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Estimation of Cost of Delays on Vessel Operations in Container Terminals of Apapa Seaports

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ABSTRACT

The study estimated cost of delays on vessel operations in container terminals of Apapa seaports. It considered secondary sources of annual data from 2007-2022. Queue model was used to answer the research questions. The study finds that the vessel operation in Apapa port experience mean delays of 4.4 days. The port users experience mean economy loss of USD 12412.11 per annum due to delays in vessel operations in container terminals and incurred mean cost of 1983737 per annum. It finds that Apapa port container terminal has mean vessel turnaround time of 6.36 days and mean vessel arrival rate of 219 vessels per annum. The mean ship traffic of 1389 vessels from 2007 to 2022 and the mean ship service rate of approximately 11 vessels/berth. Apapa port has only 20 berths which implies that the utilization coefficient of the system is not satisfied at optimal level. Apapa port ship queuing cost is $16668*LOA and cost of idle berth of $32*LOA, implying that out of 20 berths in Apapa port approximately 12 berths (61.2%) were working and fully utilized while 8 berths (38.8%) were more or less not working.

1. Introduction.

Many developing countries are working to reposition themselves within the international supply chains to become key players in global trade.

Also, have embarked on economic reforms aimed at upgrading port infrastructure, enhancing transport competitiveness, and improving overall performance in the maritime sector (Hlali et al., 2023). In this vein, cost of delays is indispensable to ensure maritime performance. Port cost is the price paid for using port facility. 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. Delays at ports occur when calling vessels cannot gain access to port or berth due to backlog of vessels waiting for berthing space or at berths waiting for loading/discharging. Delays could be as results of narrow channel to port, insufficient berths, unavailability of tug and pilot, inadequate cranes for loading and discharging as well as bureaucracy and delayed documentation. Port delays are disruption in terminal operations that can give rise to increase in cost due to long waiting time at ports.

The Lagos Port Complex (Apapa Quays) is Nigeria 'Premiere Port'. 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 (Nwoloziri and Ndubisi, 2020). In 2006, the port complex was concession and divided into multiple terminals which were

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sold to private operators to manage for a given period of time as agreed in the concession terms (Ndikom, 2008).

According to Adebayo (2005) prior to concession, delay in Apapa port container terminal was as a result of cumbersome vessel and cargo clearance system while, Uzoanya (2000) infers that the presence of 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 (2000) discussed the inability of the port to deliver customer friendly services is as result of delays fostering corrupt practices vice versa, at the ports. However, in the era of concession Emeghara (2012), posits that the issues of delays in Nigeria ports have shifted from berth scarcity-related to cargo-service problems informing that delays witness in Apapa port are related to service time of ships at berth rather than waiting to service time, crediting it to 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).

Notwithstanding, 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 Nigeria. 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, Apapa port 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., which 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, et al., (2015), there are yet cases of capital flight whereby importers prefer using the neighboring ports of Cotouou, 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, et al., 2015).

The aim of the study is to estimate cost of delays in vessel operations in container terminals of Apapa seaport, with specific objectives include to:

- Estimate the average delay in vessel operations in Apapa container terminal.
- Estimate the economic cost and implications of delay in vessel operations in Apapa container terminals.
- Determine the average service rate of vessel at berth in Apapa container terminal.
- Find the optimal service rate of ships in Apapa container terminal.
- Derive the container terminal utilization coefficient of Apapa seaport.

2. Theoretical review.

The study reviewed some basic theories which served the fundamental for the study. These include:

2.1. 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). 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 such as Apapa.

2.2. Queuing Theory.

The origin of queuing theory can be traced to A.K. Erlang in 1909. 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, et al., 2010; Canonaco et al., 2008). 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, et al., 2016).

As a branch of operations research, queuing theory is useful to make informed business decisions on how to build efficient and cost-effective workflow systems in port industry. In fact, queues make economic sense and where there are no queues means there could be costly overcapacity or no good customer. 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.

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 in the port (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, and any delay at the port costs

0.6% to 2% of the value of the goods daily (NUCTAD, 2019). There are several ways in which delays occurs as posited by (Nze & Onyemechi, 2018), there is ship berth delays caused by ships waiting for berthing spaces. delays can also occur when there is gaps when ship is waiting to load or discharge as result of unavailability of equipment or manpower. This could be drastic if it lengthens the amount of time a vessel should remain at Port, therefore causing more inconveniences.

However, queue theory has been applied in few studies such as Oyatoye, et al., (2011) which was applied on port congestion in order to enhance sustainable development of Nigeria ports. The study predicts the average arrival rate of ships in Tin Can Island port and the average service rate per ship in a month. The study found that the number of berths in Tin Can Island port was adequate for the traffic intensity of vessels but other factors leading to port congestion were identified through the content analysis.

3. Materials and Methods.

Secondary sources of data were the time series data collected from Nigerian Port Authority Annual Reports of 2007-2022 as well as Nigerian Port tariff regulation of 2004 which were publication of the Nigerian ports Authority.

Little's law developed by John Little in 1954 was adopted to formulate the queue model applied in the study. 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 λ multiplied by the average time W that a customer spends in the system in queuing theory (Branislav, 2006). 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 stated as.

$L = \lambda W$

Where:

L is the average number of customers in the system.

λ is the average arrival rate into the system.

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

Using queue model, we have that:

The average turnaround time of vessel in Apapa Ports container terminal = Wtä

The arrival rate of vessel in Apapa Ports container terminal = λä= QLä / Wtä

The average service time of vessel at berth in Apapa Ports container terminal = μä = λä/ ßb ä

The optimal service rate of ships in Apapa Ports container terminal = Φä μ = ßäb * μä

The container terminal utilization coefficient of Apapa Port = (λä/ μä) *100

The ship queuing costs in Apapa Ports container terminal = C$\ddot{v}$qä* QLä * tä

The cost of idle berth in container terminal of Apapa Ports = Cβφä * (ßbä - βφä) * tä

Where:

QLä = the average number of container ships in the queue,

ßbä = the number of container berths,

βφ ä = the average berth occupancy rate; βφä

(ßbä - βφä) = number of idle berths

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

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

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

4. Results and discussion of findings.

The data collected for the purpose of the study is presented and explained. Each dataset was analyzed in line with the objectives of the study to answer the research questions.

Table 1: Apapa container port average Turnaround Time, Vessel Calls, Vessels GRT, Berth Occupancy and Berth vacancy rates.

Year	Turnaround Time (days)	Vessel Calls	Vessels GRT	Berth Occupancy Rate (%)	Berth vacancy rate (%)
2007	8.7	1359	3325168	60.21	39.79
2008	9.6	1452	3463642	64.19	35.81
2009	9.5	1545	3109638	62.37	37.63
2010	10.15	1556	3098532	68.22	31.78
2011	7.59	1594	32869251	64.14	35.86
2012	7.96	1445	32072798	65.25	34.75
2013	5.31	1510	34189172	56.9	43.14
2014	3.91	1503	37041879	57.58	42.42
2015	3.8	1410	36290502	69.7	30.3
2016	4.7	1194	33612421	55.5	44.5
2017	5.1	1154	31614347	55.76	44.24
2018	4.7	1105	3021634	55.1	45.5
2019	5.59	1034	3207361	54.2	45.8
2020	3.7	1345	3710732	56.35	43.65
2021	5.65	1465	3509372	65.42	34.55
2022	5.75	1554	3401578	68.32	31.68
Average	6.356875	1389.0625	16721126.69	61.20063	38.8375

Source: NPA annual report 2007-2022.

Table 1 represents the turnaround time, vessel calls, vessels grt, berth occupancy and berth vacancy rates of Apapa port container terminal from 2007 to 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 Apapa 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). Apapa port has an average turnaround time of 6.356875days (≈ 6days), this shows that Apapa port does not operate within the global specified duration for a container port. The average ship traffic volume of the Apapa was calculated as 1389, implying that Apapa port, had an average annual vessel calls of 1389 in the period 2007-2024. Berth occupancy expresses 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. The average berth occupancy rate of Apapa, from 2007 to 2022 was calculated as 61.20063 as proximately 61.2%. The vacancy rate represents the percentage of berth not utilized not working or idle within the year at the port. The berth vacancy rate of Apapa, port for the periods 2007-2022 is 38.8%. In more details, the data informs that out of 100% of days of berth work days the berth were vacant, idle and unutilized for 38.8%. The average annual Gross Registered Tonnage (GRT) of vessels handled in the container terminals in Apapa ports between 2007 and 2022 explains the total number of registered tonnage of vessels that visited the ports during these periods of port concession given as 16721126.69 per annum.

Table 2: Provisional Data on Tariff and Charges for Vessel Pilotage, Mooring and Berthing Operations in Nigerian Port Container Terminals.

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

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

The table 2 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 3: Apapa port Vessel Operations in Container Terminals.

Year	Extent of Delay in Vessel Operations (days)	Estimated Cost of Delay in Vessel Operations $	Estimated Annual Cost of Vessel Operations $
2007	6.7	18210.6	1940804.2
2008	7.6	22070.4	2073618.6
2009	7.5	23175	2206433.0
2010	8.15	25362.8	2222142.3
2011	5.59	17820.9	2276410.5
2012	5.96	17224.4	2063621.8
2013	3.31	9996.2	2156449.1
2014	1.91	5741.5	2146452.3
2015	1.8	5076	2013637.9
2016	2.7	6447.6	1705165.7
2017	3.1	7154.8	1648041.2
2018	2.7	5967	1578063.8
2019	3.59	7424.1	1476667.8
2020	1.7	4573	1920810.6
2021	3.65	10694.5	2092184.1
2022	3.75	11655	2219286.0

Source: Author's calculation using port provisional data.

The result of the study in Table 3 indicates the extent of delays, estimated cost of delays and estimated annual cost in vessels operations experience in the container terminals in Apapa ports from 2007 to 2022. The delays were determined by benchmarking the ship turnaround time in port container terminals against the global standard of 2 days 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 2 day global port sector benchmark. The days outside the 2 days 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 result of the study presented in table 4 provides the descriptive analysis of vessel operations in Apapa port container terminals in the concession era from 2007-2002. The analysis indicates that the mean delay in vessel operations of Apapa container terminal 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 1.7days delay which occurred in 2020. The mean cost or economic implications of delay in vessel operations in Apapa container terminal 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 is USD 4573 which occurred in 2020. This cost of delays in vessel operations in Apapa container terminals has implications in port development as well as shipping activities in Nigerian maritime sector which affect the mean cost of vessel operations at Apapa port container termi-

Table 4: Descriptive analysis of Vessel Operations in Apapa port Container Terminals.

Stat	Delays	Cost of Delay	Annual Cost
Mean	4.356875	12412.11	1983737
Standard Error	0.553669	1781.432	62874.85
Median	3.62	10345.35	2068620
Standard Deviation	2.214674	7125.728	251499.4
Sample Variance	4.904783	50775997	6.33E+10
Kurtosis	-1.21469	-1.16431	-0.47444
Skewness	0.527588	0.598494	-0.87257
Range	6.45	20789.8	799742.7
Minimum	1.7	4573	1476668
Maximum	8.15	25362.8	2276411
Sum	69.71	198593.8	31739789
Count	16	16	16
Confidence Level (95.0%)	1.180117	3797.032	134014.6

Source: Author's calculation.

nal given as USD1983737 per annum between the periods 2007 to 2022 as the cost of vessel husbandry at the terminals with a standard deviation of 251499.4.

Table 5: The average service rate, arrival rate of vessel, optimal service rate and container terminal utilization coefficient of Apapa ports container terminals.

Apapa Container terminals	
Average turnaround time of vessel $= W_t^{ä}$	6.36 days
Average arrival rate of vessel = $\lambda^{ä} = Q_L^{ä} / W_t^{ä}$	219 vessels/year
Average vessel service rate(s) = $\mu^{ä} = \lambda^{ä} / ß_b^{ä}$	10.95 vessels/ berth
Optimal service rate of ships = $\Phi^{ä} \mu = ß^{ä}_b * \mu^{ä}$	220 vessels/ berth
Container terminal utilization coefficient = $\lambda^{ä} / \mu^{ä}$ (%)	99.5%
ship queuing costs at container terminal ($Cü_q^{ä} * Q_L^{ä} * t^{ä}$)	$16668LOA
Cost of idle berth in container terminal ($C\beta\phi^{ä} * (ß_b^{ä} - \beta\phi^{ä}) * t^{ä}$)	$32*LOA

Source: Author's calculation.

The study finds that Apapa port container terminal has the average vessel turnaround time of 6.36 days while the average vessel arrival rate is 219 vessels per annum as shown in table 5. The average annual ship traffic volume of Apapa port is 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 (μä = λä/ βbä) 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 11vessels 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) 20berths 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 βφ / ßb < 1. However, Apapa port has only 20 berths which implies that the utilization coefficient of the system is not satisfied at optimal level βφ / ßb < 1. (i.e. 61.20/20 = 3.06), hence, 20berths are not optimal for Apapa port. More berth facilities are required to handle vessel call at Apapa port. Also, the optimal service rate of ships in Apapa ports container terminal (Φä μ = ßäb * μä) is 220vessels. Having noted that the average service rate of Apapa port is 11vessels per berth on random arrival and average of 6 days turnaround time, 20 berths can only accommodate approximately 220 vessels annually on random arrival and on 6days average turnaround time operated in Apapa port. More vessels arriving would be delayed at the port which results to queuing of vessels. This informs that for Apapa port container terminal to perform effectively and optimally, average of 220 vessels would comfortably be handled by 20berths 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 (λä/ μä) *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 6days turnaround time of Apapa port otherwise, more inflow of vessel would have to queue up.

The ship queuing cost or waiting cost (C$\ddot{v}$qä* QLä * tä) of vessels in Apapa port is calculated as $16668*LOA, which implies that the average annual queuing cost at Apapa port from 2007-2022 is $16668*LOA annually. To this effect, Apapa port has an average turnaround time of 6days, average rate of vessel calls of 1389 per annum, berth rent given of $2*LOA (Length Overall) resulting to average annual ship queuing cost $16668*LOA. The cost of idle berth in Apapa Ports container terminal (Cβφä * (ßbä - βφä) * tä) is $32*LOA. 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 container terminal.

Conclusions.

In conclusion, the study used queue models to address the research questions and actualize the aim and objectives of the study. The study concludes the vessel operation in Apapa port experience average delays of 4.4 days from 2007 to 2022. The port users experience average annual economy loss of USD 12412.11 per annum as result of delays in vessel operations in the container terminals and incurred mean cost of 1983737 per annum. The study concludes that Apapa port container terminal has the mean vessel turnaround time of 6.36 days while the average vessel arrival rate is 219 vessels per annum. The average annual ship traffic volume is approximately 1389 vessels from 2007 to 2022 and the mean ship service rate as 10.95 which is approximately 11vessels/berth. Study concludes that Apapa port has only 20berths which implies that the utilization coefficient of the system is not satisfied at optimal level. Apapa port ship queuing cost is $16668*LOA and cost of idle berth of $32*LOA, impliny that out of 20 berths in Apapa port approximately 12berths (61.2%) were working and fully utilized while 8 berths (38.8%) were more or less not working and idle at one time or the other.

Recommendations.

The study recommends that 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. The terminal operators and port management should comply with the 2 days ship turnaround time benchmarks operational in global ports in order to reduce the economic cost of delay imposed by vessel operations delay in the Nigerian port sector.

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