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QUEUING THEORY APPLICATION AT TICKET WINDOWS IN RAILWAY STATIONS (A STUDY OF THE LAGOS TERMINUS, IDDO, LAGOS STATE, NIGERIA)

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ABSTRACT
Queuing is an inevitable situation experienced in everyday life. In any service system, a queue forms whenever current demand exceeds the current capacity to serve. In this paper, an analysis of the queuing situation at the ticket windows in the Nigerian Railway Corporation Lagos Terminus was carried out. To achieve this, primary data was obtained by observation and an appropriate queuing model was used to analyze the system and calculated its performance measures. Results showed that increasing the number of servers lead to a decrease in the average waiting time of passengers in queue and a decrease in the average waiting time of passenger in the system. Therefore by applying Queuing theory, the waiting time of passengers can be determined and improved upon. The study therefore recommends that management in railway stations can use results from queuing analysis in making decisions that increase the efficiency of operations at their ticket windows.

Keywords: Arrival rate, Service rate, Traffic intensity, Performance measures, Waiting times

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INTRODUCTION

Railway transportation is a major form of land-based transportation that convey large number of people and goods, using wheeled vehicles (trains and trams) that run on a track known as a railroad or railway. Railway transportation offers much potential because of its advantages like relative safety, dependability, affordability and the capability of transforming an economy through mass movement of people, goods and services (Igwe, Oyelola, Ajiboshin & Raheem, 2013). In Nigeria, railway transportation has been in existence since 1898, however in 1955, an Act establishing the Nigerian Railway Corporation (NRC) – giving it the right to construct and operate railway services in Nigeria – was passed into law (Akwara, Udaw & Ezirim, 2014). NRC also own and operate railway stations across the country with the Lagos Terminus as its busiest station. A railway station basically consists of at least one-track side platform and a station building. Inside the station building, various operations are carried out. The Ticketing operation is one of the most important operations carried out in a railway station, as tickets purchased by passengers enable access to services desired, while payments received from passengers form huge portions of revenue accrued from services offered by the station. In big stations like the Lagos Terminus, ticketing officers attend to passengers through barricaded windows known as “ticket windows”. In some railway stations, ticket windows are not sufficient and where enough windows are physically available, all may not be operational, resulting in queues. There are also observed cases where passengers are not seen at ticket windows for long periods, creating a situation where servers are idle for such periods. A lack of orderliness, owing to ticketing officers attending first to passengers they know, at the expense of other passengers that arrived earlier and cases of negative passenger behaviour (like collusion or jockeying), increase the waiting line dilemma at ticket windows. In addition, the inability of management in stations to determine the waiting times of passengers at their ticket windows and if these waiting times are adequate or to be improved on, add to the difficulty they face in solving queuing problems affecting their ticketing operations.

OBJECTIVES OF THE STUDY

The main objective of this paper is to analyze the queuing situation at ticket windows in railway stations, using the Lagos Terminus in Iddo, Lagos State, Nigeria as a reference point. Specifically, the study is set to:

1. observe the queuing system at the ticket windows.
2. identify problems arising from the observed queuing system.
3. establish an appropriate model for the queuing system with the aim of understanding and describing aspects of the problems identified.
4. attempt quantitative analysis of the performance measures of the model established.
5. determine the waiting times of passengers at the ticket windows and if these waiting times are affected by alterations in the queuing system.

LITERATURE REVIEW

The inconveniences associated with waiting in queue to access service (or receive action) are experienced by people, things and signals. Considering the railway transportation subsector in Nigeria, while it is generally believed that passenger patronage has dropped owing to high operational cost and inadequate funding, I wish to add that operational inefficiency as well as poor service delivery also contribute to this drop in patronage – a fact corroborated by Agunloye and Oduwaye (2011), where amongst other things, their study showed that 80% of railway transport patrons in Lagos metropolis agreed that services offered are ineffective and inadequate. Part of these poor services is experienced at the ticket windows in railway stations, especially in terms of their queuing situations. This problem is not limited to Nigeria alone as Shanmugasundaram and Umarani (2015) pointed out that getting tickets in an Indian railway station is difficult and the government battles to meet this ever increasing demand of almost a billion people. However, they affirmed that the application of queuing theory in tackling the problem has been feasible and effective. Yang, Li and Zhao (2014) conducted a study on “Passenger flow simulation in urban subway station based on Anylogic process and software” at the Hangzhou station in China and concluded that reducing passenger queuing time involves optimizing the queuing system by opening ticket windows in the station dynamically and at a reasonable cost during operation. Xu, Gao and Ou (2007) researched on “Service performance analysis and improvement for a ticket queue with balking customers”, focusing on queuing systems managed by ticket technology and showing that different ticket queues have significantly different balking probabilities when customer patience is low and system traffic is high. They proposed improvement in ticket queue technology, viewing it as a new area for researchers to explore, owing to its wide spread adoption in government agencies and commercial organizations. Moving a step further, Ghosal, Chaturvedi, Taywade and Jaisankar (2015) in their work on “Android application for ticket booking and ticket checking in suburban railways” proposed the use of online ticketing applications, mobile phones and other devices as a remedy to stress and tension endured by passengers standing in long queues to book tickets. The enthusiasm of stakeholders in applying queuing theory to improve their ticketing operations (especially using technology and innovation) is encouraging and should be used channeled into making good decisions for the benefit of the railway transport sub-sector in the country.

METHODOLOGY

The research design used in this study is the case study design. Primary data was obtained from direct observation of the queuing system at the ticket windows in the Lagos Terminus. Observation recording sheets, a stop watch and writing materials were the necessary tools to be used in data collection. The study population is made up of all passengers that come to the Lagos Terminus to purchase tickets and all servers that make the ticketing operation possible. The sample for the study is conveniently drawn from all passengers and servers involved in the ticketing operation from 11a.m to 4p.m, Monday to Friday, for a period of ten days.

Model specification:

Queuing theory uses models to represent various types of queuing systems encountered in real life. Basically, queuing models are logical descriptions of the behaviour of queuing systems. The appropriate queuing model for this study was established as:

M/M/c/∞/FCFS

The foregoing describes a queuing system with Poisson probability distributed arrival from an infinite calling population, exponentially distributed service time, multiple but identical servers in parallel, infinite system capacity and a first-come first-served queue discipline.

For this model, the following general assumptions were made:

1. Arrival of passengers followed a Poisson process.
2. Passenger arrival was independent and the arrival rate did not change overtime.
3. A single waiting line was formed and each arrival waited to be served regardless of the length of the queue.
4. Service times were exponentially distributed and the mean service rate was constant for each server.
5. The system had multiple but identical servers in parallel.
6. No passenger left the queue without being served.
7. Infinite capacity of the system.
8. First-come first-served queue discipline

Let λ = arrival rate
μ = service rate
c = number of servers
and ρ = Traffic intensity (= $\frac{\lambda}{c\mu}$),

The performance measures used in this study for the M/M/c/∞/FCFS queuing model, are given as follows:

(i) **Probability that the system is idle (P_o)**

$$P_0 = \left[\sum_{n=0}^{c-1} \frac{(c\rho)^n}{n!} + \frac{1}{c!}\left(\frac{(c\rho)^c}{1-\rho}\right)\right]^{-1}$$

(ii) **The average number of passengers in queue (L_q)**

$$Lq = \left[\frac{1}{(c-1)!} \left(\frac{\lambda}{\mu}\right)^c \left(\frac{(\lambda\mu)}{(c\mu-\lambda)^2}\right) \right] P_0$$

(iii) **The average number of passengers in the system (L_s)**

$$L_s = L_q + \frac{\lambda}{\mu}$$

(iv) **The average waiting time for a passenger in queue (W_q)**

$$W_q = \frac{L_q}{\lambda}$$

(v) **The average waiting time for a passenger in the system (W_s)**

$$W_s = W_q + \frac{1}{\mu}$$

The numbers of servers (c), as well as the values of the mean arrival rate (λ), mean service rate (μ) and the traffic intensity (ρ), are necessary in determining the performance measures for the model.

RESULTS AND FINDINGS

Presentation of analyzed data

Table 1: Summary and presentation of analyzed primary data for passengers that arrived and were served.

INPUTS	DAY 1	DAY 2	DAY 3	DAY 4	DAY 5	DAY 6	DAY 7	DAY 8	DAY 9	DAY 10
Number of passengers that arrived	442	396	401	423	415	433	409	381	397	401
Number of passengers served	421	381	382	395	407	406	390	374	384	392
Total Time of observation (hours)	5	5	5	5	5	5	5	5	5	5
C	2	2	2	2	2	2	2	2	2	2
Λ	88.4	79.2	80.2	84.6	83	86.6	81.8	76.2	79.4	80.2
μ	84.2	76.2	76.4	79	81.4	81.2	78	74.8	76.8	78.4
Ρ	0.5249	0.5197	0.5249	0.5354	0.5098	0.5333	0.5244	0.5094	0.5169	0.5115
P_0	0.3116	0.3160	0.3116	0.3026	0.3247	0.3044	0.3120	0.3250	0.3185	0.3232
Lq	0.3994	0.3845	0.3992	0.4305	0.3582	0.4237	0.3977	0.3569	0.3770	0.3625
Ls	1.4993	1.4239	1.4489	1.5014	1.3779	1.4902	1.4464	1.3756	1.4109	1.3855
Wq (hours)	0.0045	0.0049	0.0050	0.0051	0.0043	0.0049	0.0049	0.0047	0.0047	0.0045
Ws (hours)	0.0164	0.0180	0.0181	0.0178	0.0166	0.0172	0.0177	0.0181	0.0177	0.0173

Source: Authors' compilation

To have a holistic view of the queuing situation, the entire 10days is considered and analyzed using the same method. The results from this are shown below:

Table 2: Results from analyzed data for the entire 10 days of observation as a whole.

INPUTS	RESULTS FOR THE ENTIRE 10 DAYS
Total number of passengers that arrived in 10 days	4098
Total number of passengers served in 10 days	3932
Total time of observation in 10 days (hours)	50
C	2
λ	81.96
μ	78.64
ρ	0.5211
P_0	0.3148
L_q	0.3885
L_s	1.4307
W_q (hours)	0.0047
W_s (hours)	0.0174

Source: Authors' compilation.

The queuing model used in this study is generally referred to as the M/M/c queuing model, where c = number of servers = 2. If we consider increasing the servers from two to three and then four, we have the following:

Table 3: Reaction of the waiting times to increase in server

INPUTS	c = 2	c = 3	c = 4
ρ	0.5211	0.3474	0.2606
W_q (hours)	0.0047	0.0007	0.0001
W_s (hours)	0.0174	0.0134	0.0128

Source: Author's compilation

As servers increased from two to three, the average waiting time of a passenger in queue decreased from 0.0047hours (16.92seconds) to 0.0007hours (2.52seconds) which represents a total of 85.11% decrease. Also the average waiting time of a passenger in the system decreased from 0.0174hours (62.64seconds) to 0.0134hours (48.24seconds), representing 22.99% decrease in waiting. Furthermore, when the servers increased from three to four, W_q decreased from 0.0007hours (2.52seconds) to 0.0001hour (0.36seconds) representing a total of 85.71% decrease in waiting, while W_q decreased from 0.0134hours (48.24seconds) to 0.0128 hours (46.08seconds) representing a 4.48 % decrease in waiting. This is very important, as it shows that alterations can be applied to improve the queuing system and reduce waiting time of passengers.

CONCLUSION AND RECOMMENDATIONS

This paper demonstrates the importance of applying queuing theory in solving waiting line problems at ticket windows in railway stations. The results in this study showed that the waiting times of passengers can be measured and improved upon if necessary. The results also showed that servers can be assessed and judgments on their service rates are less difficult to make when queuing theory is applied. Based on the findings of this study, it is concluded that proper analysis of the queuing system at the ticket windows can aid the management of railway stations in making better decisions that can lead to a reduction in waiting lines at ticket windows, improve efficiency of the entire ticketing operation and ensure greater passenger satisfaction of services offered. The Nigerian Railway Corporation (NRC) can improve access to tickets by selling them in public places (other than their railway stations), through certified agents and on the internet through NRC approved online platforms. This will encourage better patronage and reduce waiting lines at ticket windows. In addition, services of trained Operations Research consultants are required to carry out periodic analysis of the queuing situation in railway stations and management in these stations should implement recommendations made by the consultants.

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