <https://port-xchange.com/blog/the-cause-and-costs-of-vessels-being-delayed-at-port/>
- Wilmsmeier, G and Hoffmann J (2018): Liner shipping connectivity and port infrastructure as determinants of freight rates in the Caribbean. *Maritime Economics and Logistics*. 10(1):130–151.

- Wilmsmeier, G. Jan Hoffmann and Ricardo J. Sanchez (2016): The Impact of Port Characteristics on International Maritime Transport Costs. *Research in Transportation Economics* 16(1):117-140. DOI: [https://dx.10.1016/S0739-8859\(06\)16006-0](https://dx.10.1016/S0739-8859(06)16006-0)
- Wilmsmeier, Gordon and Martínez-Zarzoso, Inmaculada (2019). Determinants of maritime transport costs – a panel data analysis for Latin American trade. *Taylor and Francis Journal of Transportation Planning and Technology*, 1 (33), 105-121 <https://doi.org/10.1080/03081060903429447>
- Yaakob, O. and Chau Q.P. (2015). Weather Downtime and its Effect on Fishing Operation in Peninsular Malaysia”. *Jurnal Teknologi*, 42 (A). 13-26
- Yusuf, N. B., Shekwobagwu P. G., Abdulmalik M. M. and Damana A (2022). Assessment of Factors Causing Congestion and Nature of Cargo Clearance in Apapa Port, Lagos, Nigeria. *Lapai International Journal of Management and Social Sciences*. 14(1), 121-131
- Zdenka, Z. and Edna M. (2021). Modelling of Port Container Terminal Using the Queuing Theory. Available Online @ [https://www.bib.irb.hr/293924/download/293924.modelling\\_container-trieste.doc](https://www.bib.irb.hr/293924/download/293924.modelling_container-trieste.doc)
- Zetterquist, U.E, Mullern, T. and Styhre, A. (2011). *Organizational theory. A practice Based Approach*. Oxford University press. USA ISBN 978-0-19-956930-4. 243
- Ziaul H. M. and Hans-Joachim S. (2018). the impacts of port infrastructure and logistics performance on economic growth: the mediating role of seaborne trade. *Journal of Shipping and Trade* 3(1). <https://jshippingandtrade.springeropen.com/articles/10.1186/s41072-018-0027-0>

## **APPENDIX**

Federal University of Technology Owerri (FUTO),  
Imo State,  
Dept. of Maritime Management Technology,  
21<sup>st</sup> August, 2023.

The Port Manager,  
Nigerian Ports Authority (NPA),  
Onne, Rivers State.

Sir,

### **REQUEST FOR DATA COLLECTION**

I am a PhD research student of the above-named university in the Department of Maritime Management Technology.

I am researching on the topic “Evaluation of cost of delays on vessel operations in container terminal in Nigerian ports”. Therefore, I request your assistance to access relevant materials and collect data to achieve the objectives of the study.

May I, assure you that all information collected shall be used for this purpose alone. The data required is included here below:

Thank you in anticipation for your cooperation.

Yours faithfully,



Nwolozi, Chinyeaka Nwokodi

<b>Table1: Container Ship traffic volume</b>					
<b>S/N</b>	<b>Year</b>	<b>Tin Can Island</b>	<b>Apapa</b>	<b>Rivers</b>	<b>Onne</b>
1	2007	1185	1359	455	407
2	2008	1367	1452	481	417
3	2009	1583	1545	459	435
4	2010	1666	1556	482	414
5	2011	1628	1594	584	855
6	2012	1508	1445	499	859
7	2013	1615	1510	439	823
8	2014	1692	1503	435	418
9	2015	1656	1410	373	339
10	2016	1559	1194	319	291
11	2017	1307	1154	309	276
12	2018	1101	1105	314	662
13	2019	1198	1034	321	722
14	2020	1180	1345	329	695
15	2021	1229	1465	345	721
16	2022	1230	1554	356	732

Source: NPA Annual Report (2007-2022)

<b>Table2: Vessel GRT</b>					
<b>S/N</b>	<b>Years</b>	<b>Tin Can Island</b>	<b>Apapa</b>	<b>Port Harcourt</b>	<b>Onne</b>
1	2007	30502604	3325168	6839182	4806012
2	2008	34556886	3463642	6952371	4839572
3	2009	39076852	3109638	62387526	5396277
4	2010	3976893	3098532	7186531	5353788
5	2011	32702604	32869251	8289093	4273545
6	2012	32636886	32072798	7210520	4291026
7	2013	40096754	34189172	6207092	3861299
8	2014	47231548	37041879	6761057	8926192
9	2015	45864565	36290502	5423002	7296978
10	2016	45229402	33612421	4951913	7564109
11	2017	40694756	31614347	5405540	7396251
12	2018	4205685	3021634	4927297	3674827
13	2019	4658031	3207361	5061662	4372567
14	2020	4380642	3710732	5725902	4747214
15	2021	4907524	3509372	6490843	3870523
16	2022	4958326	3401578	6405437	4362186

Source: NPA Annual Report (2007-2022)

<b>Table4: Container ship vacancy rate (%)</b>					
<b>S/N</b>	<b>Years</b>	<b>Tin Can Island</b>	<b>Apapa</b>	<b>Rivers</b>	<b>Onne</b>
1	2007	14.00	39.79	45.78	29
2	2008	39.00	35.81	44.14	66
3	2009	28.00	37.63	34.42	65
4	2010	27.00	31.78	39.69	65
5	2011	31.00	35.86	34.75	68.39
6	2012	30.09	34.75	31.09	68.91
7	2013	34.10	43.14	48.0	73.3
8	2014	28.73	42.42	27.57	55.75
9	2015	45.90	30.30	44.30	63.90
10	2016	53.60	44.50	58.30	71.50
11	2017	56.08	44.24	62.33	81.60
12	2018	57.00	45.50	56.88	78.95
13	2019	49.00	45.80	48.59	75.76
14	2020	50.00	43.65	36.70	75.64
15	2021	39.00	34.55	27.62	73.25
16	2022	36.00	31.68	38.88	72.84

Source: NPA Annual Report (2007-2022)

<b>Table3: Container ship berth occupancy rate (%)</b>					
<b>S/N</b>	<b>Year</b>	<b>Tin Can Island</b>	<b>Apapa</b>	<b>Port Harcourt</b>	<b>Onne</b>
1	2007	86.00	60.21	54.22	71
2	2008	61.00	64.19	55.86	34
3	2009	72.00	62.37	65.58	35
4	2010	73.00	68.22	60.31	35
5	2011	69.00	64.14	65.25	31.61
6	2012	69.91	65.25	68.91	31.09
7	2013	65.90	56.90	52.0	26.7
8	2014	71.27	57.58	72.43	44.25
9	2015	54.10	69.70	55.70	36.10
10	2016	46.40	55.50	41.80	28.50
11	2017	43.92	55.76	37.67	18.40
12	2018	43.00	55.10	43.12	21.05
13	2019	51.00	54.20	51.41	24.24
14	2020	50.00	56.35	63.3	24.36
15	2021	61.00	65.42	72.38	26.65
16	2022	64.00	68.32	61.12	27.16

Source: NPA Annual Report (2007-2022)

<b>Table5: Container throughput inward/outward (TEUS)</b>					
<b>S/N</b>	<b>Years</b>	<b>Tin Can Island</b>	<b>Apapa</b>	<b>Port Harcourt</b>	<b>Onne</b>
1	2007	256,963	367382	102	327836
2	2008	416,479	426573	28	364984
3	2009	543,819	372963	52	557382
4	2010	573,615	468258	117	641378
5	2011	709,880	392738	79	472863
6	2012	452215	327626	115	966834
7	2013	508774	369052	19	111553
8	2014	515898	418002	11	133863
9	2015	761178	579828	225	226031
10	2016	383212	328244	4128	94830
11	2017	774878	494067	3272	27204
12	2018	813700	496276	2046	30265
13	2019	845,157	510863	8109	28698
14	2020	722294	520848	2918	117402
15	2021	723371	498264	3072	103765
16	2022	713441	506392	2701	120070

Source: NPA Annual Report (2007-2022)

<b>Table 6: Turnaround time (days)</b>					
<b>S/N</b>	<b>Years</b>	<b>Tin Can Island</b>	<b>APAPA</b>	<b>Rivers</b>	<b>Onne</b>
1	2007	3.77	8.70	9.99	1.80
2	2008	7.00	9.60	11.71	2.80
3	2009	6.60	9.50	8.02	3.42
4	2010	5.07	10.15	10.55	4.84
5	2011	4.97	7.59	9.75	2.85
6	2012	5.04	7.96	8.71	2.50
7	2013	4.46	5.31	7.70	2.42
8	2014	3.95	3.91	9.58	2.71
9	2015	4.13	3.80	9.00	2.6
10	2016	3.51	4.70	6.40	2.40
11	2017	3.99	5.10	6.80	2.5
12	2018	4.12	4.70	5.34	2.76
13	2019	5.12	5.59	6.14	2.70
14	2020	5.13	3.70	9.6	3.06
15	2021	5.45	5.65	10.2	3.00
16	2022	4.59	5.75	10.7	2.65

Source: NPA Annual Report (2007-2022)

Source: NPA Annual Report (2007-2022)

<b>Table7: Container tonnage (inward/outward)</b>					
<b>S/N</b>	<b>Years</b>	<b>Tin Can Island</b>	<b>Apapa</b>	<b>Port Harcourt</b>	<b>Onne</b>
1	2007	3,660,616	345841	1498	2482177
2	2008	4,524,101	237845	2729	18866257
3	2009	4,425,833	372401	1204	3385455
4	2010	4,853,529	402374	2056	2921727
5	2011	5,745,702	402554	1378	3309815
6	2012	5,973743	3384711	1045	1542554
7	2013	6609603	3651384	1990	1758942
8	2014	6629753	4167351	1256	2037777
9	2015	6171256	3782741	2718	1718335
10	2016	5083760	4463559	73936	1584240
11	2017	5746325	5154042	42356	1759572
12	2018	6,240,828	5047260	387448	2660914
13	2019	5,904,054	4825010	133602	2753002
14	2020	5,512,221	5327033	193373	2767953
15	2021	6,699,277	3348634	5342039	2264920
16	2022	6,243,821	4208316	5148751	2217031

Table8: NIGERIAN PORTS AUTHORITY TARIFF: DUES & RATES REGULATIONS

S/N	Questions	Tin Can	Apapa	Port Harcourt	Onne
1	No of Container berths	13	20	8	7
2	Tug Charge (201-250 LOA)	USD 2500	USD 2500	USD 2500	USD 2500
3	Berths Rent (2days)	USD2.00/LOA	USD2.00/LOA	USD2.00 /LOA	USD2.00/LOA
4	Berthing/Mooring	USD 1176	USD1176	USD1176	USD1176
5	Pilotage rate	USD 0.112	USD 0.112	USD 0.240	USD 0.240

Source: NIGERIAN PORTS AUTHORITY TARIFF: DUES & RATES REGULATIONS (2021)

Table9: NPA THIRD PARTY TOWAGE FIND RATE AS APPLICABLE BELOW (In & Out)		
LOA OF VESSEL	RATE (USD)	UNIT OF MEASUREMENT
1 – 200 LOA	USD 2000	Per Tug/Movement
201 – 250 LOA	USD 2500	Per Tug/Movement
251 – 300 LOA	USD 3500	Per Tug/Movement
Above 300 LOA	USD 5000	Per Tug/Movement

Source: NIGERIAN PORTS AUTHORITY TARIFF: DUES & RATES REGULATIONS (2021)

Table10: BERTH RENT TO Be Provisionally Charged at the Rate of USD 2.00 x LOA x Number of Days			
TYPE OF VESSEL	RATE (USD)	UNIT OF MEASUREMENT	NUMBER OF DAYS
Container and RORO	USD2.00	LOA	2
Vessels Combo Vessels	USD2.00	LOA	3
Liquid Bulk Cargo	USD2.00	LOA	4
Vessels	USD2.00	LOA	8
Dry Bulk Cargo Vessels	USD2.00	LOA	10
General Cargo Vessels			

Source: NIGERIAN PORTS AUTHORITY TARIFF: DUES & RATES REGULATIONS (2021)

Table11: NPA Pilotage Charges			
PILOTAGE DISTRICT	PILOTAGE DUE (USD)	FOOTAGE DUE (USD)	PILOTAGE SERVICE (USD)
LAGOS PILOTAGE (Apapa, TinCan)	0.070	0.042	0.112
BONNY PORTHARCOURT PILOTAGE (Rivers, Onne)	0.150	0.090	0.240
WARRI PILOTAGE	0.138	0.082	0.220
CALABAR PILOTAGE	0.138	0.082	0.220

**Table12:** Expression of Cost of vessel terminal operations using NPA provision data

S/ N	Tin Can Island	Apapa	Rivers	Onne
1	(250+2+1176+0.112)1185	(250+2+1176+0.112)1359	(250+2+1176+0.240)455	(250+2+1176+0.240)407
2	(250+2+1176+0.112)1367	(250+2+1176+0.112)1452	(250+2+1176+0.240)481	(250+2+1176+0.240)417
3	(250+2+1176+0.112)1583	(250+2+1176+0.112)1545	(250+2+1176+0.240)459	(250+2+1176+0.240)435
4	(250+2+1176+0.112)1666	(250+2+1176+0.112)1556	(250+2+1176+0.240)482	(250+2+1176+0.240)414
5	(250+2+1176+0.112)1628	(250+2+1176+0.112)1594	(250+2+1176+0.240)584	(250+2+1176+0.240)855
6	(250+2+1176+0.112)1508	(250+2+1176+0.112)1445	(250+2+1176+0.240)499	(250+2+1176+0.240)859
7	(250+2+1176+0.112)1615	(250+2+1176+0.112)1510	(250+2+1176+0.240)439	(250+2+1176+0.240)823
8	(250+2+1176+0.112)1692	(250+2+1176+0.112)1503	(250+2+1176+0.240)435	(250+2+1176+0.240)418
9	(250+2+1176+0.112)1656	(250+2+1176+0.112)1410	(250+2+1176+0.240)373	(250+2+1176+0.240)339
10	(250+2+1176+0.112)1559	(250+2+1176+0.112)1194	(250+2+1176+0.240)319	(250+2+1176+0.240)291
11	(250+2+1176+0.112)1307	(250+2+1176+0.112)1154	(250+2+1176+0.240)309	(250+2+1176+0.240)276
12	(250+2+1176+0.112)1101	(250+2+1176+0.112)1105	(250+2+1176+0.240)314	(250+2+1176+0.240)662
13	(250+2+1176+0.112)1198	(250+2+1176+0.112)1034	(250+2+1176+0.240)321	(250+2+1176+0.240)722
14	(250+2+1176+0.112)1180	(250+2+1176+0.112)1345	(250+2+1176+0.240)329	(250+2+1176+0.240)695
15	(250+2+1176+0.112)1229	(250+2+1176+0.112)1465	(250+2+1176+0.240)345	(250+2+1176+0.240)721
16	(250+2+1176+0.112)1230	(250+2+1176+0.112)1554	(250+2+1176+0.240)356	(250+2+1176+0.240)732

Source: NIGERIAN PORTS AUTHORITY TARIFF: DUES &amp; RATES REGULATIONS (2021)

<b>Table13: Expression of Cost of terminal operations using NPA provision data</b>				
<b>S/N</b>	<b>Tin Can Island (\$)</b>	<b>Apapa (\$)</b>	<b>Rivers (\$)</b>	<b>Onne (\$)</b>
1	78039360	89498304	64209600	57435840
2	90025152	95622912	67878720	58847040
3	104250048	101747520	64774080	61387200
4	109716096	102471936	68019840	58423680
5	107213568	104974464	82414080	120657600
6	99310848	95161920	70418880	121222080
7	106357440	99442560	61951680	116141760
8	111428352	98981568	61387200	58988160
9	109057536	92856960	52637760	47839680
10	102669504	78632064	45017280	41065920
11	86073792	75997824	43606080	38949120
12	72507456	72770880	44311680	93421440
13	78895488	68095104	45299520	101888640
14	77710080	88576320	46428480	98078400
15	80937024	96479040	48686400	101747520
16	81002880	102340224	50238720	103299840

**Source:** Computed by Researcher from Nigerian Ports Authority Tariff: Dues & Rates Regulations (2021) and Annual Report (2007-2022)

S/N	Tin Can Island	Apapa	Rivers	Onne
1	1.77*2.00*1185	6.7*2.00*1359	7.99*2.00*455	0*2.00*407
2	5*2.00*1367	7.6*2.00*1452	9.71*2.00*481	0.8*2.00*417
3	4.6*2.00*1583	7.5*2.00*1545	6.02*2.00*459	1.42*2.00*435
4	3.07*2.00*1666	8.15*2.00*1556	8.55*2.00*482	2.84*2.00*414
5	2.97*2.00*1628	5.59*2.00*1594	7.75*2.00*584	0.85*2.00*855
6	3.04*2.00*1508	5.96*2.00*1445	6.71*2.00*499	0.5*2.00*859
7	2.46*2.00*1615	3.31*2.00*1510	5.7*2.00*439	0.42*2.00*823
8	1.95*2.00*1692	1.91*2.00*1503	7.58*2.00*435	0.71*2.00*418
9	2.13*2.00*1656	1.8*2.00*1410	7.00*2.00*373	0.6*2.00*339
10	1.51*2.00*1559	2.7*2.00*1194	4.4*2.00*319	0.4*2.00*291
11	1.99*2.00*1307	3.1*2.00*1154	4.8*2.00*309	0.5*2.00*276
12	2.12*2.00*1101	2.7*2.00*1105	3.34*2.00*314	0.76*2.00*662
13	3.12*2.00*1198	3.59*2.00*1034	4.14*2.00*321	0.7*2.00*722
14	3.13*2.00*1180	1.7*2.00*1345	7.6*2.00*329	1.06*2.00*695
15	3.45*2.00*1229	3.65*2.00*1465	8.2*2.00*345	1.00*2.00*721
16	2.59*2.00*1230	3.75*2.00*1554	8.7*2.00*356	0.65*2.00*732

**Source:** Computed by Researcher from Nigerian Ports Authority Tariff: Dues & Rates Regulations (2021) and Annual Report (2007-2022)

<b>Table:15:</b> Expression of Cost of Cost delay at container terminal using NPA provision data				
<b>S/N</b>	<b>Tin Can Island (\$)</b>	<b>Apapa (\$)</b>	<b>Rivers (\$)</b>	<b>Onne (\$)</b>
1	4194.9	18210.6	7270.9	0
2	13670	22070.4	9341.0	667.2
3	14563.6	23175	5526.4	1235.4
4	10229.2	25362.8	8242.2	2351.5
5	9670.3	17820.9	9052	1453.5
6	9168.6	17224.4	6696.6	859
7	7945.8	9996.2	5004.6	691.3
8	6598.8	5741.5	6594.6	593.6
9	7054.6	5076	5222	406.8
10	4708.2	6447.6	2807.2	232.8
11	5201.9	7154.8	2966.4	276
12	4668.2	5967	2097.5	1006.2
13	7475.5	7424.1	2657.9	1010.8
14	7386.8	4573	5000.8	1473.4
15	8480.1	10694.5	5658	1442
16	6371.4	11655	6194.4	951.6

**Source:** Computed by Researcher Computed by Researcher from Nigerian Ports Authority Tariff: Dues & Rates Regulations (2021) and Annual Report (2007-2022)

Relationship between Delay in vessel  
operations and port operations  
SUMMARY OUTPUT

<i>Regression Statistics</i>	
Multiple R	0.839527
R Square	0.7046901
Adjusted R Square	0.433626
Standard Error	3.319571
Observations	16

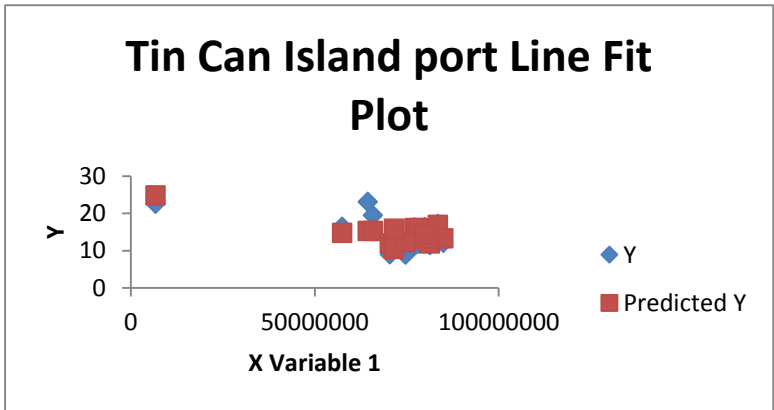
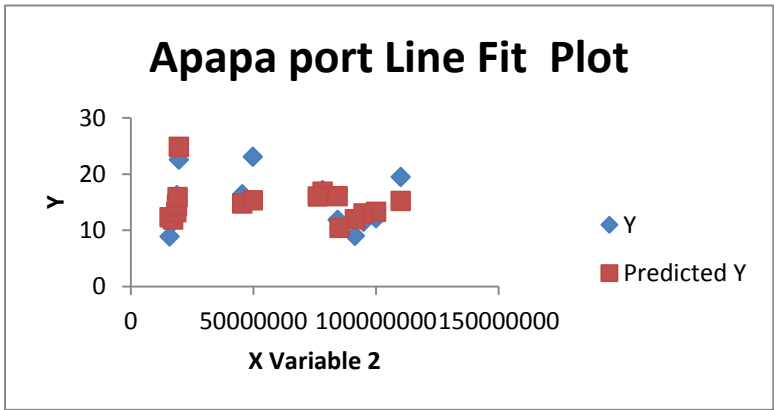
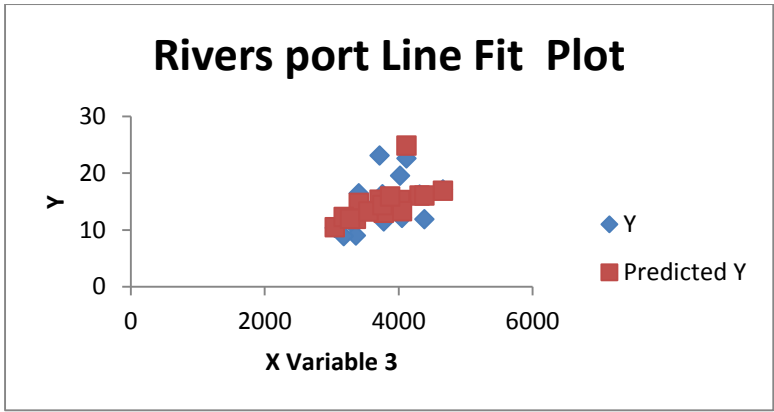
ANOVA

	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>Significance F</i>
Regression	3	159.6102	53.20341	4.828091	0.019826
Residual	12	132.2347	11.01955		
Total	15	291.8449			

	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>	<i>Lower 95%</i>	<i>Upper 95%</i>
Intercept	6.412233	8.124583	0.789238	0.445287	11.2897	24.11418
X Variable 1	1.2E-07	4.81E-08	2.49229	0.028313	2.2E-07	1.5E-08
X Variable 2	2.3E-08	2.65E-08	0.85895	0.407199	.1E-08	3.5E-08
X Variable 3	0.004786	0.001972	2.427597	0.031872	0.000491	0.009082

RESIDUAL OUTPUT

<i>Observation</i>	<i>Predicted Y</i>	<i>Residuals</i>
1	14.78204	1.677958
2	15.34384	7.766158
3	15.26424	4.275762
4	24.86604	-2.25604
5	16.92637	0.233632
6	16.05922	0.150777
7	16.0948	-4.2048
8	13.31633	-1.16633
9	13.04755	-1.51755
10	11.98403	-2.97403
11	10.46862	-0.07862
12	12.3208	-3.4008
13	11.94209	-0.39209
14	13.27722	0.212778
15	14.39155	1.908448
16	15.92524	-0.23524



## Effects of Delay Cost on Container throughput trade in Ports

### SUMMARY OUTPUT

<i>Regression Statistics</i>	
Multiple R	0.764598
R Square	0.584581
Adjusted R Square	0.305181
Standard Error	367496.6
Observations	16

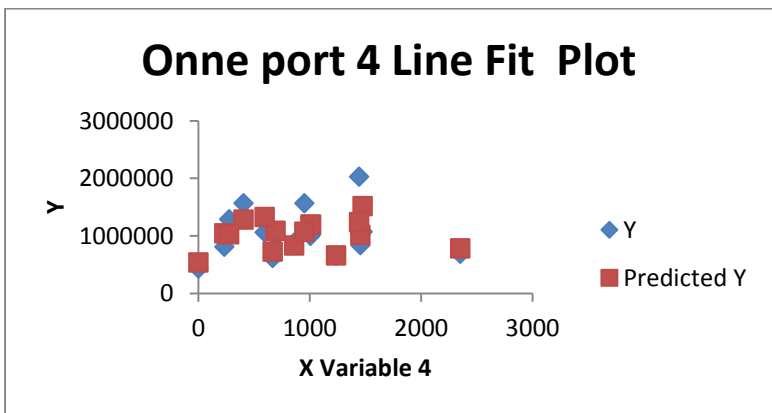
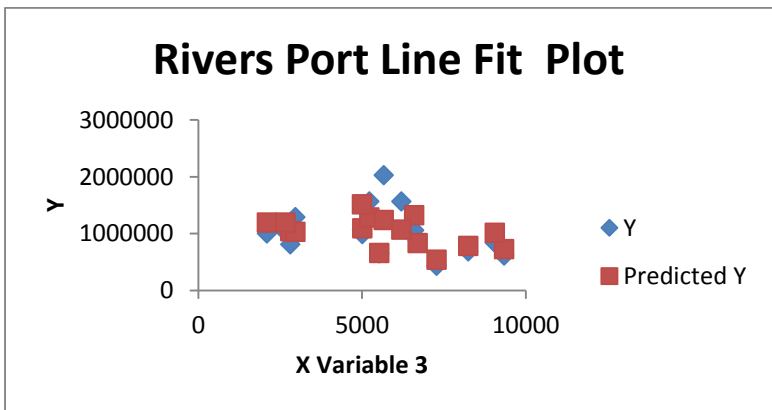
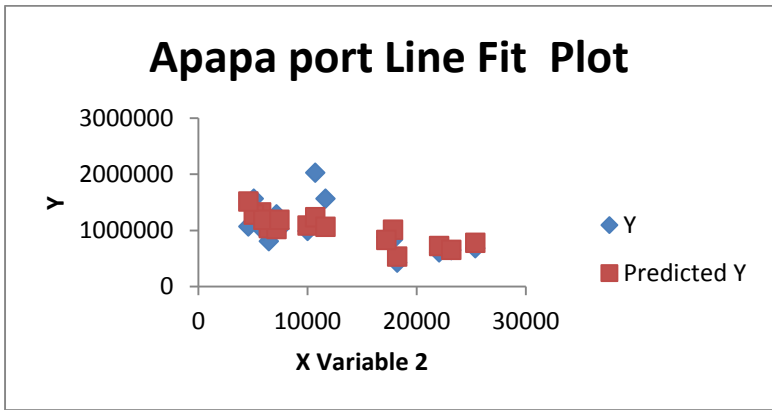
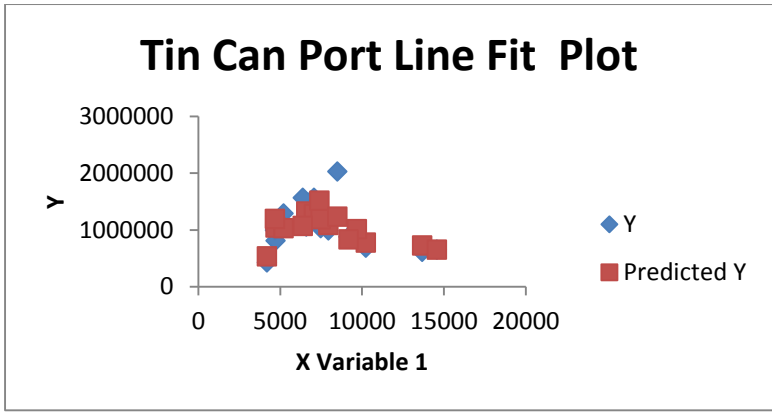
### ANOVA

	<i>Df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>Significance F</i>
Residual	11	1.49E+12	1.35E+11		
Total	15	2.55E+12			

	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>	<i>Lower 95%</i>	<i>Upper 95%</i>
Intercept	1139580	313991.9	3.629329	0.003961	448488.4	1830671
Tin Can	19.05607	47.27584	0.403083	0.694611	-84.9974	123.1095
Apapa	-52.0592	22.89472	-2.27385	0.044009	-102.45	-1.66824
Rivers	36.70338	61.83162	0.593602	0.564785	-99.3871	172.7939
Onne	197.4892	183	1.079176	0.303604	-205.291	600.2696

### RESIDUAL OUTPUT

<i>Observation</i>	<i>Predicted Y</i>	<i>Residuals</i>
1	538356.1	-106406
2	725720.8	-112739
3	657449.4	-3865.39
4	781054.5	-95117.5
5	1015406	-175429
6	833040.5	47556.49
7	1090812	-98145.8
8	1325703	-265243
9	1281764	286133.9
10	1042652	-231922
11	1029619	259957.4
12	1193599	-192632
13	1192717	-160464
14	1516804	-442997
15	1236878	792945.3
16	1069530	498367.7



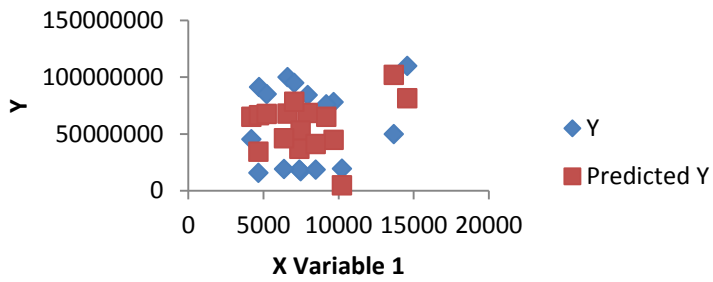
Effects of delay cost on ship calls to the container terminals in Nigeria

<i>Regression Statistics</i>						
Multiple R		0.644546				
R Square		0.41544				
Adjusted R Square		0.202872				
Standard Error		31641468				
Observations		16				
<i>ANOVA</i>						
	<i>Df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>Significance F</i>	
Regression	4	7.83E+15	1.96E+15	3.95439	0.017143	
Residual	11	1.1E+16	1E+15			
Total	15	1.88E+16				
	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>	<i>Lower 95%</i>	<i>Upper 95%</i>
Intercept	46984714	27034713	1.73794	0.110097	-1.3E+07	1.06E+08
Tin Can	7011.603	4070.452	1.722561	0.112927	-1947.4	15970.61
Apapa	-857.915	1971.236	-0.43522	0.671821	-5196.58	3480.745
Rivers	604.1185	5323.705	0.113477	0.911697	-11113.3	12321.51
Onne	-41269.2	15756.31	-2.61922	0.023862	-75948.6	-6589.76

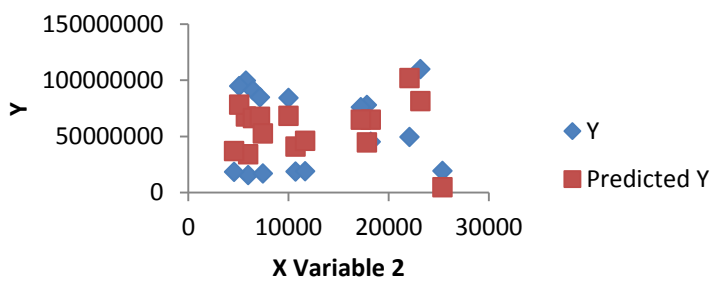
RESIDUAL OUTPUT

<i>Observation</i>	<i>Predicted Y</i>	<i>Residuals</i>
1	65167020	-2E+07
2	1.02E+08	-5.2E+07
3	81571383	28428617
4	4883491	14732253
5	44983945	33150548
6	65089549	11121681
7	68615615	15738702
8	67813704	32146972
9	78460403	16414644
10	66553669	24804176
11	67721928	17388966
12	34339203	-1.9E+07
13	52921519	-3.6E+07
14	37069865	-1.9E+07
15	41176800	-2.2E+07
16	46129853	-2.7E+07

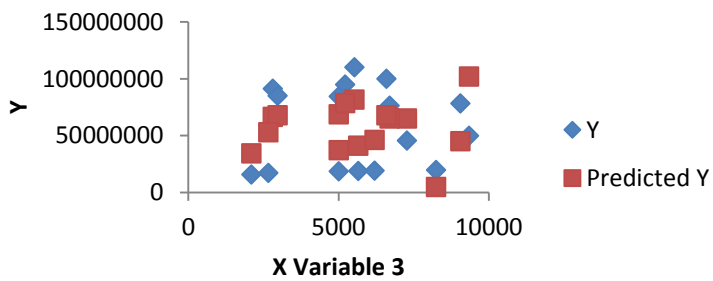
### Tin Can port 1 Line Fit Plot



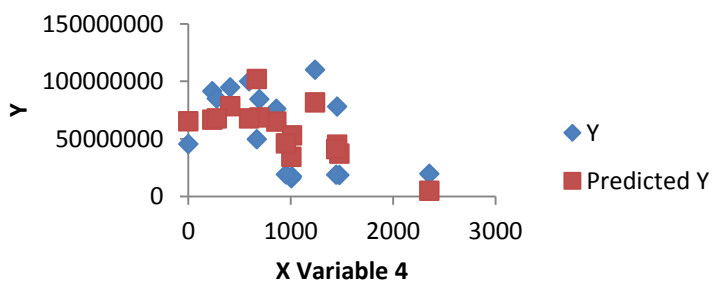
### Apapa port Line Fit Plot



### Rivers port Line Fit Plot



### Onne port Line Fit Plot



Effects of delay cost on GRT of Vessels Entered

<i>Regression Statistics</i>	
Multiple R	0.732767
R Square	0.536947
Adjusted R Square	0.368564
Standard Error	367.169
Observations	16

<i>ANOVA</i>					
	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>Significance F</i>
Regression	4	1719593	429898.2	3.188846	0.045269
Residual	11	1482944	134813.1		
Total	15	3202537			

	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>	<i>Lower 95%</i>	<i>Upper 95%</i>
Intercept	2766.173	313.712	8.817555	2.56E-06	2075.698	3456.649
Tin Can	0.038114	0.047234	0.806918	0.436813	-0.06585	0.142074
Apapa	-0.01854	0.022874	-0.81046	0.434859	-0.06888	0.031807
Rivers	0.141973	0.061777	2.298167	0.042168	0.006004	0.277942
Onne	0.152748	0.182837	0.835435	0.421249	-0.24967	0.55517

## Questionnaire

S/N	Port user satisfaction rating	20%	40%	60%	80%	100%
<b>Research Questionnaire</b>						
1	Vessel operators and cargo owners using Nigerian port industry are satisfied with the extent of delays at the ports					
2	Average delay in Vessel operations at the ports increase vessel operational cost and hence, the total transportation costs is satisfactory					
3	The Delays rate in Nigerian Ports are very insignificant and does not affects the overall vessel operation time and voyage plans of liner vessels, hence satisfactory					
4	Delays encountered by Shippers (Cargo owners/ship owners) effect on the budgets and implications on overall business transactions is insignificant, hence satisfactory					
5	Increase in vessel turnaround time of the Nigerian port is subject to operational delays at the port terminals which has incurred costs and demurrages to vessel operators, shipping company and cargo owner using Nigerian ports, however, the satisfaction can be rated at?					
6	Shipping opportunities in Nigerian ports such as import and export trade of container cargos that attract vessel tonnage and traffic volume are not affected due to delays in Nigerian ports, hence satisfactory					
7	Opportunities loss in shipping industry to Nigeria economy is subsequent to inefficient operations of Nigerian ports and delay rate is not a major consequence					
8	Port ineffectiveness as a result of operational delays is a problem contributing to opportunity loss bed veiling Nigerian port industry, however, there is still level of satisfaction derived by port users					
9	Operational delays in Nigerian ports hampers opportunities and inhibits growth in the port industry, however, there is still level of satisfaction derived by port users					
10	Port delays are the results of Capital flight and the significant effect of opportunity loss which impede ability to adapt to industry changes in global industry, however, there is still level of satisfaction derived by port users					
11	The Nigerian ports have experience loss of market share in shipping industry as many vessel operators and cargo owners divert their cargos to neighbouring countries, however, there is still level of satisfaction derived by port users					
12	Nigerian ports experience loss of goodwill as its market shares in shipping industry have substantially been reduced over the years, however, there is still level of satisfaction derived by port users					
13	Port delay has consequential effect on the behaviour of shipping companies in determining and selecting ports for a hub centres, however, there is still level of satisfaction derived by port users					

14	The market share of Nigerian ports in the shipping industry have been affected owing to many factors in which delays at the port terminals are one of the major reasons, however, there is still level of satisfaction derived by port users.					
15	Nigerian port market share in the global shipping trade among ports of neighbouring African Nations are considered the least due to inefficiency of the port operations owing factors which delays are the most consequences, however, there is still level of satisfaction derived by port users.					
16	The vessel transit time through the port in Nigeria is above 2days of global standard for container port which is as a result of unnecessary delays at the ports, however, there is still level of satisfaction derived by port users					
17	Vessel transit time in Nigerian ports is high compared to other neighbouring ports of Cotonou, Ghana etc, however, there is still level of satisfaction derived by port users.					
18	Long dwell time of container ship due to delay factors results to loss of patronage to Nigerian ports, however, there is still level of satisfaction derived by port users					
19	Long turnaround time of ships contributes to high cost of port operations in Nigeria ports, however, there is still level of satisfaction derived by port users					
20	Shippers (Cargo owners/ship owner) are dissatisfied with the operational performance of Nigerian port due to long dwell time of vessel at port leading to change in the initial voyage plan of the ship agent, however, there is still level of satisfaction derived by port users					
21	Liner shipping operators/Ship owners are not willing to repeat their vessel calls or to bring their vessels to Nigerian ports due to delays in the Nigerian operations, however, there is still level of satisfaction derived by port users					
22	Nigerian port vessel traffic volume is affected due to ineffectiveness of the port operational performance, however, there is still level of satisfaction derived by port users					
23	Times of ship calls is a significant reflection of goodwill hence, drop in times of vessel call is a result of port failures in creditable port operations by the port users, however, there is still level of satisfaction derived by port users					
24	Decline in vessel calls is subject to inadequate port operational performance to satisfy port users, however, there is still level of satisfaction derived by port users					
25	Decline in market share, loss of goodwill and opportunity loss in Nigerian ports are reflections of decrease in vessel call times, however, there is still level of satisfaction derived by port users					