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Application of Queueing theory to port congestion problem in Nigeria

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Abstract
This paper stresses the importance of queueing theory to the problem of port congestion in order to enhance sustainable development of Nigeria ports. 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 country ports 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. Queuing model was applied to the arrival and services pattern which causes the problems of congestion and proffer solutions to the problem areas. It is 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 to found out the number of berth in Nigeria port is 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.

Key words: Queue theory, port congestion, berth, arrival time, service time.

1. Introduction

The Nigerian Ports Authority (NPA) was established in 1955 and was saddled with the responsibility to oversee the activities and operations of the Ports in Nigeria. Over the years, Tin Can Island Port has experienced series of congestion which has resulted in the diversion of ships scheduled for Nigeria ports to other neighbouring country ports. The first ports congestion was experienced in Nigeria during the economy booming years of early 1970s. During that period, there were a lot of incoming goods into Nigeria because of the discovery of crude oil and the reconstruction of the devastated effect of the civil war. The period witnessed a lot of importation of cement into the country, so much that hundreds of vessels had to queue for berthing space for months, (The Cement Armada). So much money was wasted on payment of demurrage for these vessels, a development that created unpleasant consequences for the Nigeria economy.

The second Port congestion was witnessed in early 2000, when the Federal Government introduced a policy requiring 100% physical examination of all containers that were imported into the country and the contents unstuffed for the government agencies at the port to ascertain and establish that what was declared was actually what the container contained. This resulted in many consignees abandoning their containers thus creating backlog of un-cleared containers occupying the terminals and limiting the available space for in-coming containers.

The most recent port congestion was between October 2008 and March 2009. This was as a result of two factors. Firstly, the Cargo traffic in Nigeria tends to have a certain cycle. The peak period occurs between October and March. This period records more volume of goods coming into the ports. The second factor is that the Nigeria Customs Services (NCS) in an effort to fulfill its responsibility and ensure that its integrity is maintained, introduced a circular known as "Circular – 02". The circular stated that any importer who makes a false declaration will have his goods seized and the importer persecuted in the law court. This resulted in many of the consignees abandoning their cargos in the port and vicious cycle was created. Meanwhile, the shipping companies and the terminal operators continued to charge demurrage, while containers continue to come into the port without the owners clearing them out. This created a lot of problems and it got to a stage when there was no space in the terminal to discharge incoming containers, hence the ships has to queue for weeks, months before getting access to berthing space. The situation got to a stage where the Nigerian Customs Service had to put aside the circular – 02 and even gave some waiver to enable the importer clear out their goods, still the importers were not forthcoming because by then the goods had accumulated so much demurrage.

However, the random arrival of the ships makes the predictability of the system and managerial decision difficult. Queuing theory model could provide Managers/Port operators with a useful set of decision making formulas and algorithms for designing Port systems and services (Kalavaty, 2007). An example of this is the Classical Erlang blocking formula that was developed in 1917. This formula gives the probability that "berths are busy" given the fixed number of ships that can berth at the same period of time. This model will help the port managers decide what should be optimal Port size needed to effectively and efficiently serve customers` need profitably. The measure used in the model is the arrival rate and service rate of the system.

In order to respond adequately to this challenge, queueing theory was applied to arrival and service pattern in Nigeria port in order to access the business behaviour and proffer a relief for problem of congestion that seem to be reoccurring in the port even after the concessioning of the port to private sector

1.1 Statement of the Problem

Since 1977 Tin Can Island Port Nigeria, one of the Nigerians main Ports with shore facilities has been playing a vital role in the economic development of Nigeria. It handles some general purpose Ships besides having a few additional jetties to handle oil tankers and food grains etc. the Ports all over the world have changed significantly with the advent of containerization and Tin Island Port is not an exception. Tin Can Island Port despite many constraints has continued to cope with the changing mode of Maritime Trade. However, it has been suffering from the problem of poor operational efficiency.

The traffic through the Port is increasing along with the economic development of Nigeria. It has been observed frequently that arriving ships has to form queue and sometimes ships has to wait longer than necessary before berthing. In addition to that lack of adequate inland infrastructure to handle incoming containers give rise to the instance of congestion in both Cargo and Ship and delays in final delivery of goods to the importer's premises with consequent increase in transportation and other costs.

Port congestion is inimical to economic growth and has become a regular occurrence at Nigeria ports. This has been a source of concern to the Federal Government, who at various times had set up committees to find solution to the persistence occurrence of congestion at the ports. The effectiveness of a port is contingent upon the efficient loading and unloading of ship. When the traffic movement is hampered, it creates delays in the system. This waiting line delays cause ships to queue for berthing space thus creating congestion. This waiting time is calculated with the service time at the berths to form the turn-around time of ships which is one of the ways of measuring the efficiency of a port.

The ever growing international trade has made demand on quick turnaround time of ships a paramount problem in today's shipping business. These ships waiting for berth space incurs extra cost of operation, thus increasing cost of doing business for the importers. This study seeks to find ways to enhance quicker turnaround time of ships and make the Nigeria Ports attractive and cost efficient.

Consequently, the following research questions are addressed by this study

i) Is the number of berths at Tin Can Island Port adequate for its traffic volume?
ii) What are the factors responsible for port congestion in Nigeria?
iii) How can queue theory be applied to port congestion?
iv) What are the possible solutions to port congestion using queuing models?

1.2 Objective of the study

The broad objective of this study is to gain an understanding of the application of queueing theory to the problem of port congestion in Nigeria Tin Can Island Port. To achieve this however, the research will look at the following specific objectives:

i) To assess the adequacy of berths at the port
ii) To examine the use queueing model for analyzing the queue behaviour of ships in Nigeria port.
iii) To determine through the use of queue model the optimal number berth required for efficient port operation in Nigeria.
iv) To proffer solution to the problem of Port Congestion through the use of queueing model.

2. Literature Review

2.1 The Concept of Port Congestion

Over the years the traffic through the Nigeria Ports are increasing along with the economic development of the country. It is frequently observed that a queue of arriving ships is formed and sometimes ships have to wait for a longer time before berthing. This can be attributed firstly, to the mobility of the existing port facilities to match the ever increasing global trade and secondly, some obnoxious government policies and regulations. This incessant congestion in our ports has resulted in diversion of ships meant for Nigeria Ports to other neighboring country ports. In the reforms and concessioning of 2006, Tin Can Island Port was concessioned to four different private organizations to manage.

See Table 1

Maduka (2004) defined Port Congestion as massive un-cleared Cargo in the Port, resulting in delay of ships in the seaport. According to him, this occurs when ships spend longer time at berth than usual before being worked on or before berth. Onwumere (2008) refers to port congestion as a situation where in a port; ships on arrival spend more time waiting to berth. In this context, more ships will queue at the channels and the outside bar waiting to get space at the terminal for berth age. According to him, this waiting time is calculated using the service time of vessels which is one of the ways of measuring port efficiency. In his view, this is a situation where cargoes coming into the port are more than the storage facilities can handle.

2.2 The Incidence of Port Congestion in Nigeria

Port Congestion is a global phenomenon not limited to only Nigeria. In 2005 global map of congestion around the world the entire Africa was there, the West Coast of Africa including Nigeria was there, the Eastern part of Africa, around Kenya, Southern Africa even the West Coast of the United States of America was there. This was as a result of so many factors (Zhang et al, 2008).

Maduaka, (2004) highlighted the factors responsible for port congestion in Nigeria and suggested ways to control congestion at the Ports. According to him, there are advantages and disadvantages in port congestion. He stated that Port congestion brought about realization for better planning, port expansion and development. He cited loss of revenue, unemployment and bad image to the country as its major disadvantages. Classic transport magazine, a logistic, shipping and multi-modal transport stated that Port Congestion is inimical to the economic growth (volume 1 of 2009). According to the publication, port congestion has a negative implication on the economic resources, wastage of time and space as well as increase in the cost of operations and cost to the society.

Tom (2009) posited that Nigeria should be warned about reoccurrence of congestion in our port. According to him in spite of the various waivers conceded by the government the dwell time of consignment in the port is gradually jacking up against expected time. He cited the use of Manual Clearing Process as one of the major factors responsible for the reoccurrence of the looming congestion.

2.3 The Concept of Queuing Theory

Adedayo et al. (2006) stressed that many situation in life requires one to line up or queue before being attended to. This lines formed are referred to as waiting lines or queues. According to them queue occurs when the capacity of service provided fall short of the demand for the service. Sanish (2007) in his article on application of queuing to the traffic at New Mangalore Port refers to queuing theory as an analytical techniques accepted as valuable tool for solving congestion problems. According to him the primary inputs to the models are the arrival and service patterns. These patterns are generally described by suitable random distribution. He observed that the arrival rate of ships follows exponential distribution while the service time follows Erlang or Poisson distribution. He observed that queuing theory can be used to predict some important parameters like average waiting time of ships, average queuing length, average number of ships in the port and average berth utilization factor closer to the actual values.

2.4 Components of Queue Models

Queues are not an unfamiliar phenomenon and to define it requires specification of the characteristics which describes the system such as the arrival pattern, the service pattern, the queue discipline and the queue capacity Adedayo et al. (2006) observed that there are many queuing models that can be formulated. According to them it is essential that the appropriate queuing model is used to analyze problems under study.

The arrival pattern: This may be the arrival of an entity at a service point. This process involves a degree of uncertainty concerning the exact arrival times and the number of entities arriving. And to describe this process there are some important attributes such as the sources of the arrivals, the size of each arrivals, the grouping of such an arrival and the inter-arrival times.

The service pattern**:** This may be any kind of service operation which processes the arriving entities. The major features which must be specified are the number of servers and the duration of the service.

The queue discipline: This defines the rules of how the arrivals behave before service occurs.

The queue capacity**:** The queue capacity may be finite or infinite.

Sharma (2008) refers to the following as the components of queuing system.

- Calling population (or input source)

- Queue process
- Queue discipline
- Service process (or mechanism)

2.5 Historical Perceptive of Queuing Theory

The ground work for many of the earliest techniques of analysis in queuing theory was laid by Erlang who is referred to as the father of queuing theory between 1909 and 1929, Adedayo (2006). Erlang is given credit for introducing the poison process to congestion theory for the method of creating balance state equilibrium (Chapman-Kolmogorov equation) to mathematically represent the notion of statistical equilibrium. Most of the pioneers of queuing theory were by engineers seeking solution to practical real world problems.

2.6 Queuing Model of Tin Can Island Port

The system of operation at Tin Can Island Port can be model as a queuing process. Ships come to the port as customers to get service and the facilities at the port render services to ships as servers. Here, services refer to handling of cargoes and use of facilities at Tin Can Island Port for berthing of ships. A large portion of the solution of waiting line problem encountered at the ports involves making decisions in one or a combination of the following.
(i) Number of berths that are needed to serve the arriving ships.
(ii) Delay of loading/unloading of cargo/container
(iii) Future expansion of the port facilities considering the future expected port congestion at ports; an attempt is made in this study to find solution to the incidence of port congestion in Nigeria with particular reference to Tin Can Island Port.

The problem can be modeled as a multi-server queue problem with no system limit, arrival can be from a theoretically infinite source and the service is on first-come-first-serve priority rule.
S = Number of berths
N = Average arrival rate
U = Average Service rate at each berth.

2.7 Port Performance Determination

Port performances are based on data recorded by port authorities who traditionally tend to focus on traffic recordings and parameters used in measuring the Port services. Most available and reliable data are related to the maritime interface where information is more easily collected than on the land interface. Port authorities usually monitor berth occupancy and dwelling time of ships, characteristics of calls performance of ships-to-ship cargo handling availability of the main handling equipment. Additional but often less reliable data may be available as regards landward operations, dwelling time of cargo in the port, characteristics of customs and other administrative procedures and rarely the performance of handling equipment for delivery of goods.

Chen-Hsiu and Kuang-Che (2004) posited that port system efficiency may be measured by the average time ship spends in a queue. Shippers and port users are interested in reducing the waiting time in the queue system as much as possible. The ability of a port to load and unload cargo from the ship is critical to port planning factor and port efficiency.

2.8 Berth Occupancy

Berth occupancy is defined and computed on the basis of the ratio of berth waiting time to berth serving time. The acceptable levels of waiting times generally determine permissible berth occupancy ratios

(Warwar, 1980). Longer service time causes longer ship's waiting time where port facilities are inadequate and the terminal's space is over saturated.

The arrival of pattern ships of is usually a random process described by some type of probability distribution (Fararoui, 1989). A negative exponential distribution of inter-arrival times (and hence a poisson arrival rate) is the most commonly used approximation. Ships turnaround time involves the arrival of ships expecting to use port facilities and the duration of occupancy at a berth (service time). The ports or more precisely, the ship berth link are considered as queuing systems with bulk arrivals, single service and unlimited queues at an anchorage (Radmilovich, 1992). The number of available berth is an obvious factor in determining whether ships queues will be formed and what their length will be (Fararoui,1989). The time between the arrival of ships and its departure are the main factors in port's operations that influence the capacity of ports.

3. Material and methods

This section examines the relevant variables to be considered in this study and provides a relationship that exists between and among such variables, thus, leading to modeling of the possible relationship between the variables. It also throws light into the sources and types of data to be involved in the course of analysis.

3.1 Instrument for Data Collection

The data used for this study was collected both from primary and secondary sources. The primary sources are personal interview with the Port Managers and the terminal operators while the secondary sources include past records of operational activities, policy papers on government aimed at proffering solution to the problems of port congestion, papers presented by Maritime stakeholders. Also formal and informal interviews at individual level of discussions were held with the employees to obtain adequate clarification with regard to other variables that can influence the development of queuing models for Tin Can Island terminal on ship congestion.

The interview conducted with the Terminal Operators and Port Managers by the researchers at Tin Can Island Port revealed that an average of 120 vessels arrives at Tin Can Island Port in a month. It also revealed that it takes an average of 3 days to unload and load empty containers on the vessels. From the interview it was revealed that there are 10 berths at Tin Can Island Port numbered (1-10) and the vessels berth on First Come First Serve (FCFS) basis.

See Table 2

3.2 Model Formulation

A logical extension of a single-server waiting line is to have multiple servers, similar to those we are familiar with at many banks and ports. By having more than one server, the check-in process can be drastically improved. In this situation, customers wait in a single line and move to the next available server. Note that this is a different situation from one in which each server has a distinct queue, such as with highway tollbooths, bank teller windows, or super market checkout lines. In such situation, customers might "jockey" for position between servers (channels). Jockeying is the process of customers leaving one waiting line to join another in a multi-server (channel) configuration. The model assumes that all servers are fed from a single waiting line. In this section we discuss the various operating characteristics for a multi-server waiting line. The model in use can be applied to situations that meet these assumptions:

(1)The waiting line has two or more identical servers
(2)The arrivals follow a poison probability distribution with a mean arrivals rate of λ
(3) The service times follow an exponential probability distribution
(4) The mean service rate, "μ" is the same for each server
(5)The arrivals wait in a single line and then move to the first open server for service in orderly manner
(6) The queue discipline is first-come-first serve (FCFS)
(7) No balking or reneging is allowed

Using these assumptions, operations researchers have developed formulas for determining the operating characteristics of the multi-server waiting line like the case of ships awaiting berth thereby causing congestion which may not be desirable for all stakeholders. This paper relies on the laid foundation to proffer solutions to port congestion in Tin can Island Port.

Relevant Performance measures in the analysis of the model are:

- The distribution of the waiting time and the sojourn time of a ship or ships. The sojourn time is the waiting time plus the service time.
- The distribution of the number of ships in the system (including or excluding the one or those in service.)
- The distribution of the amount of work in the system (port). That is the sum of service times of the waiting ship and the residual service time of the ships in service.
- The distribution of the busy period of the server (berth). This is a period of time during which the server is working continuously.

In particularly, we are interested in mean performance measures, such as the mean waiting time and the mean sojourn time thereby leading to Port congestion.

3.3 Techniques Used For Model Solution

One of the advantages of application of queuing model for solving waiting line problem is the availability of software packages to handle and manipulate large data to get solution for effective and efficient decision making. The software packages also provide the user the opportunity for flexibility of the model in that various additional constraint can be added to take into account other constraints that may be peculiar to different situations in real life problem.

TORA menu driven optimization software package will be employed for the computation of result.

4. Results and Discussion

The congestion problem at Tin Can Island Port (TIP) was modeled as a Multi-Server queuing problem with 10 berths as currently operations at the Port. Theoretically, arrival is from infinite source and the service pattern is on First=Come-First-Server (FCFS) priority rules. Twelve Calendar months 2008 field data of arrivals and departures of vessels to and from Tin Can Island Port is considered.

See Table 3

Adedayo, et al (2008) stated that the closer the traffic intensity it to zero the more efficient the operations of the service facilities. Then from the above analysis of the traffic intensity of each of the months under consideration (January 2008 to December 2008) of port congestion problem at Tin Can Island Port Lagos and this can be seen as the traffic intensity for January is 1.5, February 1.18, for March 1.20, April 1.11, May 1.24, June 1.13, July 1.12, for August 1.13, September 1.10, October 1.18, for November 1.33 and December 1.33. This indicates that the system facilities presently at Tin Can Island Port cannot favourably cope with the flux of vessel arriving at Port and as a result there is bound to be queue.

In each of the month above, no steady state occurs because the assumption that traffic intensity (P) = λ < 1 is violated. According to Satty (1961), if $\lambda > 1$, the number of customers (Vessels) would be infinite. This means that ships arrives at a faster rate than the berths can conveniently handle, since $\lambda > \mu$. Then for each of the months, to determine the average time arriving ships queuing in the system.

See table 4

The above table shows the mean time ship spent waiting to berth in the port. These figures calculated are negative for all the months which mean that it has moved away from the positive sides and ships are forced to wait for service at Tin Can Island Port. The extension of the queue results in the negative values as shown in the above table. However, the queue does not benefit the system as well as its customers (ships).

See table 5

In the course of the analysis it is observed that the inter arrival is exponentially distributed with Parameter Lambda (λ) for each of the months as well as for the year under study.

From the above table output, the P^o column represents the probability that there are zero queues or no ship in the queue for each of the months January 2008 to December 2008 is not possible with current arrival and service rate at Tin Can Port.

It can be deduced that the probability that there is no ship in the queue for the month of January is 0.00585 which implies that the probability of ship being in the queue for the same month = $1 - P^o$, a simple mathematical manipulation shows that 0.99414 which is 99.4 percent probability of ship joining the queue on arrival while an insignificant 0.06 percent is the probability of having zero on arrival.

The same manipulation can be done for all the months and it could be established that there is queue for ships on arrival at the Port is significant throughout the year under review.

The Ls column from TORA output shows the average number of ships in the system for each of the months. The column indicates that an average of 7 ships has been in the system at a time and since the service required by each ship varies significantly from one another and relative to the load carried. Thus, there is delay in loading and off loading of ships and other human delay which will not make the system's recommendation of 6 to 7 ships in the system to work optimally. Thus, the operational inefficiency at the Port may likely be the major determinant of queue thereby causing Port Congestion. And again from the output of Tora windows version 2.00, the Lq column shows the average queuing length of ships. It was revealed that for January 2008, an arriving ship will spend an average of 7 days in the queue before being served, also an average of 5.6 days for the months of February, 6.87 days for March, 5.07 days for April, 5.97 days for May, 5.19 days for June, 5.13 days for July, 6.39 days for August, 4.89 days for September, 5.62 days for October, 6.50 days for November and 6.50 days for December.

However, the essence of the number of days and hours, minutes and seconds as shown in the analytical queuing solution was to derive the accurate number of days spent on the queue by any of the ships. Thus, this shows the number of days a ship is likely to say on the queue before berthing.

Next to be interpreted on the Tora Window Version 2.00 is the Ws column which shows the average time a ship spends in the system before being served. This also varies with the number of arrivals and the extent to which the Port could accommodate the berthing of arriving vessels. From the Ws column, the arriving ship in the month of January will wait for about 6 hours which is almost $2^1/_2$ days before joining the queue.

Also the Tora output also suggested for other months under review. The last column on table 3 of Tora output shows the average waiting time in the queue (Wq). This is the expected time that a ship may likely wait on the queue for each of the months as presented in Table 2.

It was equally observed that the waiting time on the queue in Table 2 columns 4 are all negative for all the months and by the forgoing analysis, the traffic intensity $P > 1$ for the various months. This means that waiting exceeded the positive side and ships have to queue on arrival thereby leading to congestion at Tin Can Island Port.

The result of this analysis as varied from one month to another in the above columns (Ls, Lq, Ws, Wq) with the probability table from the Tora output in this research efforts will form the basis for summary of findings, conclusion and recommendation in the next section.

5. Conclusion and Recommendations

From the study it was discovered that the problem of port congestion in Nigeria is not caused by only inadequate berthing space but majorly by the operational inefficiency of the Port Managers and Operators coupled with long years of infrastructural development neglect. Since the inception of port in Nigeria by the colonial masters in the early twenties, no systematic process for their re-development has been put in place until current concession programme.

Furthermore, It was also revealed from the study that traffic intensity (P) in the port is greater than one ($P>1$) for all the months in the year under review, which in effect shows that the current port facilities cannot adequately handle the influx of ships arriving at the port thereby causing delays.

The result of the analysis revealed that the mean time ships spend in the port exceeds positive values in all the months which indicates that ships has to queue on arrival at the port. Thus, the Tora Software analysis shows that the probability of having Zero ship (Po) in the Queue in any of the months is insignificant because of the present operational inefficiency, which shows that Queue exist in the Port thus creating congestion.

Queue theory is a viable tool for solving congestion problems and its application in this study has helped to identify the cause of congestion in the ports and has also provided the Port Managers with useful set of decision making formulas with algorithm for designing Port systems and services.

Increased competition, booming in international maritime trade and the associated port congestion is crucial in ports rethinking, how to bolster capacity and improve service quality, to maintain current and attract new business. In response to these opportunities and challenges most ports have started to or plan to redesign their operations and come up with long term investment plans and this has help to reduce the turnaround time of vessels calling at the port. The managers of Nigeria Ports should embark on serious infrastructural development to create an efficient competitive sector that will sustain economic growth in the years ahead. This view corroborates the conclusion draw by Kazeem (2010) "Although, port reform may not be a perfect policy as yet, especially in Nigeria, in our present circumstances it seems the best option for now. In a situation where all our port infrastructural facilities had become so old and obsolete, with NPA or Government having no fund to fix them, one could imaging what could have become our port today without the port reform".

The study will however, be incomplete without some recommendations on the possible means of improving the quality of services provided in Nigerian Ports to make it effective and efficient. Based on the findings, the problem of Port Congestion in Nigeria can be tackled the proper implementation of the following recommendations.

- The reduction of dwell time by introducing punitive measures to discourage improvers from using Port as storage area.
- The port managers should acquire modern and appropriate handling equipment to aid easy loading and unloading of ships.
- The operations at the ports should be properly designed, computerized for easy tracking of containers at the terminals.
- Ports customers/clearing agents should be educated on Cargo clearance procedures.
- Introduction and use of punitive measures to discourage shipping lines from delaying submission of ship manifest to customs.
- 24-hour operations must be encouraged in the ports.
- Physical expansion of Port Capacity will lead to reduction in port congestion and make the port more attractive to users.
- Improvement of hinterland link roads to the Ports should be made passable to reduce traffic in and around the port.
- Motivating and training of staff on the use of modern equipments used in ports.
- The extra containers must be taken to the customs approved of bonded terminals to ease the pressure on the ports.
- The customs clearing procedure which is the main reason for the backlog of containers in the Ports should be simplified.

We strongly believe that; if all these measures are taken, the dwell time of ships will reduce considerably, thus, eliminating congestion in the Ports. It is therefore, recommended that the concessionaires at Ports should be mandated to embark on extensive infrastructural development and capacity expansion.

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Appendix

Table 1: The terminal structure after concessioning is as follows:

S/Nos	Name of Company (Concessionaire)	Berths
1	Joseph Dan Ports Services Ltd	1-2
2	Tin Can Island Port (TCIT) Ltd	3-5
3	Ports and Cargo Nig. Ltd	6-8
4	Five Star Logistics Ltd	9-10

Source: Authors compilation 2010

Table 2: SHIP CHART AT TIN CAN ISLAND PORT in year 2008

Month under study	Total number of vessels called at TIP	Total number of vessel called at Berths	Total number vessels awaiting Berth	Percentage number of vessels at berth	Percentage of vessels awaiting berth
January	150	100	50	66.67	33.33
February	130	110	20	84.62	15.38
March	120	100	20	83.33	16.67
April	100	90	10	90.00	10.00
May	105	85	25	80.95	19.05
June	90	80	10	88.89	11.11
July	95	85	10	98.47	10.53
August	105	80	25	76.19	23.81
September	110	100	10	90.91	9.09
October	130	110	20	84.62	15.38
November	160	120	30	75.00	25.00
December	200	150	50	75.00	25.00
TOTAL	1,495				

Source: Field survey, 2010

Table 3: Determining the Traffic Intensity for Tin Can Island Port

Months under study	Total no of Vessel called at TIP	Total no of Vessel called at Berth	No of days in each month	Hours of operation Per day	Mean of Arrival rate λ	Mean of service rate *μ*	Traffic intensity λ *p* = ——
January	150	67	31	24hours	0.2016	0.1344	1.5
February	130	85	29	24hours	0.1868	0.1580	1.18
March	120	83	31	24hours	0.1613	0.1344	1.20
April	100	90	30	24hours	0.1388	0.1250	1.11
May	105	81	31	24hours	0.1411	0.1142	1.24
June	90	89	30	24hours	0.1250	0.1111	1.13
July	95	89	31	24hours	0.1277	0.1142	1.12
August	105	76	31	24hours	0.1411	0.1075	1.31
September	110	91	30	24hours	0.1528	0.1389	1.10
October	130	85	31	24hours	0.1747	0.1478	1.18
November	160	75	30	24hours	0.2222	0.1667	1.33
December	200	75	31	24hours	0.2688	0.2016	1.33
TOTAL	**1495**	**81**					

Source: Computations from data obtained at field work

Table 4: Analysis of average time ships spent in the system

MONTHS	λ for each months	*μ* Service rate for each month	Mean time ships spent in the port waiting to berth $\frac{1}{\mu - \lambda}$
January	0.2016	0.1344	$\frac{1}{0.1344-0.2016}$ = $\frac{1}{-0.0672}$ = -14.88
February	0.1868	0.1580	$\frac{1}{0.1580-0.1868}$ = $\frac{1}{-0.0288}$ = -37.17
March	0.1613	0.1344	$\frac{1}{0.1344-0.1613}$ = $\frac{1}{-0.269}$ = -37.17
April	0.1388	0.1250	$\frac{1}{0.1250-0.1388}$ = $\frac{1}{-0.0138}$ = -72.46
May	0.1411	0.1142	$\frac{1}{0.1142-0.1411}$ = $\frac{1}{-0.0269}$ = - 37.17
June	0.1250	0.1111	$\frac{1}{0.1111-0.1250}$ = $\frac{1}{-0.0139}$ =

			-71.94
July	0.1277	0.1142	$\frac{1}{0.1142-0.1277} = \frac{1}{-0.0135} = -74.07$
August	0.1411	0.1075	1 $\frac{1}{0.1025-0.1411} = \frac{}{-0.0336} = -29.76$
September	0.1528	0.1389	$\frac{1}{0.1389-0.1528} = \frac{1}{-0.0139} = -71.94$
October	0.1747	0.1478	$\frac{1}{0.1478-0.1747} = \frac{1}{-0.269} = -37.17$
November	0.2222	0.1667	$\frac{1}{0.1667-0.2222} = \frac{1}{-0.0555} = -18.02$
December	0.2688	0.2016	$\frac{1}{0.2016-0.2688} = \frac{1}{-0.0672} = -14.88$

Table 5: Output of TORA Software analysis for Tin Can Island Port Congestion problem

Months	**Server**	**λ**	**μ**	**L'daoff**	**Po**	**Ls**	**Lq**	**Ws**	**Wq**
Jan.	10	0.2015	0.1344	0.13361	0.00585	8.12866	7.13451	60.83687	53.3940
Feb.	10	0.1868	0.1580	0.15805	0.03450	6.57998	5.61448	41.63167	35.52293
March	10	0.1613	0.1344	0.11239	0.00895	7.86552	6.87446	69.98686	61.16851
April	10	0.1388	0.1250	0.11862	0.05101	6.02457	5.07558	50.78720	42.78720
May	10	0.1411	0.1142	0.11129	0.02548	6.94461	5.97009	62.40099	53.64442
June	10	0.1250	0.1111	0.10587	0.04708	6.14680	5.19388	58.06042	49.05952
July	10	0.1277	0.1142	0.10862	0.04889	6.08995	5.13883	56.06812	47.31156
August	10	0.1411	0.1075	0.10572	0.1652	7.38197	6.39849	69.82292	60.52059
Sept.	10	0.1528	0.1389	0.13141	0.05394	5.93657	4.99051	45.17679	37.97736
Oct.	10	0.1747	0.1478	0.14272	0.03439	6.58410	5.61849	46.13396	39.36806
Nov.	10	0.2222	0.1667	0.16424	0.01473	7.48314	6.49788	45.56110	39.56230
Dec.	10	0.2688	0.2016	0.19864	0.10470	7.48507	6.49977	37.68224	32.72192