Development Of A Decision Support System In Determining Optimum Number Of Server For Nnpc Mega Petroleum Stations

Mbachu, Victor M. , Onyechi, Pius C., Ogunoh, Victor A.

Abstract: Customers queue up at the Nigerian National Petroleum Corporation (NNPC) mega stations to purchase the Premium Motor Spirit (PMS), Dual Purpose Kerosene (DPK) and Automotive Gas Oil (AGO) popularly called petrol, kerosene and diesel respectively in the country. The PMS usually has the highest demand due to its various uses, and the queue for the product at NNPC Mega station during period of scarcity (referred to here as peak periods) has varying average arrival rate at various time of the day. The waiting situation is exasperating to the customers and the management. Thus an operational plan module for determining basically the optimum number of active servers to salve the queue problem in the Stations, while attending to vehicles with minimum demand of 10 litres of PMS was developed. The following optimal active servers were obtained and recommended for the corresponded arrival rate of 1 car per minute to 4 cars per minute, at 72- 80% system utilization rate, a known average service rate of 0.457 cars per minute and average waiting time of 2.6954 minutes to 0.9737 minutes. Simulation of the system was done generating a model which suggests optimum number of server given arrival rates and average service rate.

1. Introduction

A queue, which could deteriorate to congestion if effective queue management decisions are not implemented, is a waiting line for service that forms either due to inability to meet up with arriving demands as a result of insufficient service capacity or due to stochastic nature of customer arrival and demand. All the components of production system are unhappy with lengthy and longer queue length and waiting time respectively. Unfortunately queuing inevitably occurs in the present world with explosive population demanding regular services like personal, public, transport, telecommunication, maintenance, computer, health and administrative services. It is therefore encountered almost every day in our daily lives in one form or another e.g. on our way to work, waiting for services in hospitals, phone booths, filling stations etc (Hiller and Lieberman, 2005). However, since waiting line is part of our daily life, all we should hope to achieve is to minimize its inconvenience to some acceptable levels. The basic strategy of combating queue build-up is by increasing the service capacity of a service facility. Some of the direct methods of increasing service capacity are by increasing the number of servers, increasing the speed of the servers, replacing the existing servers with faster ones etc.

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The quest to address the supply needs of petroleum products such as the Premium Motor Spirit (PMS), Dual Purpose Kerosene (DPK) and Automotive Gas Oil (AGO) popularly called petrol, kerosene and diesel respectively necessitated the introduction of NNPC Mega Petroleum Stations across Nigeria. Whenever these petroleum products are scarce in the country, the NNPC Mega Petroleum stations serves as a good and reliable source where consumers purchase these products due to quality and being the fact that the products are being sold at government approved prizes. A mega station is characterized by six pump dispensing devices with two nozzles on each pump, totaling twelve servers per station for PMS refill. This value seems arbitrarily fixed, and affects their queue performance. At maximum demand periods, service systems are being over utilized and customers queue up for longer time than necessary before being served while at minimum demand period, server idleness becomes high and increases running cost of operation. The need of however, developing a decision support system that gives a good tradeoff between system utilization and waiting time became imperative. This will assist the operations manager in deciding the minimum number of servers for each mega petroleum station that can serve both maximum and minimum demand periods.

2. Review of Past Work

In recent times, queuing theory and the diverse areas of its applications has grown tremendously. Takagi (1991) considered queuing phenomena with regard to its applications and performance evaluation in computer and communication systems. Obamiro (2003) Applied Queuing Model in Determining the Optimum number of Service Facility in Nigerian Hospitals. He however achieved this by determining some queuing parameters which enabled him to improve the performance of the system. Mgbemena (2010) was able to model the queuing system of some banks in Nigeria using regression analysis. In her work, she created queuing management software in MATLAB that shows at a glance, the behavior of the queuing system and the unit that needs attention at any time. The essence was to improve the customer service system in Nigerian banks. Chinwuko and Nwosu (2014) adopted the single line multi-server queuing existing model to analyze the queuing system of First Bank Nigeria PLC. In their work, they suggested a need to increase the number of servers in order to serve customers better in the case study organization. Ohaneme et al, (2011) proposed the single line multi-server queuing system which they simulated using c-programming to be adopted at the Nigerian National Petroleum Corporation (NNPC) Mega petroleum station in Awka, Anambra State in order to avoid congestion and delay of customers. Here, the queue performance at NNPC mega petroleum station Enugu and Owerri at peak demand period were evaluated, establishing a decision support system for operation management in the Mega petroleum stations.

3. Characteristics of Queuing System

The mechanism of the queuing process is very simple. Customers (not necessarily human customers) are arriving for service, waiting for service if it is not immediate, and leaving the system as soon as they are served. There are six basic characteristics of queuing processes which provide an adequate description of a queuing system: (1) arrival pattern of customers, (2) service pattern of servers, (3) number of service channels, (4) system capacity and (5) queue discipline. In usual queuing systems the arrival pattern of customers is stochastic. Queue discipline refers to the manner in which customers are selected for service when a queue has formed. The most common discipline is first come, first served (FCFS), but there are many others like last come, first served (LCFS) which is applicable in many inventory systems as it is easier to reach the nearest item; randomly selecting for service (RSS) independent of the arrival time of the customer; and a variety of priority schemes, the customers with higher priority being served ahead of the lower priority customers regardless of the order in which they arrived to the system.

4 Types of Queuing Systems

There are four major types of queuing system. Lapin (1981) broadly categorized queuing system structures into the following.

a. Single-server, Single-phase system:

This is a situation in which single queue of customers are to be served by a single service facility (server) one after the other. An example is bottles or cans of minerals or beer to be cocked in a production process. Diagrammatically it is depicted in figure 1

b. Single-server, Multiple-phases System:

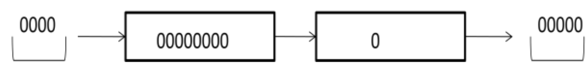
In this situation, there's still a single queue but customers receive more than one kind of service before departing the queuing system as shown in figure 2. For example, in the university, students first arrive at the registration desk, get the registration done and then wait in a queue for their forms to be signed, after signing; they join another queue for submission. Students have to join queue at each phase of the system.

c. Multiple-servers, Single-phase System:

This is a queuing system characterized by a situation whereby there is a more than one service facility (servers) providing identical service but drawn on a single waiting line. An example is a petroleum service station. As illustrated by figure 3.

d. Multiple servers, Multiple-phases System:

According to Singh (2007), this type of system has numerous queues and a complex network of multiple phases of services involved as can be seen in figure 4. This type of service is typically seen in a hospital setting, multi-specialty outpatient clinics, patient first form the queue for registration, and then he/she is triage for assessment, then for diagnostics, review, treatment, intervention or prescription and finally exits from the system or triage to different provider.



Arrivals Queue service facility Departures

Figure 1.: *Single-server, Single phase System.*
Source: Adopted from Obamiro (2003)

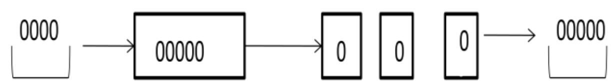


Figure 2*: Single-server, multiple phases System*
Source: Adopted from Obamiro (2003)

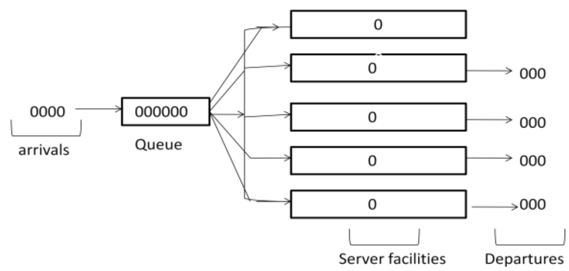


Figure 3: *Multiple-servers, Single phase System*
Source: Adopted from Obamiro (2003)

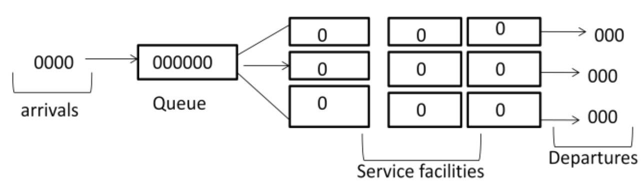


Figure 4: *Multiple-servers, Multiple-phase System*
Source: Adopted from Obamiro (2003)

5 Performance Evaluation of Queuing Systems

Hillier and Lieberman, (2005) put forth the following performance parameters in a queuing system:

a. System Utilization (p): System Utilization is the most important measure of a queuing system. It is the ratio of system capacity used to available capacity. It measures the average time the system is busy. System utilization of zero means that there is nobody in the system. On the other hand, a system utilization of one or more signifies that there is infinite number of people on the waiting line. This means that the available servers cannot cope with the arriving demand. Thus something has to be done on the service facility (Egolum, 2001). Based on Egolum (2001), System Utilization should be greater than 0 but less than 0.8.

b. Mean Number in the system (Ls): Mean number in the system is the average number of system users (entities) in the system; it includes those in the queue and those being served by the server(s).

c. Mean Number in Queue (Lq): Mean number in the queue is the average or expected number of system users in the queue (waiting line), waiting for their turn to be served.

d. The average waiting time for an arrival not immediately served (Wa)

e. Mean Time in System (Ws): Mean time in the system is the expected value or average waiting time an entity will spend in the queuing system. It includes the average time waiting for service to begin and the average service time.

f. Mean Time in Queue (Wq): Mean time in the queue is the expected value or average time an entity will spend in the queue, waiting for service to begin.

g. Probability of zero customers in the system (P_O)

h. Probability of waiting (Pw): This is the probability that an arrival will have to wait for its service to begin.

6 Methodology

The single line multi server queuing equations stated below were adopted and coded in Microsoft Excel which was used to develop the decision support system that generates the results of the queue performance at various arrival rates of customers in both case study establishments. The essence was to determine the best server utilization that can serve both maximum and minimum demand periods. Based on Egolum (2001), System Utilization should be greater than 0 but less than 0.8.Thus, system utilization was optimized towards the 80% limit as other parameters improves. This will however, assist in decision making as regards number of servers to be engaged for duty.

Single Line Multi Server Queuing Equations

i. The average utilization of the system:

$$\rho = \frac{\bar{\lambda}}{m(\bar{\mu})} \qquad (1)$$

ii. The probability that there are no customers in the system:

$$P_0 = \left[\sum_{n=0}^{M-1} \frac{\left(\frac{\bar{\lambda}}{\mu}\right)^n}{n!} + \frac{\left(\frac{\bar{\lambda}}{\mu}\right)^M}{M!\left(1-\frac{\bar{\lambda}}{M\mu}\right)}\right]^{-1} \qquad (2)$$

iii. The average number of customers waiting for service:

$$L_q = \frac{\bar{\lambda}\mu\left(\frac{\bar{\lambda}}{\mu}\right)^M}{(M-1)!(M\mu-\bar{\lambda})^2} P_0 \qquad (3)$$

iv. The average number of customers in the system:

$$L_s = L_q + (\bar{\lambda}/\bar{\mu}) \qquad (4)$$

v. The average time a customer spends in line waiting for service:

$$W_Q = \frac{L_Q}{\bar{\lambda}} \qquad (5)$$

vi. The average time a customer spends in the system:

$$W_s = \frac{L_s}{\bar{\lambda}} \qquad (6)$$

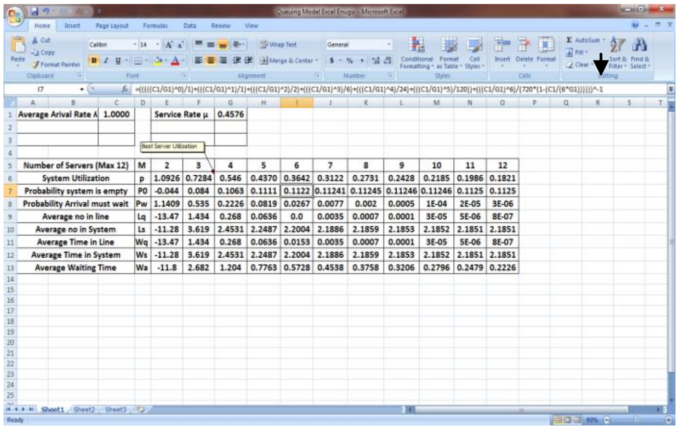
vii. The average waiting time of a customer on arrival not immediately served:

$$W_a = \frac{1}{M\mu-\bar{\lambda}} \qquad (7)$$

viii. Probability that an arriving customer must wait:

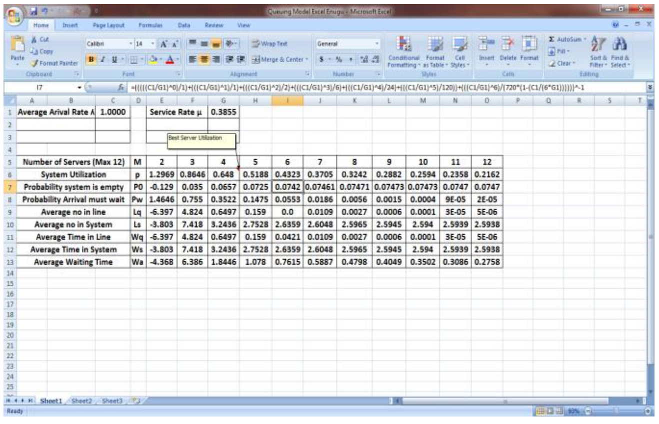
$$p_w = \frac{W_Q}{W_a} \qquad (8)$$

(Blanc, 2011; Sztrik, 2011; and Nain, 2004)



Average Arival Rate λ	1.0000		Service Rate µ	0.4576							
Number of Servers (Max 12)	M	2	3	4	5	6	7	8	9	10	11	12
System Utilization	p	1.0926	0.7284	0.546	0.4370	0.3642	0.3122	0.2731	0.2428	0.2185	0.1986	0.1821
Probability system is empty	P0	-0.044	0.084	0.1063	0.1111	0.1122	0.11241	0.11245	0.11246	0.11246	0.1125	0.1125
Probability Arrival must wait	Pw	1.1409	0.535	0.2226	0.0819	0.0267	0.0077	0.002	0.0005	1E-04	2E-05	3E-06
Average no in line	Lq	-13.47	1.434	0.268	0.0636	0.0	0.0035	0.0007	0.0001	3E-05	5E-06	8E-07
Average no in System	Ls	-11.28	3.619	2.4531	2.2487	2.2004	2.1886	2.1859	2.1853	2.1852	2.1851	2.1851
Average Time in Line	Wq	-13.47	1.434	0.268	0.0636	0.0153	0.0035	0.0007	0.0001	3E-05	5E-06	8E-07
Average Time in System	Ws	-11.28	3.619	2.4531	2.2487	2.2004	2.1886	2.1859	2.1853	2.1852	2.1851	2.1851
Average Waiting Time	Wa	-11.8	2.682	1.204	0.7763	0.5728	0.4538	0.3758	0.3206	0.2796	0.2479	0.2226

Figure 5: *Coding Environment of the decision support system displaying the results of the queue performance when average arrival rate ($\bar{\lambda}$) = 1.000, and average service rate (pr server) ($\bar{\mu}$) = 0.45764 cars/minutes with = 2 – 12 servers in NNPC Mega Petroleum Station Enugu.*



Average Arival Rate λ	1.0000		Service Rate µ	0.3855							
Number of Servers (Max 12)	M	2	3	4	5	6	7	8	9	10	11	12
System Utilization	p	1.2969	0.8646	0.648	0.5188	0.4323	0.3705	0.3242	0.2882	0.2594	0.2358	0.2162
Probability system is empty	P0	-0.129	0.035	0.0657	0.0725	0.0742	0.07461	0.07471	0.07473	0.07473	0.0747	0.0747
Probability Arrival must wait	Pw	1.4646	0.755	0.3522	0.1475	0.0553	0.0186	0.0056	0.0015	0.0004	9E-05	2E-05
Average no in line	Lq	-6.397	4.824	0.6497	0.159	0.0	0.0109	0.0027	0.0006	0.0001	3E-05	5E-06
Average no in System	Ls	-3.803	7.418	3.2436	2.7528	2.6359	2.6048	2.5965	2.5945	2.594	2.5939	2.5938
Average Time in Line	Wq	-6.397	4.824	0.6497	0.159	0.0421	0.0109	0.0027	0.0006	0.0001	3E-05	5E-06
Average Time in System	Ws	-3.803	7.418	3.2436	2.7528	2.6359	2.6048	2.5965	2.5945	2.594	2.5939	2.5938
Average Waiting Time	Wa	-4.368	6.386	1.8446	1.078	0.7615	0.5887	0.4798	0.4049	0.3502	0.3086	0.2758

Figure 6: *Coding Environment of the decision support system displaying the results of the queue performance when average arrival rate ($\bar{\lambda}$) = 1.000, and average service rate (pr server) ($\bar{\mu}$) = 0.38553 cars/minutes with = 2 – 12 servers in NNPC Mega Petroleum Station Owerri.*

7. Simulation Results of various Arrival Rate of Customers/Mins

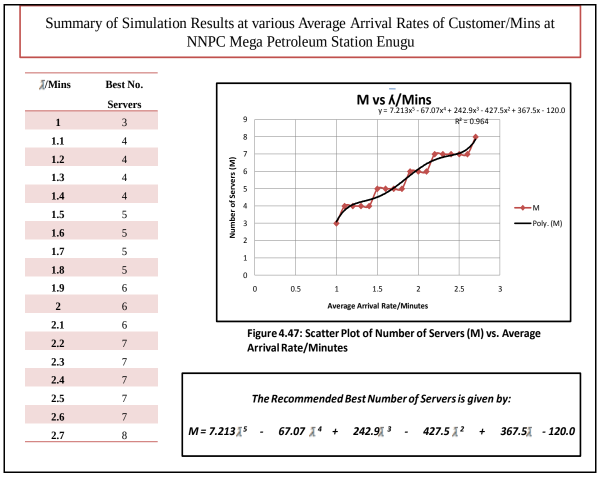


Figure 7: *Summary of Simulation Results at various Average Arrival Rates of Customer/Mins at NNPC Mega Petroleum Station Enugu*

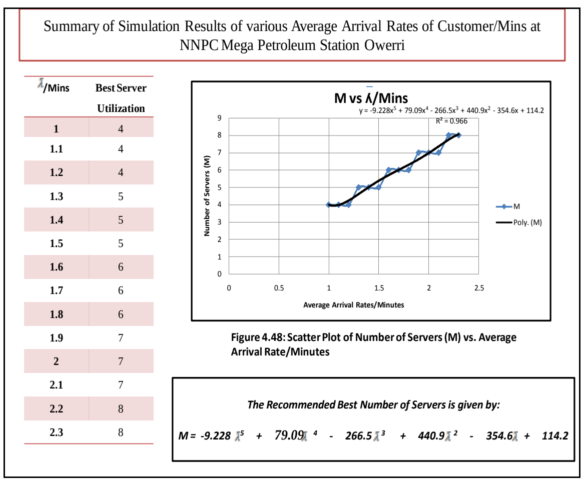


Figure 8: *Summary of Simulation Results at various Average Arrival Rates of Customer/Mins at NNPC Mega Petroleum Station Owerri.*

8. Conclusion

The evaluation of queuing system in an establishment is very essential for the betterment of the establishment. Most establishments are not aware on the significance of evaluating their queue performance. The implication of this is that they are not able to tell the minimum number of servers that can service their customers at peak periods. This results to customers spending longer time than necessary before receiving service. In respect of this, a decision support system has been developed using the application of Microsoft Excel which can be used in evaluating queue performance. The simulation of average arrival rates of customers in NNPC Mega Station Enugu and Owerri respectively using the developed decision support system gives the best server utilization at various arrival rates. This will assist in determining the best number of server that can serve both maximum and minimum demand periods. The developed support system can be adopted in any establishments but only applicable to where single line multi-server queues exist.

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