AN INVESTIGATION OF THE PERFORMANCE LEVELOF AUTOMATED TELLER MACHINES (ATMs) QUEUEING SYSTEM A CASE STUDY OF STANBIC IBTC BANK MINNA, NIGER STATE, NIGERIA

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Abstract
In this paper, the performance level of Stanbic IBTC Bank Automated Teller Machines (ATMs) queuing system located in Minna Central has been effectively investigated using a multiple server queuing model (M/M/S). The data used in the research was collected for a period of five working days from 8am to 6pm. It was found that the queuing system has an arrival rate of 0.54 customers per minute which is equivalent to 32 customers per hour and the service rate of 0.79 customers per minute also equivalent to 47 customers per hour. The machines have a total busy time of 3.418 hours with an idle time of 6.582hours in the total of the 10 banking hours considered in a day. It was also observed that a customer spent a total of 1.434 minutes in the system where the utilization factor of the system is 0.3418(34.18%). This result indicates a good service delivery level of the Automated Teller Machines (ATMs) and there is no need for an additional ATM at the location. We however recommend that a preventive maintenance should be routinely carried out on ATMs to maintain the existing service delivery by the machines.

Keywords: ATMs, Customers, IBTC Bank, Minna, Queuing System, Stanbic IBTC Bank

Introduction

Queues are waiting lines or a sequence of people, vehicles waiting to be attended to or served. It is a common practice to see a very long waiting lines of customers to be serviced either at the Automated Teller Machine (ATM) stand, in a banking hall, a post-office, supermarkets, hospitals, beauty stores, restaurants, employees in an organization waiting to enter the elevator, vehicles waiting at filling stations to be served and passengers. As it is well known that waiting for so long on a queue usually leads to customers' dissatisfactions as a results of waiting cost incur by them and providing too much service capacity involves excessive costs on the path of service providers, hence there is need to balance this conflicting cost through acceptable scientific techniques that will assist the management of an organization for optimal decision making. The aim of this research is to investigate the performance level of Stanbic IBTC Automated Teller Machines located in Minna Central with a view to providing the management of the bank with information that will be used to provide optimal service delivery to her customers without incurring unnecessary cost. Many researchers have tried to help several organizations with information that will assist them in best decision making, among them are: Nsude et al., (2017) studied the ATM queuing system of First Bank of Nigeria Afikpo branch, Ebony State, Nigeria focusing on multiple-lines, multiple server queuing systems of the bank. Based on the results of their study, they suggested that, there is need to reduce the number of servers in the bank from four to three to reduce the idle time of the servers and also reduce the operation cost. Presented in (Shastrakar & Pokley, 2017) is a study on the waiting time of customer to deposit electricity bill at a cash counter. The researchers through their study observed that the percentage of idle workstation is approximately 50%, utilization factor and probability of no customer in the system are near about equivalent. They concluded that the system has the capacity to accommodate more customers. Thomas (2014) research on how to reduce customer waiting time and improve service processes. The objective was to reduce the average time a customer spent in the system, focusing on customer waiting time as well as other areas that can be improved. Sundarapandian (2009) reviewed the use of queuing theory in pharmacy application with particular attention to improving customer satisfaction. Customer satisfaction was improved by predicting and reducing waiting times and adjusting staffing. The study and application of queuing models have also been reported in; (Adamu, 2015), (Damondhar & Shastraka, 2018), (Munirat et al., 2015), (Nityangini & Pravin, 2016), (Shastrakar & Pokley, 2017) and (Sushil et al., 2017).

Materials and Methods

Data used for this research was collected from Stanbic IBTC Bank Plc ATM service point, located in Minna Central, Niger state, Nigeria for a period of five working days from 8:00am to 6:00pm for the two ATMs available at the point. The methods employed during data collection was direct observation of customers where their arrival time and service time were recorded directly in real time into a form that was designed for the research.

The M/M/S Model

The model adopted in this research is M/M/S (∞ /FCFS) it is a Multi-server Queuing Model, for this queuing system, it is assumed that the arrivals follow a Poisson probability distribution at an average of λ customers per unit of time. It is also assumed that they are served on a first-come, first-served basis by any of the ATMs. The service times are distributed exponentially, with an average of μ customers per unit of time and number of servers S (ATMs). If there are n customers in the queuing system at any point in time, then the following two cases may arise:

(i) If n < S, (number of customers in the system is less than the number of ATMs), then there will be no queue. However, (S – n) number of ATMs will not be busy. The combined service rate will then be $\mu_n = n\mu$; n < S

(ii) If n ≥ S, (number of customers in the system is more than or equal to the number of ATMs) then all ATMs will be busy and the maximum number of customers in the queue will be (n – S). The combined service rate will be $\mu_n = S\mu$; n ≥ S.

From the model, the probability of having n customer in the system is given by

The probability of n customers in the queuing system is given by

$$P_n = \begin{cases} \dfrac{\rho^n}{n!} P_0 & ; n \le s \\ \dfrac{\rho^n}{s!\, s^{n-s}} P_0 & ; n > s \end{cases} \tag{1}$$

where n is the number of customer(s), s is the number of servers and ρ is the utilization factor of the system.

The probability that the ATM is idle (P_o) that is, the probability of no customer at the ATMs stand is given by

$$p_o = \left[\sum_{n=0}^{s-1} \frac{1}{n!} (\lambda/\mu)^n + \frac{1}{s!} (\lambda/\mu)^s \left(\frac{s\mu}{s\mu - \lambda}\right) \right]^{-1} \tag{2}$$

Expected number of customers waiting in the queue (i.e. queue length)

$$L_q = \left[\frac{1}{(s-1)!} \left(\frac{\lambda}{\mu}\right)^s \frac{\lambda\mu}{(s\mu - \lambda)^2} \right] p_0 \tag{3}$$

Expected number of customers in a system

$$L_s = L_q + \frac{\lambda}{\mu} \tag{4}$$

Expected waiting time of a customer in the queue

$$W_q = \left[\frac{1}{(s-1)!} \left(\frac{\lambda}{\mu} \right)^s \frac{\lambda\mu}{(s\mu - \lambda)^2} \right] p_o = \frac{L_q}{\lambda} \tag{5}$$

Expected waiting time that a customer spends in a system

$$W_s = W_q + \frac{1}{\mu} \tag{6}$$

Utilization factor i.e. the fraction of time servers is busy

$$\rho = \frac{\lambda}{s\mu} \tag{7}$$

The probability that on arrival a customer must wait for service

$$P_s = \frac{1}{s!} \left(\frac{\lambda}{\mu} \right)^s \left(\frac{s\mu}{s\mu - \lambda} \right) P_0 \tag{8}$$

Results and Discussion

The summary of data collected for a period of five working days (Monday - Friday) from 8am-6pm is presented in Table 1

Table 1

Days	Inter-Arrival Time (MIN)	Service Time for ATM 1 (MIN)	Service Time for ATM 2 (MIN)	Total No of Customers
Monday	594	444	358	307
Tuesday	601	409	414	356
Wednesday	595	403	370	300
Thursday	596	407	381	289
Friday	599	454	451	365
Total	2985	2117	1974	1617

From Table 1, we obtain the following:

1. Average Inter-Arrival time for each Day = $\frac{total\ inter-arrival\ time\ for\ each\ day}{total\ no\ of\ customers\ for\ each\ day}$

Hence, Average inter-arrival time for Monday is= $\frac{594}{307} = 1.935$ minutes

Average inter-arrival time for Tuesday is= $\frac{601}{356} = 1.688$ minutes

Average inter-arrival time for Wednesday is= $\frac{595}{300} = 1.983$ minutes

Average inter-arrival time for Thursday is= $\frac{596}{289} = 2.062$ minutes

Average inter-arrival time for Friday is= $\frac{599}{365} = 1.641$minutes

2. The Average service time for each server is = $\frac{total\ service\ time\ for\ each\ day}{total\ no\ of\ customers\ for\ each\ day}$

Hence, (a) the average service time for ATM 1 is= $\frac{total\ service\ time\ for\ each\ day}{total\ no\ of\ customers\ for\ each\ day}$

Therefore, the average service time for Monday is= $\frac{444}{307} = 1.446$ minutes

Average service time for Tuesday is= $\frac{409}{356} = 1.149$ minutes

Average service time for Wednesday is= $\frac{403}{300} = 1.343$ minutes
Average service time for Thursday is = $\frac{407}{289} = 1.408$ minutes
Average service time for Friday is= $\frac{454}{365} = 1.244$ minutes
(b) The average service time for ATM 2 is = $\frac{total\ service\ time\ for\ each\ day}{total\ no\ of\ customers\ for\ each\ day}$
Hence, the average service time for Monday is = $\frac{358}{307} = 1.166$ minutes
Average service time for Tuesday is = $\frac{414}{356} = 1.163$ minutes
Average service time for Wednesday is = $\frac{370}{300} = 1.233$ minutes
Average service time for Thursday is = $\frac{381}{289} = 1.318$ minutes
Average service time for Friday is= $\frac{451}{365} = 1.236$ minutes

Table 2: Shows the Total, Average Inter-arrival Time and Service Time with Total Number of Customers for the five Working Days considered

Days		Inter-Arrival Time (MIN)	Service Time ATM 1 (MIN)	Service Time ATM 2 (MIN)	Total Number of Customers
Mon	Total	594	444	358	307
	Average	1.935	1.446	1.166	
Tue	Total	601	409	414	356
	Average	1.688	1.149	1.163	
Wed	Total	595	403	370	300
	Average	1.983	1.343	1.233	
Thur	Total	596	407	381	289
	Average	2.062	1.408	1.318	
Fri	Total	599	454	451	365
	Average	1.641	1.244	1.236	

The Total 2 is presentation of the average inter-arrival time of the customer in the system and the average service time for the two ATMs for the five Working Days considered.

From the Table 2 we obtain,
The Total average service time for ATM 1 is= $\frac{sum\ of\ average\ service\ time\ for\ mon-friday}{5}$
$= \frac{6.590}{5} = 1.318$ minutes
The Total average service time for ATM 2 is= $\frac{sum\ of\ average\ service\ time\ for\ mon-friday}{5} =$
$= \frac{6.116}{5} = 1.223$ minutes
Hence, The Average service Time for the system is $\frac{ATM\ 1\ av\ service\ time + ATM\ 2\ av\ service\ time}{2} =$
$\frac{1.223+1.318}{2} = 1.27$ minutes

Hence, The Average Inter-arrival Time for the system is= $\frac{sum\ of\ av\ inter-arrival\ time\ (mon-fri)}{5}$

$$= \frac{9.309}{5} = 1.86\ minutes$$

Hence, the Average inter-arrival time is 1.86minutes
The average service time is 1.27minutes
Then, the service rate and arrival rate is calculated as;

Service rate(μ) $= \frac{1}{average\ service\ time} = \frac{1}{1.27} = 0.787$ Customers per minute= 47.4 Customers per hour

Arrival rate (λ) $= \frac{1}{average\ arrival\ time} = \frac{1}{1.86} =$ 0.538 Customers per minute= 32.4 Customers per hour

Using equation (7) we obtain $\rho = \frac{\lambda}{s\mu} = \frac{0.54}{2 \times 0.79} = 0.3418$ or 34.18%

To calculate probability of no customer in the system, we use equation (1)

$$P_0 = \left[\sum_{n=0}^{1} \frac{1}{0!}\left(\frac{0.54}{0.79}\right)^0 + \frac{1}{1!}\left(\frac{0.54}{0.79}\right)^1 + \frac{1}{2!}\left(\frac{0.54}{0.79}\right)^2 \times \left(\frac{1}{1-0.3418}\right) \right]^{-1}$$

$$P_0 = \left[\sum_{n=0}^{1} 1 + 0.6835 + 0.2336 \times 1.5193 \right]^{-1}$$

$$P_0 = [1.6835 + 0.3549]^{-1} = \frac{1}{2.0387} = 0.4905$$

To obtain the expected number of customers waiting in the queue, we use equation (3)

$$L_q = \left[\frac{1}{(2-1)!}\left(\frac{0.54}{0.79}\right)^2 \times \frac{0.54 \times 0.79}{(1.58-0.54)^2} \right] \times 0.4905$$

$L_q =$ 0.0904 Customers

To calculate expected number of customers in the system, we use equation (4)

$$L_s = 0.0904 + \frac{0.54}{0.79} = 0.7740 \text{ customers}$$

Using equation (5) we obtain expected waiting time in the queue as

$$W_q = \frac{0.0904}{0.54} = 0.1680 \text{ minutes}$$

Using equation (6) we obtain expected waiting time in the system as

$$W_s = 0.1680 + \frac{1}{0.79} = 1.434 Minutes$$

Using equation (1) we obtain probability of n customers in the queuing system as

$$P_n = \begin{cases} \frac{\rho^n}{n!} p_o; & n \le s \\ \frac{\rho^n}{s! s^{n-s}} p_o; & n > s \end{cases}$$

where, $\rho = \frac{\lambda}{s\mu}$

Probability when n$\leq$s i.e. $n \leq 2$, $n = 0,1,2$

$$P_0 = \frac{\rho^n}{n!} P_0 = \frac{(0.3418)^0}{0!}(0.4905) = 0.4905$$

$$P_1 = \frac{\rho^n}{n!} P_0 = \frac{(0.3418)^1}{1!}(0.4905) = 0.1677$$

$$P_2 = \frac{\rho^n}{n!} P_0 = \frac{(0.3418)^2}{2!}(0.4905) = 0.0287$$

The probability when n > 2 i.e. $n = 3,4,5,\ldots$

$$P_3 = \frac{\rho^n}{s!s^{n-s}} P_0 = \frac{(0.3418)^3}{2!2^{3-2}} \times 0.4905 = 0.004897$$

$$P_4 = \frac{\rho^n}{s!s^{n-s}} P_0 = \frac{(0.3418)^4}{2!2^{4-2}} \times 0.4905 = 0.0008368$$

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$$P_{12} = \frac{\rho^n}{s!s^{n-s}} P_0 = \frac{(0.3418)^{12}}{2!2^{12-2}}(0.4905) = 0.0000000006089$$

The values from P_0 to P_{12} is presented in Table 3

Table 3: Probability of n customers in the system

N	Probability	Cumulative
0	0.4905	0.4905
1	0.1677	0.6582
2	0.02870	0.6869
3	0.004897	0.691797
4	0.0008368	0.6926338
5	0.0001430	0.6927768
6	0.00002444	0.69280124
7	0.000004177	0.692805417
8	0.0000007138	0.6928061308
9	0.0000001220	0.6928062528
10	0.00000002085	0.6928062736
11	0.000000003563	0.6928062772
12	0.0000000006089	0.6928062778

From the Table 3, it can be observed that as n increases the probability decreases. This means that probability of having no customer in system is unlikely while the probability of having many customers in the system is also unlikely.
The probability that on arrival a customer has to wait for service is calculated using equation (8) thus

$$P_s = \frac{1}{2!}\left(\frac{0.54}{0.79}\right)^2 \left(\frac{2 \times 0.79}{2 \times 0.79 - 0.54}\right) \times 0.4905$$

$$P_s = \frac{1}{2}(0.467)(1.519) \times 0.4905$$

$P_s = 0.174$

Busy time of the system:

To calculate the busy time of the machines we multiply the banking hours of the ATM machine used by the utilization factor i.e.

$$\text{Busy Time} = \text{Banking hours of ATMs} \times \frac{\lambda}{s\mu} \qquad (9)$$

Busy Time $= 10 \times (0.3418) = 3.418$ hours

Idle time of the system:

To calculate the idle time of the machine we subtract Busy time from Banking hours of the ATM i.e.

Idle Time = Banking hours of ATM – Busy time (10)

Idle Time = 10-3.418 = 6.582 hours

Table 4: The table below shows the values of the parameters & some queue formulae used

Queue parameters &formulae	Value
Arrival rate λ	0.54
Service rate μ	0.79
Utilization factor ρ	0.3418
Expected number of customers in system L_S	0.7740
Average Length of queue L_q	0.0904
Expected waiting time in the system W_s	1.4340
Expected waiting time in queue W_q	0.1680
Prob of zero customers in the system P_0	0.4905
Prob that a customer must wait for service on arrival P_S	0.1740

The number of customers recorded during the five working days considered is 1617 persons with arrival rate of 0.54 customers per minute equivalent to 32.4customer per hour while the service rate is 0.79 customer per minutes also equivalent to 47.4 customers per hour. This shows that the service rate of the system is greater than the arrival rate, which implies that customers don't have to queue up for so long to be served. Probability that the ATMs are idle is 0.4905, which implies a probability of 49.05% idle time and 50.95% busy time of the ATMs and the traffic intensity is 0.3418 (34.18%). A customer spent a total time of 1.434 minutes in the system.

Conclusion

The performance level of the Stanbic IBTC Bank ATMs stand located in Minna central has been effectively investigated using the M/M/S Queuing model. It was observed that the busy time of the machine is 3.418 Hours while the idle time is 6.582 hours in the 10 hours of banking time. The utilization factor is 0.3418 or 34.18%, this implies good service delivery by the machines therefore no urgent need for an additional ATM at the location.

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