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MODELLING AN ATM QUEUING SYSTEM FOR SERVICE OPTIMIZATION: A CASE STUDY

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Abstract:
In our daily life we generally find a long queue at the ATM machine. As a result of this a customer has to spend considerable amount of time in queue. In line with the realization of the vision of the cash-less policy as being fronted by the Central Bank of Nigeria, this paper seeks to solve problems of long waiting time and queue lengths of customers known to be associated with the queuing system of the Automated Teller Machine (ATM), an indispensable piece of machinery for successful implementation of the policy. To this end, a single-channel queuing model with Poisson arrivals has been applied in modelling an ATM queuing system of First Bank of Nigeria, Panseke, Abeokuta, Ogun State in a bid to have a comprehensive mathematical picture of the queuing system of the bank's ATM. Primary data via observation method was employed which entails the arrival time of each customer over three periods; the first period was in the morning (8am to 9am), second period was in the afternoon (1pm to 2pm) and the third period was in the evening (4pm to 5pm). Lottery method of Simple Random Sampling technique was used in the selection of the ATM under study. Data collected were analysed for appropriate queuing parameters and measures of performance using R programming software, version 4.0.5. The findings show among others that steady state occurs for period 1 and 2 only since ρ (capacity utilization) is less than 1, while it is absent for period 3 since $\rho > 1$. In addition, the queue and waiting times are less between 8am and 9am and would probably result in gain of business, increase satisfaction of the customer and reduction of employee workload but relatively rise between 1pm and 2pm.

Keywords: ATM, Modelling, Queuing

1. Introduction

Every relationship is a game and banker-customer relationship is not an exception. The corporate objective of any bank which is maximization of shareholders' wealth can only be achieved if customers are retained and satisfied. This is in line with Philip Kotler's (1999) perception that the key to successful marketing of financial services is identification and packaging of customers' needs to their satisfaction. The competition in Nigerian

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banking sector is getting more intense, partly due to regulatory imperatives of universal banking and also due to customers' awareness of their rights. Bank customers have become increasingly demanding, as they require high quality, low priced and immediate service delivery. They want additional improvement of value from their chosen banks (Olaniyi, 2004).

Service delivery in banks is personal, customers are either served immediately or join a queue (waiting line) if the system is busy. A queue occurs where facilities are limited and cannot satisfy demand made against them at a particular period. However, most customers are not comfortable with waiting or queuing (Olaniyi, 2004). The danger of keeping customers in a queue is that their waiting time may amount to or could become a cost to them (i.e. bank customers). According to Elegalam (1978), customers are prepared not to spend more cost of waiting/queuing. The time wasted on the queue would have been judiciously utilized elsewhere (the opportunity cost of time spent in queuing).

Although there have been significant reforms in recent times all in an effort to maximize profit, reduce cost and satisfy customers optimally in the most generally acceptable international standard. Despite these entire sterling efforts one phenomenon remains inevitable: queue. It is a common practice to see a very long waiting line of customers to be serviced either at the Automated Teller Machine (ATM) or within the banking hall.

Though similar waiting lines are seen in places like; busstop, fast food restaurants, clinics and hospitals, traffic light, supermarket, etc. but long waiting line in the banking sector is worrisome be.

According to Sharma (2007), queue is a general phenomenon in everyday life. Queues are formed when customers (human or not) demanding service have to wait because their number exceeds the number of servers available; or the facility doesn't work efficiently or takes more than the time prescribed to service a customer. Some customers wait when the total number of customers requiring service exceeds the number of service facilities, some service facilities stand idle when the total number of service facilities exceeds the number of customers requiring service. Taha (2003) defines queue as simply a waiting line, while (Hiray, 2008) put it in similar way as a waiting line by two important elements: the population source of customer from which they can draw and the service system. The population of customer could be finite or infinite.

Waiting line management has the greatest dilemma for managers seeking to improve the on investment of their operation; as customers don't tolerate waiting intensely. Whenever customer feels that he/she has waited too long at a station for a service, they would either opt out prematurely or may not come back to the station next time when needed a service. This would of course reduce customer demand and in the long run revenue and profit. Moreover, longer waiting time might increase cost because it equals to more space or facilities, which mean additional cost on the management (Anderson, 2007).

Despite being in the technology era; line are experienced at within and Banks ATMs in developing nations than elsewhere. ATM are adopted so as to reduce waiting time, offers considerable ease to both the bank and their customers; as it enables customers to make financial transactions at more convenient times and locations, during and after banking hours. Most importantly, ATM, are designed to provide efficient and improved services to customers at the shortest possible time. Yet customers spend a considerable time before they are finally served. Businesses especially banks are striving very hard to provide the best level of service possible, minimizing the service time, giving the customer a much better experience. However, in situations where queue arises in a system, it is appropriate to attempt to minimize the length of the queue rather than to eliminate it completely; complete elimination may be infeasible Therefore, a systematic study of waiting line system would assist the management of the Bank in making certain decisions in an effort minimize the time a customer spends in a service facility.

The banking sector which is the largest and most competitive unit of Nigeria's financial sector, acting as a financial intermediary between the surplus and deficit agents of the economy has always been the center of attraction to many

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customers that want to carry out one transaction or the other through the services provided by these banks. However, the major problem is the inability of the banks to match their service facilities to the needs of customers without much delay.

The common experience in Nigeria is that most banks do not have the facilities and capacities to service the number of customers without much delay on the part of the customers. The problem in this regard had been that though bank customers for instance, have always been desirous of spending the least possible time in banking transactions, this age-long desire is yet to be met by the banks. Banks on the other hand, want to attract, retain customers and at the same time optimize profit. Profit making in banks is a function of management ability to provide efficient services to customers at little or no time wastage (Agbadudu, 1996). One major recurring problem in Nigerian Banks is congestion at the banking halls; this has led to the movement of customers from one bank to the other, where they can obtain banking services without much delay.

Despite technological advancement in the banking sector, such as Internet Banking, Mobile or Telephone Banking, Automated Teller Machine (ATM) and so on by banks in attempt to minimize waiting line problem at over-the counter services have not yielded the much desired result due to frequent breakdown of such computerization and fraudulent activities. Hence, long queue persisted in almost all Nigerian banks.

Application of the analytical queuing models in studying and analyzing ATM waiting lines with the hope of reducing this unhealthy phenomenon in the banking systems have been shown in Olatokun and Igbinedion (2009), Ogunwale and Olubiyi (2010), Vasumathi and Dhanavanthan (2010), Al-Jumaily and Al-Jabori (2012). A good number of researchers in the past have assumed the poisson arrival distribution, the exponential service time distribution and automatically applied the M/M/1 or the M/M/c queue models in solving the problem of long waiting time of customers and server over utilization not minding whether the arrival distribution is Poisson or not and whether or not the service time distribution is exponential. The common recommendation made by these researchers is that the number of ATMs should be increased thereby incurring new cost of purchase, installation and maintenance not considering the speed of the machines.

It is to this effect that these researchers have then gone ahead to model an ATM queuing system for service optimization using First Bank of Nigeria Limited as a case study.

2. Scope of the study

This work covers the examination of the queuing system of a randomly selected (out of a population of 8) ATM of First Bank of Nigeria Limited located at the Panseke area in Abeokuta, Ogun State, Nigeria. It entails the arrival time of each customer over three periods; morning (8am to 9am), afternoon (1pm to 2pm) and evening (4pm to 5pm). This work covers the FIFO-Queue method to optimization queues in bank.

3. Objectives of the study

The broad objective of the study is to examine an ATM service optimization of using queuing model. The specific objectives are to:

(i) determine customers' average arrival rate and service rate of the ATM;

(ii) ascertain average (or expected) number of customers in the queue and in the ATM;

(iii) ascertain the average (or expected) time a customer spend in the queue and in the ATM;

(iv) determine the probability that there will be no customer in the queue.

4. Assumptions made on the system

(1) Single channel queue.
(2) There is an infinite population from which customers originate.
(3) Poisson arrival (Random arrivals).
(4) Exponential distribution of service time.
(5) Arrival in group at the same time (i.e. bulk arrival) is treated as single arrival.
(6) The waiting area for customers is adequate.
(7) The queue discipline is First In First Out (FIFO).

5. Literature review

Unmanaged queues are detrimental to the gainful operation of service systems and results in a lot of other managerial problems. Queuing theory deals with the mathematical description of behavior of queues. Queuing theory can be applied to a variety of operational situations where it is not possible to predict accurately the arrival rate of customers and service rate of service facilities. In particular, it can be used to determine the level of service (either the service rate or the number of service facilities). The problems of queues at various sectors have been studied and the key reasons which result into long queues have been identified. The suitable queuing models have been developed for different queues by studying the arrival and service patterns of customers.

Bankley et al. (2006) cited in Musara and Fatoki (2010) opine that technology provides enhanced insight into handling old and new tasks. Technology has changed not only the way we do business but has also changed virtually all sphere of human life. Abor (2005) affirms that technology affects even the direction of an economy and its capacity for continued growth. Human beings consciously or unconsciously interact with products of technology in almost all their daily activities. These products have made the performance of activities which hitherto were carried our stressfully and unproductively much more convenient, faster, easier and more accurate.

In the banking industry, information and communication technology is playing a major role in addressing operational challenges such as quicker exchange of data, information processing, record storage and retrieval and many more.

In Nigeria, a study conducted by Olaniyi (2004) revealed a positive correlation between arrival rates of customers and bank's service rates. He concluded that the potential utilization of the banks service facility was 3.18% efficient and idle 68.2% of the time. However, Ashley (2000) asserted that even if service system can provide service at a faster rate than customers arrival rate, waiting lines can still form if the arrival and service processes are random.

One week survey conducted by Elegalam (1978) revealed that 59.2% of the 390 persons making withdrawals from their accounts spent between 30 to 60 minutes while 7% spent between 90 and 120 minutes. Bale (1996) while paraphrasing Alamatu and Ariyo (1983) observed that the mean time spent was 53 minutes but customers prefer to spend a maximum of 20 minutes. Their study revealed worse service delays in urban centres (average of 64.32 minutes) compared to (average of 22.2 minutes) in rural areas. To buttress these observations, Juwah (1986) found out that customers spend between 55.27 to 64.56 minutes making withdrawal from their accounts. Efforts in this study are directed towards application of queuing models in capacity planning to reduce customer waiting time and total operating costs.

Kassum et al (2006) did a comparative analysis of queue efficiency of old and new generation banks in ille-Ife, IIlorin. The study revealed that the time spent on queue for services in old generation bank is in aggregate longer than the new generation bank. Furthermore, new generation banks were found to be more efficient in timely service delivery than the old generation banks. Similarly, Ogunwale and Olubiyi (2010) did a comparative analysis of waiting time of customers in Guaranty Trust Bank (GTB) and Union Bank in Ado-Ekiti. Data were collected by observation in respect of the number of persons being served and the number of arrivals for 21days. The study revealed that the traffic intensity in Union bank is 0.47 while that of GTB is 0.22. The probability of no customer in the system of Union bank is 0.36 while the probability of no queue in GTB is 0.16. The average time spent in the system of Union Bank is 1minute 40 seconds while that of GTB was 1minute. The average waiting time of customers in Union Bank is 0.60minute and that of GTB was 0.01 minute. They concluded that the time spent in queuing and servicing is much less in GTB than that of Union Bank.

Kembe et al (2012) investigated a study of waiting and service costs of a multi-server queuing model in a specialist hospital in Makurdi. Queuing characteristics were analyzed using a multi-server queuing model and the waiting and service costs determined with a view to determining the optimal service level. The data were analyzed using TORA optimization software as well as using descriptive analysis. The results of the analysis showed that average queue length, waiting time of patients as well as overutilization of doctors at the clinic could be reduced at an optimal server level of 12 doctors and at a minimum total cost as against the present server level of 10 doctors with high total cost which include waiting and service costs.

Patel and Bhathawala (2012) used the Little's theorem and M/M/1 queuing model to examine bank ATM queuing model in India. The study revealed that the arrival rate at a bank ATM on Monday during banking time is one (1) customer per minute while the service rate is 1.66 customers per minute. The average number of customer in the ATM is 1.5 and the utilization period is 0.60. Anichebe (2013) investigated queuing model as a technique of queue solution in Nigeria banking industry. Descriptive research method was employed in carrying out the study at United Bank for Africa, Gariki branch, Enugu through observation, interview and questionnaire administration. The variables measured include arrival rate and service rate. They were analyzed for simultaneous efficiency in customer satisfaction and cost minimization through the use of a multi-channel queuing model, which were compared for a number of queue performances such as the average number of customers in the queue and in the system, average time each customer spends in the queue and in the system and the probability of the system being idle. It was discovered that that using a three-server system was better than a two-server or four-server systems in terms of performance criteria used and the study inter-alia recommended that management should adopt a three-server model to reduce total expected costs and increase customer satisfaction. Similarly, Sheikh, Singh and Kashyap (2013) examined the application of queuing theory for improvement of banking service in India. The M/M/Z/: FCFS model was converted into M/M/1: FCFS to know which one was more efficient, a line or more lines. The findings of the study revealed that the efficiency of commercial banks was improved by the queuing number, the service stations number and the optimal service rate. The time of customer queuing is reduced and customer satisfaction is increased. It proved that the optimal model of the queuing is feasible.

Additionally, Bakari et al (2014) evaluated the queuing process and its application to customer service delivery in Fidelity Bank PLC, Maiduguri. The data for the study was collected from primary source and was limited to ATM service point of Fidelity Bank PLC located in West-end, Maiduguri. Data was collected during working hours (i.e. 8am to 4pm) over ten (10) working days. The study revealed that the traffic intensity (utilization factor) is 0.96 which indicates that the system operates under a steady-state condition. Thus the value of the traffic intensity, which is the probability that the system is busy, implies that 95% of the time period considered during data collection the system was busy as against 4% idle time. This indicates high utilization of the system. Yakubu and Najim (2014) examined the application of queuing theory to ATM service optimization in Ghana. Direct nonparticipatory observation and questionnaire were engaged to record time measurements and primary data. Measurements were taken on arrival times and service times of customers who arrived at the terminal within the hours of 8am to 4pm. The chi-squared Goodness of Fit test was performed on collected data. The M/M/s queuing model was used to illustrate the ATM queuing system of the bank. A queuing theory based decision support system was developed as a result and applied to analyze and suggest improvement in waiting time. Two ATMs at a service rate of 0.60 customers per minute was found to be optimal for the case bank albeit waiting time were found to be relatively higher during the hour of 11am to 1pm and month ending. The study further revealed that although queuing theory was applied in finding optimal service level, waiting time might still be lengthy because of external factor of service unavailability of ATM.

6. Methodology

Data for this study was collected from a randomly selected ATM service point of First Bank of Nigeria PLC, Panseke branch, Abeokuta, Ogun State. The method employed during data collection was direct observation. Data were collected for a randomly selected working day over three periods; morning (8am to 9am), afternoon (1pm to 2pm) and evening (4pm to 5pm). The population of the study is infinite and

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arrival rate was random. The variables measured include arrival rate and service rate. The arrival times of all customers as they arrive randomly were recorded, the time they start being served and the time the service was completed were also recorded. Data collected were analysed for appropriate queuing parameters and measures of performance using R programming software, version 4.0.5.

7. Model specification

Queuing Model with Single Queue and a Single ATM [(M/M/1): (/FCFS)].

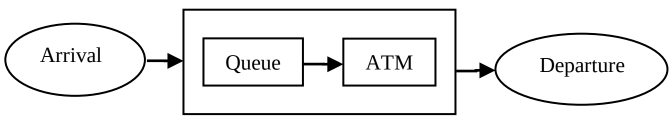

Fig. 1: Single Queue with a Single Server

This model is based on certain assumptions about the queue system:

(i) Arrivals are described by Poisson probability distribution and come from an infinite population.
(ii) Single waiting line and each arrival waits to be served regardless of the length of the queue (i.e. infinite capacity) and that there is no balking or reneging.
(iii) Service times are exponentially distributed.
(iv) Customers are served FCFS (First Come, First Served) basis.
(v) Customer's arrival is independent but the arrival rate (average number of arrivals) does not change over time.
(vi) To achieving a steady-state condition and for the empirical results to be valid, the average arrival rate must be less than the average service rate (i.e. $\lambda<\mu$). If λ μ, the geometric series will not converge, and the steady-state probabilities will not exist.

Parameters in Queuing model

(i) n = Number of total customers in the system (in queue plus in service)
(ii) λ = Arrival rate [1/ (average number of customers arriving in each queue in a system
(i) in one hour)]
(ii) μ = serving rate [1/ (average number of customers being served at a server per hour)]
(iii) s = number of service channel channels (service facilities or servers)
(iv) p = System intensity or load, utilization factor (the expected factor of time the server
(v) is busy). P = λ/μ

Performance Measure

Notations and their Description for Single Server Model (Fig. 1) assuming the system is in steady-state condition are as follows:

(a) The utilization factor for the system (ρ), that is, the probability that the ATM is being used or busy.

$$\rho = \lambda / \mu$$

ρ must be less than 1 for there to be a steady state. Otherwise, customers are tending to arrive faster than they can be served. The queue will grow and grow. The formula above gives impossible results if ρ is 1 or bigger.

(b) The probability that the ATM is idle (P_0) that is, the probability of no customer in the ATM.

$$P_0 = 1 - \rho$$

(c) The average number of customers in the ATM (L_s)

$$L_s = \frac{\rho}{1-\rho} = \frac{\lambda}{\mu - \lambda}$$

(d) The average (or expected) number of customer waiting for the service in the queue (L_q)

$$L_q = \frac{\rho^2}{1-\rho} = \frac{\lambda^2}{\mu(\mu - \lambda)}$$

(e) The average (expected) waiting time a customer spends in the ATM (W_s).

$$W_s = \frac{1}{\mu - \lambda} = \frac{L_s}{\lambda}$$

(f) The average (expected) waiting time a customer spends in the queue W_q.

$$W_q = \frac{\lambda}{\mu(\mu - \lambda)} = \frac{L_q}{\lambda}$$

(g) The expected length of non-empty queue (L):

$$L = \frac{\mu}{\mu - \lambda}$$

(h) The variance (fluctuation) of queue length

$$Var(n) = \frac{\rho}{(1-\rho)^2} = \frac{\lambda n}{(\mu-\lambda)^2}$$

8. Data presentation

Table 1: Morning period (8:00:00 AM to 9:00:00 AM)

Arrival time	Inter-Arrival time	Number of people in Queue	Service time	Departure time
8:00:00	0:00:00	4	0:02:00	8:02:00
8:02:00	0:01:00	6	0:02:40	8:04:40
8:04:40	0:03:00	2	0:02:20	8:07:00
8:07:00	0:01:00	6	0:01:20	8:08:20
8:08:20	0:00:00	3	0:01:00	8:09:20
8:09:20	0:01:00	2	0:00:45	8:10:05
8:10:05	0:01:00	1	0:01:00	8:11:05
8:11:05	0:02:00	0	0:00:30	8:11:35
8:11:35	0:00:00	1	0:01:00	8:12:35
8:12:35	0:01:00	5	0:00:25	8:13:00
8:13:00	0:02:00	7	0:00:45	8:13:45
8:13:45	0:00:30	2	0:00:50	8:14:35
8:14:35	0:00:00	1	0:01:00	8:15:35
8:15:35	0:01:00	0	0:00:30	8:16:05
8:16:05	0:00:00	2	0:00:50	8:16:55
8:16:55	0:01:00	3	0:00:30	8:17:25
8:17:25	0:00:30	4	0:00:30	8:17:55
8:17:55	0:00:00	5	0:00:30	8:18:25
8:18:25	0:00:00	2	0:01:00	8:19:25
8:19:25	0:00:00	0	0:01:00	8:20:25
8:20:25	0:00:00	6	0:01:30	8:21:55
8:21:55	0:01:00	1	0:01:00	8:22:55
8:22:55	0:00:00	3	0:00:30	8:23:25
8:23:25	0:01:00	0	0:00:30	8:23:55
8:23:55	0:00:00	1	0:00:30	8:24:25
8:24:25	0:00:00	2	0:00:45	8:25:10
8:25:10	0:00:00	0	0:00:40	8:25:50
8:25:50	0:01:00	1	0:00:30	8:26:20
8:26:20	0:00:30	0	0:00:50	8:27:10
8:27:10	0:00:00	1	0:00:40	8:27:50
8:27:50	0:00:30	1	0:00:20	8:28:10
8:28:10	0:00:40	3	0:00:45	8:28:55
8:28:55	0:00:00	2	0:01:00	8:29:55
8:29:55	0:00:00	1	0:01:00	8:30:55
8:30:55	0:01:00	0	0:00:30	8:31:25
8:31:25	0:00:00	2	0:00:50	8:32:15
8:32:15	0:01:00	3	0:00:30	8:32:45
8:32:45	0:00:30	4	0:00:30	8:33:15
8:33:15	0:00:00	5	0:00:30	8:33:45
8:33:45	0:00:00	2	0:01:00	8:34:45
8:34:45	0:00:00	0	0:01:00	8:35:45
8:35:45	0:00:00	6	0:01:30	8:37:15
8:37:15	0:01:00	1	0:01:00	8:38:15
8:38:15	0:00:00	3	0:00:30	8:38:45
8:38:45	0:01:00	0	0:00:30	8:39:15
8:39:15	0:00:00	1	0:00:30	8:39:45
8:39:45	0:00:00	2	0:00:45	8:40:30
8:40:30	0:00:00	0	0:00:40	8:41:10
8:41:10	0:01:00	1	0:00:30	8:41:40
8:41:40	0:00:30	0	0:00:50	8:42:30
8:42:30	0:00:00	6	0:01:30	8:44:00
8:44:00	0:00:01	0	0:01:00	8:45:00
8:45:00	0:00:02	4	0:01:05	8:46:05
8:46:05	0:00:25	1	0:02:00	8:48:05
8:48:05	0:00:00	0	0:03:00	8:51:05
8:51:05	0:01:00	2	0:02:00	8:53:05
8:53:05	0:02:00	2	0:03:00	8:56:05
8:56:05	0:00:00	1	0:02:00	8:58:05
8:58:05	0:01:00	2	0:00:40	8:58:45
8:58:45	0:00:30	0	0:01:00	8:59:45
8:59:45	0:00:35	3	0:00:20	9:00:05

Source: *First Bank of Nigeria ATM, Panseke Branch (2021).*

Table 2: Afternoon period (1:00:00 to 2:00:00)

Arrival time	Inter-Arrival time	Number of people in Queue	Service time	Departure time
1:00:00	0:00:00	2	0:01:00	1:01:00
1:01:00	0:01:00	3	0:02:30	1:03:30
1:03:30	0:02:00	3	0:02:00	1:05:30
1:05:30	0:01:00	4	0:01:00	1:06:30
1:06:30	0:01:00	3	0:01:00	1:07:30
1:07:30	0:00:00	2	0:01:00	1:08:30
1:08:30	0:01:00	1	0:00:45	1:09:15
1:09:15	0:00:00	1	0:01:00	1:10:15
1:10:15	0:01:00	0	0:02:10	1:12:25
1:12:25	0:01:00	2	0:01:00	1:13:25
1:13:25	0:01:00	1	0:00:30	1:13:55
1:13:55	0:01:00	0	0:01:00	1:14:55
1:14:55	0:01:00	0	0:02:00	1:16:55

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1:16:55	0:02:00	1	0:00:30	1:17:25
1:17:25	0:00:00	3	0:00:40	1:18:05
1:18:05	0:00:30	2	0:00:30	1:18:35
1:18:35	0:00:30	1	0:01:00	1:19:35
1:19:35	0:00:00	0	0:01:00	1:20:35
1:20:35	0:01:00	0	0:01:00	1:21:35
1:21:35	0:02:00	2	0:00:50	1:22:25
1:22:25	0:00:00	0	0:02:00	1:24:25
1:24:25	0:02:00	1	0:01:00	1:25:25
1:25:25	0:01:00	2	0:01:00	1:26:25
1:26:25	0:00:00	0	0:01:00	1:27:25
1:27:25	0:01:00	1	0:01:00	1:28:25
1:28:25	0:01:00	2	0:00:50	1:29:15
1:29:15	0:00:50	2	0:01:10	1:30:25
1:30:25	0:01:10	3	0:00:30	1:30:55
1:30:55	0:00:30	3	0:00:30	1:31:25
1:31:25	0:00:30	4	0:00:30	1:31:55
1:31:55	0:00:00	5	0:01:00	1:32:55
1:32:55	0:00:00	2	0:01:00	1:33:55
1:33:55	0:01:00	0	0:01:00	1:34:55
1:34:55	0:01:00	2	0:00:30	1:35:25
1:35:25	0:01:00	0	0:00:30	1:35:55
1:35:55	0:00:00	1	0:01:00	1:36:55
1:36:55	0:01:00	2	0:01:00	1:37:55
1:37:55	0:00:00	0	0:00:30	1:38:25
1:38:25	0:01:00	2	0:01:00	1:39:25
1:39:25	0:00:00	2	0:01:00	1:40:25
1:40:25	0:01:00	2	0:00:40	1:41:05
1:41:05	0:00:00	0	0:00:30	1:41:35
1:41:35	0:00:00	0	0:02:00	1:43:35
1:43:35	0:00:40	1	0:01:20	1:44:55
1:44:55	0:01:20	1	0:00:30	1:45:25
1:45:25	0:00:30	1	0:00:30	1:45:55
1:45:55	0:00:00	0	0:00:30	1:46:25
1:46:25	0:00:00	0	0:00:30	1:46:55
1:46:55	0:00:30	1	0:00:40	1:47:35
1:47:35	0:00:30	1	0:00:40	1:48:15
1:48:15	0:00:00	0	0:03:00	1:51:15
1:51:15	0:01:00	2	0:02:00	1:53:15
1:53:15	0:02:00	2	0:03:00	1:56:15
1:56:15	0:00:00	1	0:02:00	1:58:15
1:58:15	0:01:00	2	0:00:40	1:58:55
1:58:55	0:00:30	0	0:01:00	1:59:55

Source: *First Bank of Nigeria ATM, Panseke Branch (2021).*

Table 3: Evening period (4:00:00 PM to 5:00:00PM)

Arrival time	Inter-Arrival time	Number of people in Queue	Service time	Departure time
4:00:00	0:00:00	4	0:02:00	4:02:00
4:02:00	0:01:00	6	0:02:40	4:04:40
4:04:40	0:03:00	2	0:02:20	4:07:00
4:07:00	0:01:00	6	0:01:20	4:08:20
4:08:20	0:00:00	3	0:01:00	4:09:20
4:09:20	0:01:00	2	0:00:45	4:10:05
4:10:05	0:01:00	4	0:01:00	4:11:05
4:11:05	0:02:00	7	0:00:30	4:11:35
4:11:35	0:00:00	4	0:01:00	4:12:35
4:12:35	0:01:00	5	0:00:25	4:13:00
4:13:00	0:02:00	7	0:00:45	4:13:45
4:13:45	0:00:30	2	0:00:50	4:14:35
4:14:35	0:00:00	4	0:01:00	4:15:35
4:15:35	0:01:00	6	0:00:30	4:16:05
4:16:05	0:00:00	2	0:00:50	4:16:55
4:16:55	0:01:00	4	0:00:30	4:17:25
4:17:25	0:00:30	4	0:00:30	4:17:55
4:17:55	0:00:00	5	0:00:30	4:18:25
4:18:25	0:00:00	5	0:01:00	4:19:25
4:19:25	0:00:00	3	0:01:00	4:20:25
4:20:25	0:00:00	7	0:01:30	4:21:55
4:21:55	0:00:00	5	0:00:50	4:22:45
4:22:45	0:01:00	5	0:00:30	4:23:15
4:23:15	0:00:30	4	0:00:30	4:23:45
4:23:45	0:00:00	5	0:00:30	4:24:15
4:24:15	0:00:00	4	0:01:00	4:25:15
4:25:15	0:00:00	5	0:01:00	4:26:15
4:26:15	0:00:00	6	0:01:30	4:27:45
4:27:45	0:01:00	6	0:00:30	4:28:15
4:28:15	0:00:00	2	0:00:40	4:28:55
4:28:55	0:01:00	4	0:00:35	4:29:30
4:29:30	0:00:30	5	0:00:00	4:29:30
4:29:30	0:00:01	2	0:00:30	4:30:00
4:30:00	0:00:23	4	0:01:00	4:31:00
4:31:00	0:00:24	5	0:00:45	4:31:45
4:31:45	0:00:30	4	0:00:30	4:32:15

4:32:15	0:00:00	3	0:01:00	4:33:15
4:33:15	0:01:00	3	0:01:30	4:34:45
4:34:45	0:00:00	3	0:01:20	4:36:05
4:36:05	0:00:00	6	0:01:30	4:37:35
4:37:35	0:00:01	2	0:01:00	4:38:35
4:38:35	0:00:02	4	0:01:05	4:39:40
4:39:40	0:01:00	5	0:00:25	4:40:05
4:40:05	0:02:00	7	0:00:45	4:40:50
4:40:50	0:00:30	2	0:00:50	4:41:40
4:41:40	0:00:00	3	0:01:00	4:42:40
4:42:40	0:01:00	5	0:00:25	4:43:05
4:43:05	0:02:00	7	0:00:45	4:43:50
4:43:50	0:00:30	2	0:00:50	4:44:40
4:44:40	0:00:00	4	0:01:00	4:45:40
4:45:40	0:00:02	4	0:01:05	4:46:45
4:46:45	0:01:00	5	0:00:25	4:47:10
4:47:10	0:02:00	9	0:00:45	4:47:55
4:47:55	0:01:00	6	0:00:30	4:48:25
4:48:25	0:00:00	2	0:00:40	4:49:05
4:49:05	0:01:00	4	0:00:35	4:49:40
4:49:40	0:01:00	6	0:00:30	4:50:10
4:50:10	0:00:00	5	0:00:40	4:50:50
4:50:50	0:01:00	7	0:00:35	4:51:25
4:51:25	0:00:30	4	0:00:00	4:51:25
4:51:25	0:00:01	3	0:00:30	4:51:55
4:51:55	0:00:23	3	0:01:00	4:52:55
4:52:55	0:00:02	4	0:01:05	4:54:00
4:54:00	0:01:00	5	0:00:25	4:54:25
4:54:25	0:02:00	9	0:00:45	4:55:10
4:55:10	0:01:00	6	0:00:30	4:55:40
4:55:40	0:00:00	4	0:00:40	4:56:20
4:56:20	0:01:00	4	0:00:35	4:56:55
4:56:55	0:01:00	6	0:00:30	4:57:25
4:57:25	0:00:02	4	0:01:05	4:58:30
4:58:30	0:01:00	5	0:00:25	4:58:55
4:58:55	0:02:00	7	0:00:45	4:59:40
4:59:40	0:00:30	5	0:00:50	5:00:30
5:00:30	0:00:00	3	0:01:00	5:01:30
5:01:30	0:01:00	5	0:00:25	5:01:55

Source: *First Bank of Nigeria ATM, Panseke Branch (2021).*

9. Data analysis

Table 4: Queuing parameters and measure of performance for the three periods

Parameter	**Period 1** (8am to 9am)	**Period 2** (1pm to 2pm)	**Period 3** (4pm to 5pm)
λ	0.50	0.74	0.72
μ	0.89	0.92	0.63
ρ	0.5618	0.8043	1.1429
L_s	1.28	4.11	-
L_q	0.72	3.31	-
W_s	2.56	5.55	-
W_q	1.44	4.46	-
P_0	0.4382	0.1957	-

Table 5: Probability of n number of customers existing in the system for the periods

n	Period 1 (P_n)	Period 2 (P_n)	Period 3 (P_n)
0	0.4382	0.1957	-
1	0.2462	0.1574	-
2	0.1383	0.1266	-
3	0.0777	0.1018	-
4	0.0437	0.0819	-
5	0.0245	0.0659	-
6	0.0138	0.0530	-
7	0.0077	0.0426	-
8	0.0043	0.0343	-
9	0.0024	0.0276	-
10	0.0014	0.0222	-

10. Discussion of results

The findings show that steady state occurs for Periods 1 and 2 only (ρ < 1), while it is absent for Period 3 (ρ > 1). For Period 1, the capacity utilization (ρ) of 0.5618 implies that the server is busy 56.18% of the time. P_0 – the probability that there is no customer in the queue is estimated as 0.4382 i.e. there is approximately 43.82% chance that there will be no customer in the queue at a point in time. L_s – Average numbers of customers in the system at a point is 1.28, L_q – Average number of customers waiting in the queue is 0.72, W_s – Average waiting time in system is 2.56 minutes and W_q– Average waiting time in queue is 1.44 minutes.

For Period 2, the capacity utilization (ρ) of 0.8043 implies that the server is busy 80.43% of the time. P_0 – the probability that there is no customer in the queue is estimated as 0.1957 i.e. there is approximately 19.57% chance that there will be no customer in the queue at a point in time. L_s –

Average numbers of customers in the system at a point is 4.11, L_q – Average number of customers waiting in the queue is 0.3.31, W_s – Average waiting time in system is 5.55 minutes and W_q – Average waiting time in queue is 4.46 minutes.
For Period 3, the measure of performance (L_s , L_s , W_s , W_q and P_n) gives impossible results, which are negative values, since the capacity utilization (ρ) is greater than 1. This implies that customers are tending to arrive faster than they can be served between 4pm and 5pm.

11. Conclusions

On the basis of the scope of the study and analysis of the data, it can be concluded that the queue and waiting times are less between 8am and 9am and would probably result in gain of business, increase satisfaction of the customer and reduction of employee workload but relatively rise between 1pm and 2pm. More also, customers are tending to arrive faster than they can be served between 4pm and 5m. This may not be unconnected with the fact that the period is the closing hour of majority of employees. Since the percentage of time the ATM will be busy is higher than 50% for the periods, the ATM performance can be considered acceptable, though it could be improved.

12. Recommendations

The bank management should key into the use of queuing model for constant evaluation of their ATM for service optimization. Regular upgrading of the operating system of each automated teller machine, to enhance efficiency should be prioritized. The management should also make sure that all the automated teller machines are dispensing at all times especially between 4pm and 5pm when employees are expected to be closing for the day. Poor power supply to the ATM could slow down the service rate; as such alternative power supply should be considered.

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