

Performance Evaluation of Queuing in an Established Petroleum Dispensary System Using Simulation Technique

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Abstract: There had always been chaotic situations in petrol service stations necessitated by the unhealthy environmental hazards created as a result of scarcity of the product in Nigeria in recent times. This unhealthy situation is brought about by long queues whenever petroleum product is in short supply that make buyers to either sleep in the filling station or spending greater period of their time looking for petroleum product for the whole day. The scarcity can be attributed either to artificial or deliberate actions by dealers especially during festive periods. The type of queuing system adopted in a business is an important factor in determining how efficient the business is run. The current queuing system in Nigeria National Petroleum Corporation (NNPC) Mega petroleum service station at Awka, South-East Nigeria is analyzed in which it is observed that the service points sell products randomly to available customers which result to long queues in the service points thereby increasing customers' waiting time. In this work, a single-channel, multiple-server model was developed. Kendall's notation (A/B/C/K/N/D) was used to describe the queue characteristic. Arrival time of customers, service and departure of customers occur continuously and independent of one another. Poisson probability distribution is used to estimate the number of arrivals per unit length of time. The facilities are in parallel arrangement and customers are served on the first come first serve (FCFS) queue discipline. The system has infinite queue system. The system is simulated using C-programming language. The results obtained show that there is a tremendous improvement in the efficiency of the customer services when the queuing system is strictly adhered to. This ensures that the average waiting time of the customers is drastically reduced.

Keywords: Queuing, DPK, PMS, average waiting time, poisson probability,

I INTRODUCTION

The quest to quell the prevailing problems of irregularities, congestions and delays experienced in the queuing system of Nigeria National Petroleum Cooperation (NNPC) Mega Filling Station in Awka, South-East Nigeria has been the desire of users of petroleum products in the area. These problems result in long queue which are found in this filling station always on daily bases. The long queues are normally experienced in the purchase of petroleum products like Dual Purpose Kerosene (DPK) and Premium Motor Spirit (PMS), popularly called kerosene and petrol in the country. Queuing is due to the randomness in service time and the principal actors are the customer and the server. The chaotic situations can be as a result of scarcity of petroleum products from the supply source which results in (i) creation of chaotic situations, (ii) customers having to wait for too long without being served, and (iii) impatient customers leaving thereby affecting the rate of economic growth. However the causes of congestion may include; (a) faulty fuel pump dispensary (meter), (b) inaccurate metering and high cost of fuel at other filling station, (c) location of the filling station, (d) inadequate service space and channels.

This work gives the vivid analysis of the proposed queuing model to be adopted in the filling station to find optimum utility service in petrol service stations. Having a good understanding of the behaviours of the processes involved will enable the management of this station to make intelligent decisions on staffing and capacity of the servers.

To study the entire system statistical queuing theory is deployed. Queue is associated with arrivals and services of components. It is an aspect of life we encounter regularly in our daily lives. Queues are formed, even when we are stopped at a traffic light. It represents a sequence of persons, vehicles etc waiting their turn of services. Queue exists in two basic forms; structured and unstructured queue [1]. However queue theory is the study of these organised sequences of items from a mathematical standpoint. In recent time queue models are of much relevance to the analysing of congestion and delay in communication networks, computer systems, transportation engineering etc. more recent investigation has centred on understanding the system components and how they interact. One method of analysing the performance of such systems is to approximate them by more tractable objects since they cannot be analysed in closed form because they are frequently heavily loaded. Queuing forms part of our daily activities, its application is widely pronounced in banking operations, filling stations, hospitals, traffic light junctions etc.

Queuing is unpleasant and cannot be avoided in as much as the number of persons arriving at the service centre is greater than the capacity of the service capability. However a good queue management technique will control the congestion by reducing waiting time. Queue helps to provide better services and also achieve higher efficiency. In PSTN, queuing allows the system to queue their customers request until free resources become available [2]. To design an effective congestion control algorithms, a good knowledge of the relationship between the congestion and delay is needed and queue theory have all the required tools for the analysis of queue system.

Queue theory is the mathematical study of waiting lines. It provides mathematical analysis of several related processes such as arriving at the queue, waiting in the queue and being served at the queue. Several performance measures (average waiting time in the queue, the expected number of waiting or receiving services and the probability of encountering the system in certain state) can be derived and calculated using queue theory.

This work therefore develop suitable queuing models for the NNPC mega station in Awka to determine the inter-arrival time, mean service time and mean waiting time for the customers. The models when implemented will help in reducing the waiting time of customers in the station thereby reducing the queue length. The data collected (i.e., vehicular traffic) are between 7am to 12pm only for three days while considerations are made only on Premium Motor Spirit (PMS), excluding Automotive Diesel Oil (AGO) and Dual Purpose Kerosene (DPK).

II Data Collection and System Design Analysis

The data was collected for three days during the NNPC's peak period. This is between the hours of 7.00am and 12.00pm. Stop-watch was used in the data collection of arrival time of customers, when service time starts and stops for the six servers reserved for the purchase of petroleum products by vehicles. From this analysis, the inter-arrival time and service time was calculated.

This work is concerned with the analysis and design of queuing system for Nigeria National Petroleum Company (NNPC) Mega Station, Awka, Anambra State, Nigeria using simulation method. When the system gets congested, the system delay increases and a long waiting time actually results in the customer's dissatisfaction causing the customer to leave the queue before service is rendered.

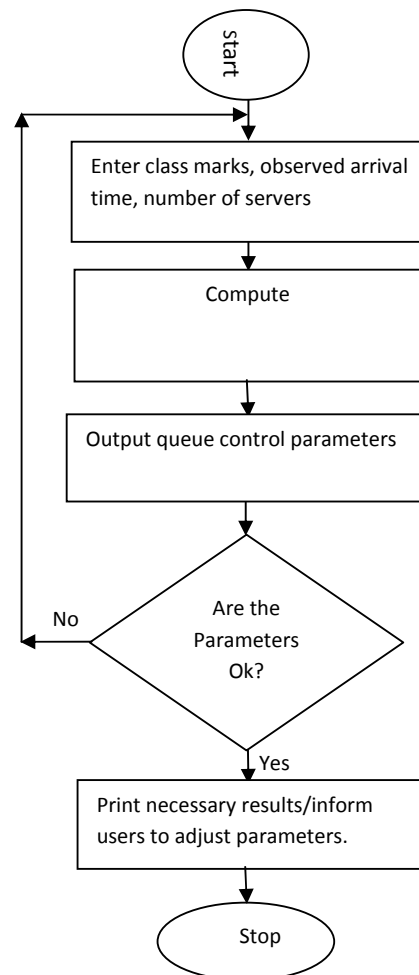


Figure 3: Activity diagram of queuing system

Any attempt to reduce the waiting time will increase investment. In line with this, it is necessary to access the queue formations in real life where attempts are made to test the models and their parameters. Analysing the system and the experiments using the performance metrics obtained will assist the management to make useful decisions on staffing their service system as well as server capacity to the extent

expected [3]. System analysis describes what systems do, identify the problem area and provide solution on how to meet the users' need.

The proposed system is an electronic based system that uses the supply parameters to calculate the best values to ensure cutting customers waiting time from when he joins the queue till when he makes an exit from the system to the barest minimum. This will result in reducing customers waiting time, increasing the financial inflow to the station as a result to increase in service rate and customer satisfaction, improving in customers' satisfaction level and above all reduce idleness of service pump attendants as a result of uneven distribution of queue length.

Tables 1 and 2 shows the data collected from NNPC Mega Station, Awka for inter-arrival time of customers and service time for six servers.

Let F_1 = Observed frequencies of inter-arrival time for day 1

F_2 = Observed frequencies of inter-arrival time for day 2

F_3 = Observed frequencies of inter-arrival time for day 3

Table 1: Results of inter-arrival time/ frequencies for 3 days							
Inter-Arrival Time (Minutes)	Class mark (T)	F_1	$F_1 t$	F_2	$F_2 t$	F_3	$F_3 t$
1-10	5.5	78	429	93	511.5	84	462
11-20	15.5	33	511.5	41	635.5	53	821.5
21-30	25.5	24	612	35	892	34	867
31-40	35.5	18	639	25	887.5	32	113.6
41-50	45.5	22	1001	34	1547	27	1228.5
51-60	55.5	60	3330	34	1887	32	1776
61-70	65.5	12	786	17	1113.5	17	1113.5
71-80	75.5	9	679.5	17	1283.5	15	1132.5
81-90	85.5	6	513	6	513	7	598.5
91-100	95.5	4	382	7	668.5	13	1241.5
101-110	105.5	9	949.5	7	738.5	12	1266
111-120	115.5	20	2310	14	1617	8	924
121-	125.5	4	502	11	1380	13	1631

130					5		5
131-140	135.5	1	135.5	9	1219.5	11	1490.5
141-150	145.5	4	582	2	291	5	727.5
151-160	155.5	2	311	4	622	4	622
161-170	165.5	2	331	4	622	1	165.5
171-180	175.5	16	2808	8	1404	3	526.5
Total		32	1684	368	17874	371	17730.5

The performance metrics for the entire system include:

- Inter-arrival time: inter-arrival for S number of days is the time duration between
- Mean inter-arrival time
- Service time
- Mean service time
- Average service rate
- Arrival rate
- Mean arrival rate
- Traffic intensity
- Probability that the system is idle

The mean inter-arrival time from data collected for day 1

$$\bar{t}_1 = \frac{\sum f_1 t}{\sum f_1} \tag{1}$$

$$= \frac{16812}{324} = 51.89 \sim 52 \text{ sec/car}$$

Hence arrival rate, $\lambda_1 = \frac{1}{\bar{t}_1}$

$$= \frac{1}{52} = 0.0192 \text{ car/sec}$$

$$= 1.152 \text{ car/min} \sim 1 \text{ car/min}$$

The mean inter-arrival time from data collected for day 2

$$\bar{t}_2 = \frac{\sum f_2 t}{\sum f_2} \tag{2}$$

$$= \frac{17874}{368} = 48.57 \sim 49 \text{ sec/car}$$

$$\lambda_2 = \frac{1}{\bar{t}_2} = \frac{1}{49} = 0.0204 \text{ car/sec}$$

$$= 1.224 \text{ car/min } 1 \text{ car/min}$$

The mean inter-arrival time from data collected for day 3

$$t_3 = \frac{\sum f_s t}{\sum f_s} \quad (3)$$

$$= \frac{17730.5}{371} = 47.79 \sim 48 \text{ sec/car}$$

$$\lambda_3 = \frac{1}{\bar{t}_3} = \frac{1}{48} = 0.0208 \text{ car/sec}$$

$$= 1.248 \text{ car/min } \sim 1 \text{ car/min}$$

The Average Inter-Arrival Times

$$T = \frac{t_1 + t_2 + t_3}{3} \quad (4)$$

$$= \frac{52 + 49 + 48}{3}$$

$$= \frac{149}{3}$$

$$= 49.66 \sim 50 \text{ sec/car}$$

III The Average Arrival Rate

$$\lambda = \frac{1}{T} \quad (5)$$

$$= \frac{1}{50} = 0.02 \text{ car/sec} = 1.2 \text{ car/min}$$

$$\sim 1 \text{ car/min}$$

Let F_1, F_2, F_3, F_4, F_5 and F_6 be observed frequencies of service time for servers 1 to 6.

	Service time interval (mins)		Total
	0-4	5-9	
F_1	62	23	85
$F_1 t$	124	161	285

F_2	66	19	85
$F_2 t$	132	133	265
F_3	60	22	82
$F_3 t$	120	154	274
F_4	57	24	81
$F_4 t$	114	168	282
F_5	59	24	83
$F_5 t$	118	168	286
F_6	65	18	83
$F_6 t$	130	126	256

The mean service time \bar{t} for servers 1 to 6 is given by (6) and the result of the service time and the service rate is shown in table 3

$$\bar{t}_s = \frac{\sum f_s t}{\sum f_s} \quad (6)$$

The service rate for the servers is given by

$$\mu_n = \frac{1}{\bar{t}_s} \quad (7)$$

where s ranges from 1 to 6 showing the number of servers.

No. of servers	\bar{t}_s (mins/car)	μ_s (cars/mins)
1	3.35	0.30
2	3.12	0.32
3	3.34	0.30
4	3.48	0.29
5	3.44	0.29
6	3.08	0.32

The average service time \bar{T}_s for the six servers is given by

$$\bar{T}_s = \frac{\sum \bar{t}_s}{s} \quad (8)$$

$$= \frac{\bar{t}_1 + \bar{t}_2 + \bar{t}_3 + \bar{t}_4 + \bar{t}_5 + \bar{t}_6}{6}$$

$$= \frac{3.35 + 3.12 + 3.34 + 3.48 + 3.44 + 3.08}{6}$$

$$= \frac{19.81}{6}$$

$$= 3.302 \sim 3 \text{ mins/car}$$

The Average Service Rate $\bar{\mu}_s$ is given by

$$\bar{\mu}_s = \frac{1}{T} \quad (9)$$

$$= \frac{1}{3} = 0.33 \text{ car/min}$$

IV Performance Measures for M/M/S Queue Model

To calculate any performance measures, the traffic intensity (ρ) and the probability that the system shall be idle (P_0) shall be first known.

The Traffic Intensity,

$$\rho = \frac{\lambda}{s\mu} \quad (10)$$

where λ = Arrival rate per minute

S = Number of Servers

M = Service rate per minute

$$\rho = \frac{1.2}{6 \times 0.33} = \frac{1.2}{1.98} = 0.606 \sim 0.61$$

The probability that the system shall be idle

$$P_0 = \left[\sum_{n=0}^{s-1} \frac{1}{n!} \left(\frac{\lambda}{\mu} \right)^n + \frac{1}{s!} \left(\frac{\lambda}{\mu} \right)^n \frac{s\mu}{s\mu - \lambda} \right]^{-1} \quad (11)$$

$$= \left[\sum_{n=0}^{6-1} \frac{1}{n!} \left(\frac{\lambda}{\mu} \right)^n + \frac{1}{6!} \left(\frac{\lambda}{\mu} \right)^n \frac{s\mu}{s\mu - \lambda} \right]^{-1}$$

Thus the percentage of idleness in the system will be 2.5%.

(1)

Expected Number of customers waiting in the queue L_q is given by;

$$L_q = \left[\frac{1}{(s-1)!} \left(\frac{\lambda}{\mu} \right)^s \frac{\lambda\mu}{(s\mu - \lambda)^2} \right] P_0 \quad (12)$$

(2) Expected Number of customers in the system L_s is

$$L_s = L_q + \frac{\lambda}{\mu} \quad (13)$$

(3) Expected waiting time of a customer in the queue W_s is

$$W_s = W_q + \frac{L_q}{\lambda} \quad (14)$$

(4) Expected Waiting time of a customer in the system W_s ,

$$W_s = W_q + \frac{1}{\mu} \quad (15)$$

V Simulating and Result Analysis

In this section, we will simulate a single line multi-server queuing system. The simulation is begun by identifying the problem of the queuing system and carefully modify the system. Our single line multi-server queuing system will operate with the principle of infinite queue length. The customers in the queue will be served by multiple servers [4]. The state of the system at any point is a set of relevant properties which that system has at that time. The state of the system can change if;

i.

customer arrives at the system. Then the state of the system will change in the sense that the customer can join the queue thereby increasing the queue length. If there are no customers in the queue, the arriving customer is served by the server immediately thus changing the system state from remaining idle to busy state.

ii.

customers whose services have been completed depart from the service facility thus changing the state of the system by reducing the queue length if there are still customers waiting in a queue for services or setting the new state of the system to be either busy or idle.

The system is finally simulated using software written in C-Programming language. This actually involves the replacement of an existing system with a new one. Once the program code is debugged and certified error free, and the system appears to be producing the desired result, the system change-over procedures start. The changeover can be direct, parallel or pilot. In direct changeover, an existing system has no resemblance of the new system. In this case the user decides to change automatically to the new system which should now be operational while the old (existing) system is discarded. Parallel changeovers refer to the comparison of the results of the existing and new systems in a view of getting satisfactory output thereby discarding the old system. Pilot changeover is applied where the new system is small in scope. With pilot changeover, it is possible to test it at a separate site before it is implemented on the operational environment. However, parallel changeover method is applied because it allows the new

system to be tested for reliability and to ensure that it satisfies the initial specification.

VI Conclusion

The revolution currently being experienced in the information technology sector has precipitated industries and commercial organizations to embrace queuing systems as the only sure means of providing value-added services to her customers. The need for this innovation cannot be overemphasized if our industries and commercial organizations want to be in the forefront of global industries and service delivery standard [5].

The queuing system is designed to provide fast, efficient, comfortable, cost effective and safe means of delivering services. The system eliminates the problem of time wastage, space constraint, risk and other associated negative issues experienced by customers.

Queuing systems if well implemented can enhance the service delivery to customers and will eliminate in its entirety the constraints inherent in insufficient servers and poor queuing organizations maximizing the usage of facilities potential with little effort. To this end, queuing system will definitely launch the industrial sector into a different dimension when fully implemented.

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