Application of Wait-In Line Model on Decongestion of Container Terminal at Tin-Can Island Port Apapa Lagos

By

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Abstract

This paper examines the application of wait-in line model on decongestion of container terminal at Tin-Can Island Port Apapa Lagos. Wait-in-line causes inconvenience to economic cost of individual and organizations. It has been observed that this model "wait-in-line" is yet to be applied in Tin-Can Island port Apapa with the aim of decongesting the port. Explanatory research design method was adapted for the study. Data used for the study were collected from secondary sources which includes past records of operational activities from Nigeria Port Authority, policy papers of government, papers presented by Maritime stakeholders including journals aimed at decongesting the terminal. Wait-in-Line Model was used to analyse the data collected with the aid of TORA software. The study found out that when the servers were increased, traffic intensity was reduced drastically (?<1) thereby decongesting the terminal. It was therefore concluded that increase in the number of servers will significantly reduce the probability that there are queue at the Port. Based on the conclusion, the study therefore recommended that more servers should be provided and also review of some existing policies that hindered the speedy clearance process by the Custom Authority and that Intermediate transportation should be encouraged.

Key words: Wait-in-Line, Container Terminal, Decongestion, Traffic Intensity, Stakeholders.

Introduction

Wait-in-Line Model is one of the most widely quantitative techniques used in Operations Management for analysis. Wait-in-Line which is another term for queues are an everyday occurrence affecting people shopping for groceries, buying gasoline, making bank deposits or waiting on the telephone for the first available airline reservation to answer. It may also take the form of machine waiting to be repaired, trucks/vessels in line to be unloaded and passengers at the airports to purchase tickets or aircrafts lined up on the runway waiting for permission to takeoff (Erlang, 1909). Wait-in-Line also occurs in filling stations, bus-stops, canteens and hospitals where patients wait for minutes, hour, days or months to receive medical service; waiting before, during or after being attended to the unpleasant experience of waiting in line can often have a negative effect on the rest of customers' experiences with a particular firm (Scotland, 1991). The way in which managers address the wait-in-line issues is critical to the long term success of their firms (Davis, Aquilano & Chase., 2003). The three basic components of a waiting line process are arrivals, service facilities, and the actual queue otherwise represented by Kendall's notation M/M/1.

Nigeria 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 neighboring country's 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 goods coming into Nigeria. 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 goods 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. To address this issue in 2002 Tin Can Island Port was concession to five (5) firms, namely Joseph Dan Port Services Ltd taking charge of berth 1-2 Tin Can Island Container Terminal Port (TCIT) Ltd taking charge of Berth 3-5; Ports & Cargo Nigeria Ltd taking charge of Berths 6-8; Five Star Logistics Ltd taking charge of Berths 9-10; and Ports & Terminal Multipurpose Ltd (GRIMMALDI) taking care of Berths 11-12. Even with the concessioning, congestion at the ports still persists. While the most recent port congestion started in October 2012 to date. This was as a result of two factors; firstly, the Cargo traffic in Nigeria tends to have certain cycle. The peak period occurs between October and March. This period records more volume of goods coming into the port. The second factor is that the Nigerian Customs Service (NCS) in an effort to fulfil its responsibility and ensure that its integrity is maintained introduced a circular known as "Circular-02". The circular stated that any importer who makes false declaration will have his goods seized and the importer prosecuted in the law court. This resulted in many of the consignees abandoning their cargos in the port and a 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 owners clearing them out. This created a lot of problems and it got to a stage when there were no spaces in the terminal to discharge incoming containers, hence the ships have to queue for weeks, months before getting access to berthing space. The situation got to a stage where the Nigeria Customs Service had to put aside the circular-02 and even gave some waiver to enable the importers clear out their goods, still the importers were not forthcoming because by then the goods had accumulated so much demurrage.

Container terminals can be described as an open systems of materials flow with two external interfaces. These interfaces are the quayside designed for loading and unloading of ships, and the landside where containers are loaded and unloaded on/ off the trucks (Steenken, Vob, and Stahlbock, 2004). Most terminals are taking measure to increase their through put and capacity (Huynh and Walton, 2005) by introducing new technology, optimizing equipment dwell times, increasing storage density, optimizing ship turn-around times, optimizing truck - turnaround times.

A great variety of container terminals exists mainly depending on which type of handling equipment are combined to form a terminal system. Koshnevis and Asef-vaziri (2000) define three performance analysis variables including throughput, space utilization and equipment utilization. Kozan (2000) discusses three major factors influencing the transfer efficiency of seaport container terminals by developing a network model. Similar studies in this field are carried out by Nam and Ha (2001), Lie, Jula, and Ioannou, (2002). Nishimura, Imai, and Papadimitriou, (2009) implemented Lagrange method for optimizing the container yard operation and consequently arrived at minimizing the trucks'congestions at the gate of the port complexes particularly Iranian Sea Port and reduces the trucks'turnaround time.

Berth planning problems may be formulated as an optimization problem depending on the specific objective and restrictions that have to be observed. Kim and Kim (2002) have discussed a method of sorting yard-side equipment during loading operations in container by an encoding method. Park and Kim (2003) have discussed a Mixed Integer- Programming Model which simultaneously schedule of berth and container cranes. Legato and Mazza (2001), Nishimura el al (2009), Imai, Sun, Nishimura, and Papadimitriou, (2005) , Moorthy and Teo (2006) have all carried out numerous studies on berth planning problems. Lee and Chen (2009) optimized the berth operation evaluating different arrivals patterns.

Statement of the Problem

It has been observed frequently that arrival of ships or vessels have to form wait-in-line and sometimes ships have to wait longer than necessary before berthing. In several cases, ships have to be diverted to other countries within the West African Coast like Republic of Benin etc. Onwemere (2008) observed that more ships will queue at the base and outside base waiting to get space at the terminal for berth age. Lack of adequate inland infrastructure to handle incoming containers give rise to the instance of congestion at the terminal, delays in final delivery of goods by importer's based on consequent increase in transportation and other costs (Maduka, 2004). Other reasons for this could be associated with strict compliance of policy by government requiring 100% physical examination of all containers; increasing traffic due to economic development; and the effects of circular-O2 that makes false declaration of goods punishable by imprisonment. With all these hurdles militating against the operations of the port, it therefore became absolutely necessary to devise ways of optimizing and improving the operations of the terminal. Sunish (2007), was of the opinion that wait-in-line model can be used to solve congestion problems. However, a similar study was carried out by Oyetoye, Adebiyi, Okoye & Amole (2011) who examined problems of congestion in Nigerian Ports but failed to examine how the model can be used to decongest the Port. Hence this study intends to examine the application of this model on decongestion of container terminal at the Tin Can Island Port Apapa, Lagos State.

Objective of the Study

The main objective of the study is to examine the application of Wait-in- Line Model on container terminal decongestion at the Tin Can Island Port, Apapa, Lagos. The specific objective is to investigate the traffic intensity at the container terminal using wait-in-line method.

Literature Review

Theoretical Framework

Wait-in-line model also known as queuing model dates back nearly 100 years with the work of. Erlang in 1909 in a paper titled: The Theory of probability and telephone conversation. His work laid the foundation for Poisson and exponential distribution in queuing theory as a toll for performance evaluation of computer systems and components of computer systems. Presently, queuing theory is divided into two branches; the theory permits the derivation and calculation of several performance measures including the average waiting time in the queue or the system, the expected number of waiting or receiving service, and the probability of encountering the system in certain state (empty or full) having an available server or having to wait a certain time to be served (Hervey, 2002). There are others who have contributed to the development of Queuing theory namely Kendall (1918-2007), who through its work identified some basic elements of queues names input process, service mechanism, system capacity and service discipline.

Little in 1961 through research discovered that the average number of customers in systems is equal to the average arrival rate of the customer to the system multiplied by the average system time per customer. Queuing Theory is the mathematical study of waiting lines, or queues. The theory enables mathematical analysis of several related processes, including arriving at the (back of the) queue, waiting in the queue (essentially a storage process), and being served at the front of the queue.

Zoran and Brainslav (2005), states that Queuing Theory is a collection of mathematical models of various queuing system. It is used extensively to analyze production and service processes exhibiting random variability in market demand (arrival times) and processes.

In shipping industry, port container terminal productivity can be measured in two types of operations. First is the vessel operation, which involves discharge and loading of container onto vessel. The other one is receiving and delivering operations, where container transfers to and from outside trucks (Kim and park, 2003). Productivity in port container operation is key determinant for the cost of providing container stevedoring services which involves the whole scenario of container terminal when productivity of particular terminal is being questioned by clients. Meyrick and associates and Tasman Asia Pacific (1998) report, there are two partial productivity measure used in port productivity studies. First is annually lifts per employee (labor productivity), and is defined as the number of container movements (container lifts) per terminal employee. The other is net crane rate (capital productivity), and it is defined as the number of container movements (container lifts) per net crane hour. This is the key word of an efficient container terminal when it report only high productivity to their stakeholders.

Many varieties of container terminals exist mainly depending on which type of handling equipments are combined to form a terminal system. Koshnevis and Asef-Vaziri (2000) defined three performance analysis variables including throughout, space utilization and equipment utilization. Kozan (2000) discussed the major factors influencing the transfer efficiency of seaport container terminals by developing a network model. Nishimura et al. (2001) implemented Lagrange's method for optimizing the container yard operation. Similar studies in this field were carried out by Nam and Ha (2000), Lie et al. (2002), Vis and de Koster (2003), and Murty, Liu, Wan and Linn (2003). Berth planning problems may be formulated as a different combination of optimization problems, depending on the specific objectives, and restrictions that have to be observed.

Legato and Mazzo (2001), Nishimura et al. (2001), Imai et al. (2005), Moorthy and Teo (2006) have all carried out numerous studies on berth planning problems. Lee and Chen (2009) optimizing the berth operation by evaluating different arrival patterns. Nowadays, the logistics activities, especially at large container terminals, have reached a degree of complexity that further improvement through interaction of scientific solutions are required. Simulation models have become the viable tools for decision-making in port activities. Kia, Shayan, & Ghotb (2002) investigated the performance of a container terminal in relation to its handling techniques and the impact it made on the capacity of terminals. Parola and Sciomachen (2005) presented a discrete event simulation modeling approach related to the logistic chains of an intermodal network. Bielli, Boulmakoul & Rida (2006) provided a help-tool in a port decision support system implementation simulation via java environment. Froyland, Koch, Megow, Duane, E. & Wren, H. (2008) presented an algorithm to manage the container exchange facility, including the allocation of delivery locations for trucks and other container carries. Zeng and Yang (2009) developed a simulation optimization method for scheduling loading operations in container terminals. The time trucks spend at a terminal for loading/unloading of cargo (truck turn-around time) is a real cost scenario which affects the overall cost of the container trade. Historically, truck turn-around times have received a very little attention from terminal operators because landslide congestions have never been a barrier to their smooth operations. Truck turn-around times are the times that a truck takes to complete an activity such as picking up an import container. As shown in the studies conducted by Regan and Golob (2000), Klodzinski and Al-Deek (2000) and Huynh and Walton (2005), by optimizing the truck turn-around times and thereby the landslide shipping cost, terminals would gain a competitive advantage in the industry. Murty, Liu, Wan and Linn (2003) have described a variety of inter-related decisions made during daily operations at a container terminal. Their goal was to minimize the waiting time of customer trucks.

Conceptual Framework

Wait-in-line causes inconvenience to economic costs of individuals and organizations. Hospitals, airlines, banks, manufacturing firms, seaports etc, must be efficient in other to minimize the total waiting cost and the cost of providing service to their customers. Therefore, speed of service is increasingly becoming a very important competitive parameter (Katz, Larson & Larson, 1991). Davis et al. (2003) assert that providing ever- faster service with the ultimate goal of having zero customers waiting time, has recently received managerial attention for several reasons.

First, in the more highly developed countries, where standard of living are high, time becomes more valuable as a commodity and consequently, customers are less willing to wait for service. Secondly, there is a growing realization by organizations that the way they treat their customers today significantly impact on whether or not their services will encourage customer loyalty. Finally, advances in technology such as global telephone link, computers and internet etc. have provided firms with ability to provide faster services. For these reasons, some administrators, physician and managers are continuously finding means to deliver faster services, believing that the waiting period will affect their service evaluation negatively, (Nosek and Wilson, 2001). Sanish (2007) in his article on application of queuing to the traffic at New Mangalore Port refers to Wait-in-Line Model as an analytical technique accepted as a valuable tool for solving congestion problems. According to him, the primary inputs to the models are the arrival and service patterns. There patterns are generally described by suitable random distribution. He observed that the arrival rate of ships follow Erlang Poisson Distribution while the service time follows Exponential Distribution. He also observed that the model can be used to predict some important parameters like average waiting time of ships, average queuing length, average number of ships in the ports and average berth or terminals utilization factor closer to the actual values.

Cochran and Bhati (2006) also argued that higher operational efficiency of the hospital is likely to help to control the cost of medical services and consequently to provide more affordable care and improve access to the public. Addressing the problem of queuing involves a trade-off between the cost of customers waiting time and the cost of providing faster service. Researchers have argued that service waits can be controlled by two techniques: operations management or production management. The operation management aspects deal with the management of how patients (customers), queues and serves can be coordinated towards the goal of rendering effective service at the least cost (Katz et al., 1991). Adebayo, Ojo and Obamiro (2006) stressed that many situations in life requires one to line up or queue before being attended to. The lines formed are referred to as waiting lines or queue. According to them queue occurs when the capacity of service provided falls short of the demand for the service.

Kandemir and Cavas (2007), says that Wait-in-line are formed when demand for a service exceeds its supply or when resources are limited. Obamiro (2003) opined that for many patients or customers wait-in-line or queuing is annoying.

Wait-In-Line Model Formulation

An 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/ trucks wait in a single line and move to the next available server. However, this is a different situation from one in which each sever has a distinct queue, such as highway tollbooths, bank teller windows, or super market checkout lines. In such situations customers might "jockey" for position between servers (channels). Jockeying is the process of customers leaving one waiting line to join another in a multiple 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 must meet the following assumptions:

1. The waiting line must have two or more identical servers.
2. The arrivals must follow a Poisson probability distribution with a mean arrivals rate (?)
3. The service times must follow an exponential probability distribution
4. The mean service rate; (?) "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, formulas are developed for determining the operations and measurement of the variables.

Service channels will be measured by looking at the number of service points and queues such that when vessels arrived in the system either at a regular interval or at random, the expected number in the system can be measured and expected number being served can also be measured.

λ = Arrival rate

μ = Service rate

λ = Traffic intensity = λ/μ

LS = Expected number of customers in system = Lq + λ/μ

Lq = Expected number of customers in the queue

Ws = Expected waiting time in the system = Wq + $1/\mu$

Where

Wq = Expected waiting time in the queue

c = Number of servers

Facility utilization, Fu = ?/c

Capacity utilization will be dealt with by measuring the actual output per potential output i.e by measuring the probability of no vessels at the terminal on arrival.

NOTE: Po = c! (1-?) n=c-1
(?c) c+c! (1- ?) ? n = 0 1/n (Pc)n

Source: John A. B. (2010). Queuing theory and its application. New York University. Toronto Canada.

Other measures are:

Cost of server = Server cost + customer waiting cost

Service cost = Labour cost of service + Any expenditure incurred as a direct consequence of providing services.

Waiting cost is based on the average number of customer in the system. This is given by:

Total Cost = Wc (λ/μ-?) - Sc (Note: For Further Studies)

Source: John A. B. (2010).

Operatonalization of Variables

Decongestion is taken as the dependent variable while maritime model is the independent variable. Decongestion is measured using Wc, Wq and ? while wait-in-line model is measured usingλand μ. Mathematically, this is expressed as follows:

D = f (Ws, Wq & ?) and

W-L-M = f (λ, μ)

For this study, the following relations were used

Ws = Expected waiting time of vessels in the system

Wq = Expected waiting time in the queue

Fu = Facility Utilization

p = Traffic intensity

λ = Arrival rate

μ = Service rate

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Model for the Study

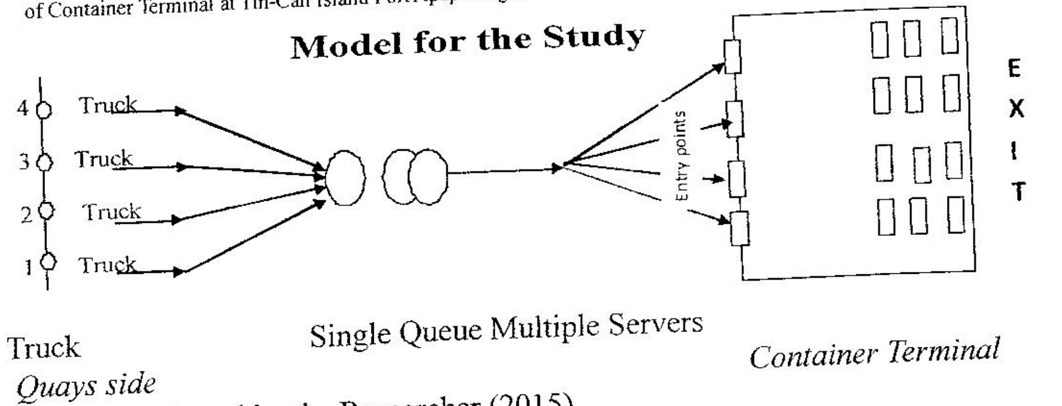

Figure 1. Developed by the Researcher (2015).

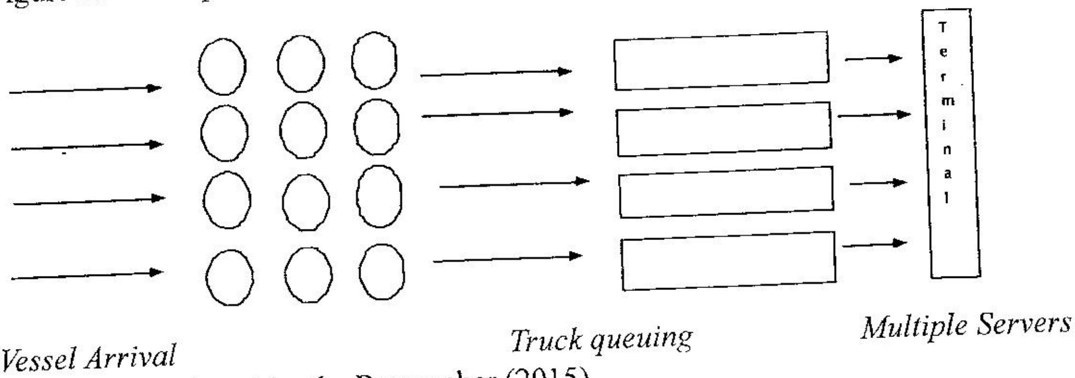

Figure 2: Developed by the Researcher (2015)

Components of the Model

Wait-in-line is 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 queue capacity. Adebayo 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 the 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 arrival, 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 arrival entities. The major features which must be specified are the number of servers and duration of the service.

The service channel: this refers to the number service points and queue.
Traffic Intensity: This is the ratio of the average arrival rate to the average service rate.
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)

Research Methods

Explanatory research design method was adapted for this study.. Data used for the study were collected from secondary sources which includes past records of operational activities from Nigeria Port Authority (Tin Can Island Ports Administrators), policy papers of government, papers presented by Maritime stakeholders including journals aimed at decongesting the terminal.

Results and Discussions

Data collected were analyzed using descriptive statistics, Wait-in-Line Model with the aid of TORA software. Congestion problem at Tin Can Island Port (TIP) was modelled as a Single and Multi-Server queuing. However for decongestion multiple queue and multiple servers were introduced. Arrival of the vessels at Tin Can Island Port is from infinite source and service pattern is on First-Come-First-Serve (FCFS) priority rule. Data collected covered the periods January 2014 to December 2014.

Table 1: TRAFFIC INTENSITY DECONGESTION AT THE TIN CAN ISLAND (JANUARY-DECEMBER 2014).

Month	Total no of vessels at shore on arrival	Total number of vessels called at berth	Number of vessels awaiting berth	Percentage no of vessels at berth	Percentage no of vessels awaiting berth	Number of days in each months	Hours of operations per day	Lamda (λ)	Mu (μ)	Traffic intensity(ρ)	[illegible] vessels spent waiting to berth k = 1/u-x
uary	130	115	15	88.46	11.54	31	24 hrs	0.17	0.15	1.13	-50
ruary	112	94	18	83.93	16.07	29	24 hrs	0.16	0.1351	1.19	-39
rch	123	100	23	81.30	18.70	31	24 hrs	0.17	0.1344	1.23	-32
il	89	86	3	96.63	3.37	30	24 hrs	0.12	0.1194	1.04	-238
y	159	132	27	83.02	16.98	31	24 hrs	0.21	0.1774	1.20	-28
e	110	102	8	92.73	7.27	30	24 hrs	0.15	0.1417	1.08	-90
/	169	141	28	83.43	16.57	31	24 hrs	0.23	0.1895	1.20	-27
gust	144	126	18	87.50	12.50	31	24 hrs	0.19	0.1694	1.14	-41
tember	128	95	33	74.22	25.78	30	24 hrs	0.18	0.1319	1.35	-22
ober	160	110	50	68.75	31.25	31	24 hrs	0.22	0.1478	1.46	-15
vember	143	110	33	76.92	23.08	30	24 hrs	0.2	0.1528	1.30	-22
cember	121	93	28	76.86	23.14	31	24 hrs	0.16	0.125	1.30	-27

Source: Computation from data obtained from NPA Bulletin (2014)

The probability that there are zero queues or no ship in the queue (Po)

From the TORA table output, the Po column represents the probability that there are zero queues or no ship in the queue for each of the months. It can be deduced that the probability that there is no ship in the queue for the month of January when there is only one server is 0.028 which implies that the probability of ship being in the queue for the same month = 1 - Po, a simple mathematical manipulation shows that 0.972 which is 97% percent probability of ship joining the queue on arrival while an insignificant 0.03 percent is the probability of having zero on arrival. The same was done for all the months and was established that the queue for vessels on arrival at the terminal is significant throughout the year under review. Invariably, as the number of servers increases the number of queue reduces.

The average number of ships in the system for each month (Ls)

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 9 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.

The average time a ship spends in the system before being served (Ws)

The Ws column 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 57.86 hours which is almost 2½ days before joining the queue.

Also the TORA output also suggested for other months, the minimum hours under review was 41.78 hours for the month of July.

Conclusion and Recommendations

The operational inefficiency at the Port is one of the major determinants of queue thereby causing Port Congestion. It was observed that the mean waiting times on the queue (k) are all negative for all the months (see table 2) and by the foregoing analysis, the traffic intensity ? is greater than 1 for the various months. However, the servers when increased, ? was reduced drastically (?<1) up to when ? is less than 1 which leads to decongestion at the terminal.

* The authority should encourage the use of the port as container transit and not as container storage areas which will help in decongesting the terminal and enhance operational efficiency of port activities.
* Review of some existing policy that hindered the speedy clearance process by the custom Authority, such as physical examination instead of auto scan examination in line with international standard which automatically decongest the port environment.
* Vessel traffic service (VTS) that involves a traffic monitoring service for improving safety, efficiency of vessel traffic and production of the environment should be made effective and efficient with the supply of modern equipment by NPA for the discharge of their duties.
* There is need to enforce the 48hrs clearance of container at the container terminal to make them competitive and give way for decongestion.
* There is need to enforce standard operative procedures for development.
* There is need to check the presence of government agencies in the port on what they are doing and what they must not do.
* There is need to stream line container clearance procedures and ensure that the port can compete with others in western central Africa.
* There is need to have input of shippers council of Nigeria

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