Global Journal of Human-Social Science: G
Linguistics & Education
Volume 21 Issue 8 Version 1.0 Year 2021
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals
Online ISSN: 2249-460X & Print ISSN: 0975-587X

Achieving Optimality and Efficiency Services in the Bank: A Queuing Theory Approach

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GJHSS-G Classification: *FOR Code: 139999*

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I. Introduction

Man's daily life is characterised by his waiting for services. Man is seen to wait for visually any service or services rendered ranging from services he derives from restaurant to a pump station to a grocery store to a banking hall and the list are endless. It is interesting also to note that waiting for services or the waiting phenomenon is not only related to man or man characterised but can be seen also in jobs, that is, jobs can be carried out on machines, at a traffic light junction, cars will definitely wait and so on. The study of waiting lines can also be referred to as queuing theory, thus, waiting lines are also queues. One can see the usefulness of queuing theory or waiting lines in both service and manufacturing phases of life. Queuing theory can be traced to a Danish researcher named A. K. Erlang in 1909, he was known for his application to telephone traffic, looking at the fluctuating demand. Although, queuing theory are applied visually to all phases of life that need optimality and efficient services. A more comprehensive definition of Queuing theory is that Queuing theory is a branch of operations research and also a mathematical study of queues or one can say of waiting lines where models are constructed for effective prediction of both the queuing lengths and waiting times with reference to balancing the trade-off between the service costs and the waiting costs.

In Nigeria, long queues are always observed before the Automated Teller Machines (ATMs) in various banks and thus this work is aimed at finding ways of reducing the queues for optimal and effective services rendered. In a nutshell, the objective of this study is to examine the efficiency in the services rendered by some banks in the University of Nigeria, Nsukka campus branch thereby seeing to how optimality can be achieved in the services rendered by these banks. Thus, the central forms would be on the services rendered through ATMs since the bank made it compulsory that non bulk withdrawals must make use of ATM services and many people usually find it more convenient to make transfers and other forms of payments through ATMs.

a) Automated Teller Machine (ATM)

The acronym ATM stands for automated teller machine which also can be referred in the United States as Automatic Teller Machine, in Canada, as both Automated Teller Machine (ATM) and also Automated Banking Machine, names like hole in the wall, any time money, cash dispenser, bankomat etc (WIKIPEDIA, 2019) are also regular names of the ATM. An ATM is defined as an electronic telecommunications device which permits customers of banks or financial institutions to access their account balances, make withdrawals, transfer funds or perform any form of financial transactions at any convenient time without the need or presence or through a bank staff.

The ATM comprises of both the hardware and software, the hardware of the automated teller machine ranges from the Central Processing Unit (CPU) which actually controls the user interface and the transaction devices to the Magnetic or Chip card reader that is used to identify customer distinctly, then to the personal identification number (PIN) pad, which accepts and encrypts the personal identification number to the Secure crypto-processor which is usually within a secure enclosure and then the Display, which provides the customer the environment to perform transactions. The Function key buttons or touch screen are another hardware part of the ATMs that are used for selecting different aspects of the transactions. The Record printer provides the customer with his or her transaction

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records. The Vault stores the parts of the machinery requiring restricted access. The housing are for beauty, that is, aesthetics and finally the Sensors and Indicators. The software part are seen majorly in the operating system of the device and the most widely used operating system is the Microsoft Windows operating system. It is interesting to note that a numeric password is assigned to the customer as his or her PIN, these numbers when entered wrongly for several times would bring about a card seizure by the machine as a form of precaution so as to prevent an unauthorised person or persons from working out the number by guess work (Lin & Yang, 2006)

b) *The Queuing Theory Concept*

Queuing theory is a branch of operations research and also a mathematical study of queues or one can say of waiting lines where models are constructed for effective prediction of both the queuing lengths and waiting times with reference to balancing the trade-off between the service costs and the waiting costs.

Characteristics of a Queuing system or Waiting Line System.

There are basically three parts of the waiting line system and they are:

- Arrival characteristics: this is also known as the inputs, that is, the input to the system, the input source. The arrival characteristics have three major features and they are size of the source population, that is the arrival or input population, the population size can be either limited, otherwise known as finite or unlimited (infinite). A population size is said to be unlimited when its source is just but a small portion of the prospective potential arrivals. A population size is limited if and only if the population in question is seen around the vicinity, example is a photocopying shop with a specific number of photocopying machines, this is because the copier machines are the prospective and potential customer that requires services whenever it is faulty. The second feature is the pattern of the arrivals into the system, customers can arrive randomly or arrive non-randomly, a customer may arrive into the bank at 15minutes interval or otherwise but the time between each arrival must be same (non-random). It is of utmost important for one to note that when arrivals are random, then they are independent of one another and predicting its occurrences are not as easy and straight forward as non-random scenario. The Poisson distribution is the probability distribution that is used to estimate the number of arrivals per unit of time. Thus the Probability Density Function (PDF) of the Poisson distribution is given as:

$$P(x) = \frac{e^{-\lambda}\lambda^{x}}{x!} \quad \text{For } x = 0, 1, 2, \ldots \qquad (1)$$

where $P(x)$ implies the probability of the arrivals of x

x implies the number of arrivals (inputs) per unit of time

λ implies the average arrival rate

e = 2.7183 which is the base of the natural logarithm.

The third feature is the arrivals' behaviour, it is assumed that one of the characteristics of a customer arriving into a system is that he or she is patient and would abide by the rules of a waiting line or queue. The customer arriving into the system shouldn't be a balk fellow or a reneging fellow or even a jockeying fellow. A Balking fellow is one who leaves his/her queue because he/she cannot wait or because the queue is too long or because there isn't enough space for him/her to stand. A reneging fellow is one that abandons his/her line because of his impatience. A jockeying fellow is a person that leaves his/her queue for another or rather say shifts from an already existing queue of his to another queue.

- The queue discipline characteristics: the waiting line can either be limited or unlimited, one talks of unlimited assumption assumptions when there are no restriction as regards its size and the discipline characteristics are just rules that necessitate easy and fast flow of the waiting lines or queues, e.g. FIFO rule that is, first in first out rule or say FCFS, that is, first come first serve. At times, the FIFO rule is not followed judiciously because of priority or say in cases of emergencies like in a hospital, a case that is very serious can come in as emergency and thus the FIFO rule will no longer hold.
- The service facility characteristics: in the service facility characteristics, there are basically two features that constitute what it is all about. They are the service system design and the service time distribution. In the case of the service system designs, one is most concerned with the type of channel system or phase system the organisation has adopted. There are single channel queuing system and multiple channel queuing system. Most ATMs seen in Nigeria operate the multiple channel waiting or queuing system. In a single channel, the customer follows a single line , receives his/her services only from one station and exit also from there after services have been rendered while in the multiple channel system, the customer follows one line but receives services from different servers. On assumption, the negative exponential probability distribution can be used to describe the service times. Thus, like the arrival patterns, the service patterns can either be non-random or random in nature.

II. Literature Review

Researchers such as (Sheikh, Singh, & Kashyap, 2013a), studied queuing model for banking system with particular emphasis on waiting lines and service efficiency which they regarded as the most important elements for any progressive bank. They concluded as service level increases, the waiting time of her customers reduces. Thus, the service efficiency is increased and also customer satisfaction. In another study conducted by (Sheikh, Singh, & Kashyap, 2013b), they still emphasised on the waiting lines but with particular reference were placed on the achievement of optimality and service efficiency in the banking sector and also on her improvement but this time, they were looking at it via the operational costs. They also used the optimality model and saw that it was feasible since it brought about customer satisfaction and improved services.

The banking institution was also looked into by (Ahmed, 2018), he actually examined the actual waiting time and service deliveries as Sheikh et al (2013) but with respect to some selected banks in Bangladesh. They concluded that for banks to achieve efficient service deliveries, they should focus on ways of handling waiting lines of customers so as to bring about time minimization. Agyei, Asare-Darko, & Odilon (2015) modelled and analysed the queuing systems in the banking sector, they obtained their data at the Ghana commercial bank premises Kumasi main branch for one month through the method of observation, interviews and use of questionnaires. Their results showed that a 5 teller system was better off than a 4 or 6 teller systems as regards increased customer satisfaction and also in reduction of economic cost.

Adedoyin, Alawaye, & Taofeek-Ibrahim (2014) applied the queuing theory to the banking sector but with respect to the congestion problem. Their aim was to ascertain efficiency in the banking sector. Their results showed that the arrival of customers doesn't follow a Poisson distribution and the utilization factor of 0.2763 implied that the services rendered by the bank (First Bank) in Ilorin is efficient.

III. Methodology

a) The Survey Design

This study applied an observatory technique in the collection of data. The researcher employed the services of Statisticians in the data collection. They visited the banks in question and observed how the customers came in per hour, the time spent on the waiting line, how long they spent in front of the ATMs from 8a.m to 6p.m on Monday, the 7th of January, 8th of January and 11th of January 2019. The days are Monday, Tuesday and Friday respectively. The visits to the banks were done same time simultaneously. The choice of Friday was prompted because of the official close of working activities for the week and beginning of the weekend but since the study was on the ATMs, the belief was that there would be influx of customers on Fridays because of the weekend. Though the ATMs offer other functions but for security purposes the researchers were only interested in the average time the customer spends at the machine, the average time the customer spends on the queue, the average number of customers presented in the queuing system and not necessary what he/she or the transaction he/she carries out in front of the machine.

b) A brief Description of the Banks Selected for the Study

There are three (3) banks selected for the study and they are:

- First Bank Plc
- Diamond Bank Plc
- Fidelity Bank Plc

All banks are domiciled in the University of Nigeria, Nsukka campus. These banks officially works five days in a week but the ATMs work 24 hours/ 7 days meaning, the ATMs offer services for 24 hours a day and runs for 7 days in a week. The banking services opens at 8a.m and entrance door closes exactly 4p.m. at 4p.m, the customers inside the main banking halls aren't chased out but rather they are attended to until all customers are duly serviced. The ATMs are all outside the main banking halls for easy accessibility after official close of work. In First bank, which henceforth would be regarded as Bank X, there are 7 number of ATMs in totality, 4 outside the bank gate, that is, 2 by the right and 2 by the left and 3 inside the premises of the bank. Diamond Bank would henceforth be referred to as Bank Y. Bank Y houses 5 ATMs, 3 are housed outside the bank gate on a row and 2 inside the banking premises. Fidelity Bank is Bank Z in the course of this study and a total of 5 ATMs are housed by the bank, 2 outside the bank gate and 3 on a row inside the banking premises. The ATMs offer the following services in addition to the major cash withdrawal functions:

- Balance enquiry
- Statement enquiry that can be printable in some cases
- Pin change
- Cash deposit
- Funds transfer
- Credit card payment
- Utility bill payment etc

c) The Multi-Server Queuing System Model (M/M/S)

There are basically four models for the queuing system but for this study, the second model; Model B would be applied. This is because in the banking system today, there are multi servers or tellers. The era of single server in the banking sector is gone and thus the model A (M/M/1) wouldn't be the best model to use.

Assumptions of the Multiple Channel Queuing System Model (Model B) are:

1. Arrivals follow a Poisson probability distribution.
2. Service times are exponentially distributed.
3. Services rendered would be on a first come first served basis.
4. All servers perform at the same rate.
5. Arrivals are not dependent on preceding arrivals
6. Average number of arrivals, that is the arrival rate does not change over time
7. Arrival rate tends to infinity, meaning that it comes from a very large or infinite population
8. The service time of one customer varies from the other, thus, they are independent but their average rate is definitely known
9. The arrival rate is slower than the service rate that is the service rate is much faster than the arrival rate.

Thus, the model is given as:

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

for $M\mu > \lambda$

Equation (2) is the probability that there exist zero customers in the system

Where

M implies the number of channels that are available

λ is the average arrival rate

μ is the average service rate at each channel in the system

Then Equation (3) is given as:

$$L_s = \frac{\lambda\mu\left(\lambda/\mu\right)^M}{(M-1)!\,(M\mu-\lambda)^2} P_0 + \frac{\lambda}{\mu} \text{..(3)}$$

Equation (3) is the average number of customers in the system

$$W_s = \frac{\mu\left(\lambda/\mu\right)^M}{(M-1)!\,(M\mu-\lambda)^2} P_0 + \frac{1}{\mu} = \frac{L_s}{\lambda} \text{...(4)}$$

Equation (4) is the average time that a customer spends in the waiting line and then he/she is been serviced.

The average number of customers in line waiting for service is given as:

$$L_q = L_s - \frac{\lambda}{\mu} \text{...(5)}$$

Equation (6) is the average time a customer spends in the queue waiting to be served and it is given as:

$$W_q = W_s - \frac{1}{\mu} = \frac{L_q}{\lambda} \text{..6}$$

IV. Analysis and Interpretation of Results

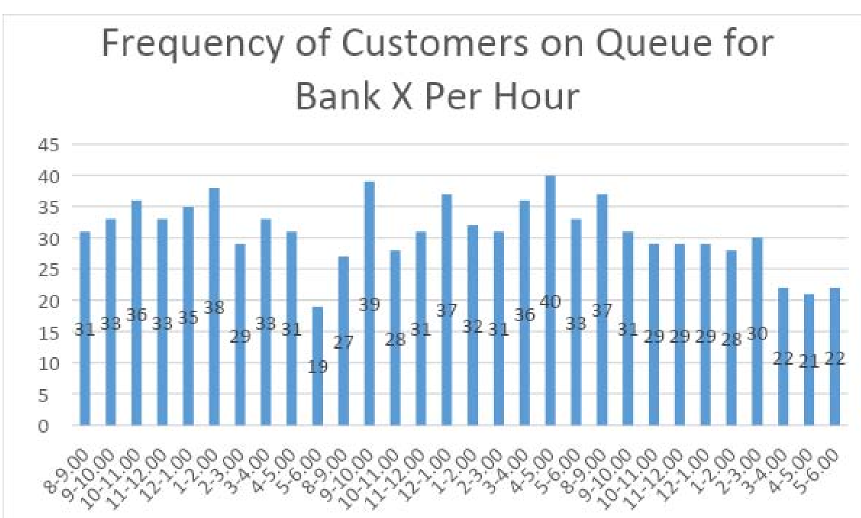

Figure 1A: Frequency of Customers on Queue for Bank X per hour

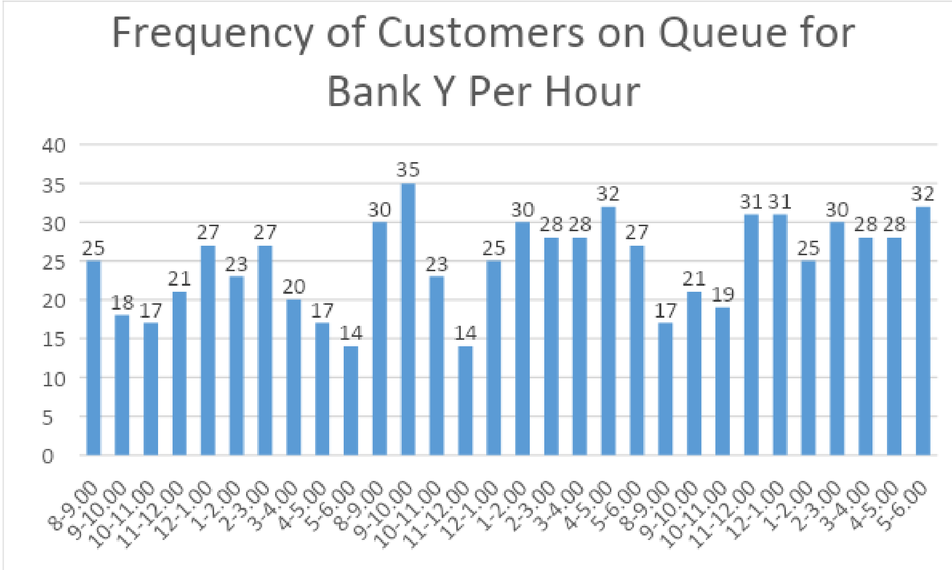

Figure 1B: Frequency of Customers on Queue for Bank Y Per Hour

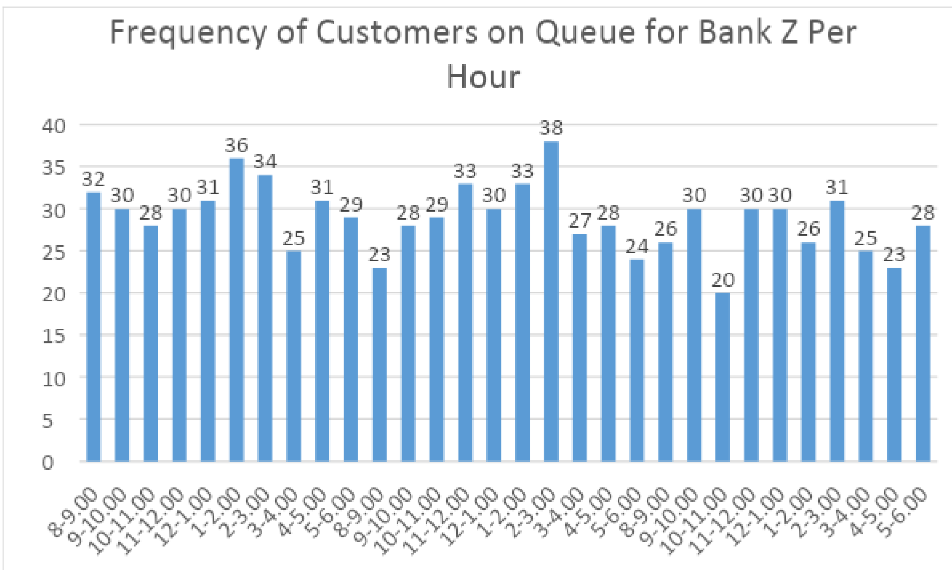

Figure 1C: Frequency of Customers on Queue for Bank Z Per Hour

From Figures 1A, B and C above, one can see the frequencies of customers on queue for Banks X, Y, Z per hour respectively. For bank X, the least total number of 19 per hour was seen on the 8/01/19 at 8a.m to 9a.m and the maximum frequency for bank X was still seen on the same day at 9a.m to 10a.m. thus, the range for the total frequencies lies between 19 and 39.

For Bank Y, the range lies between 14 and 35 with a minimum total frequencies of 14 at 5p.m to 6p.m on 7/01/19 and another 14 on 8/01/19 at 11a.m to 12noon respectively. A maximum total frequency of 35customers at 9a.m to 11a.m on 8/01/19 was also recorded.

For Bank Z, a minimum total frequency of 23 and maximum of 38 customers were observed both on 8/01/19 at 8a.m to 9a.m and 2p.m to 3p.m.

From the figures above, it can be deduced that the assumption that-there are more customers on Fridays because Fridays mark the beginning of the weekend was disputed, customers come to the Bank to use the ATMs at their own spare time and not necessary because it is on a Friday.

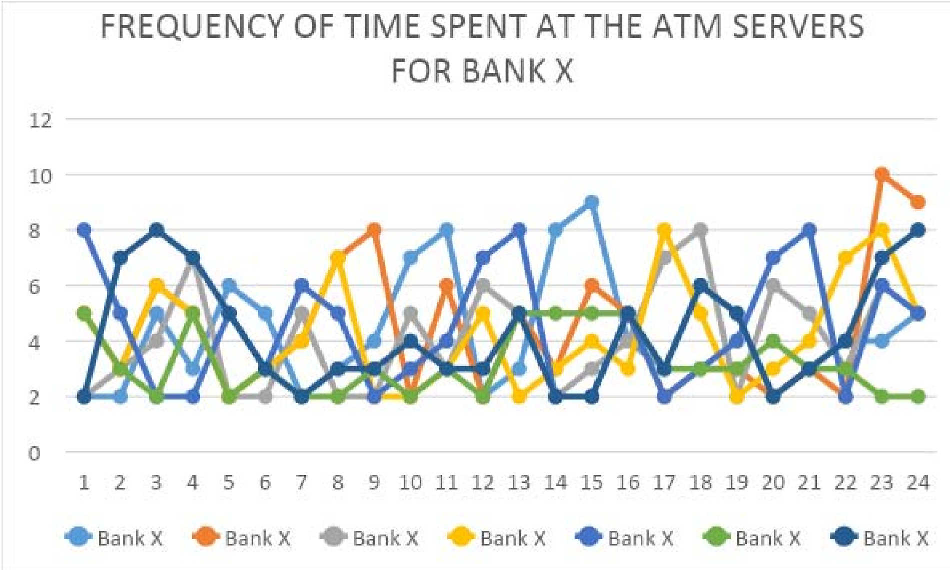

Figure 2A: Frequency of Time Spent at the ATM servers for Bank X

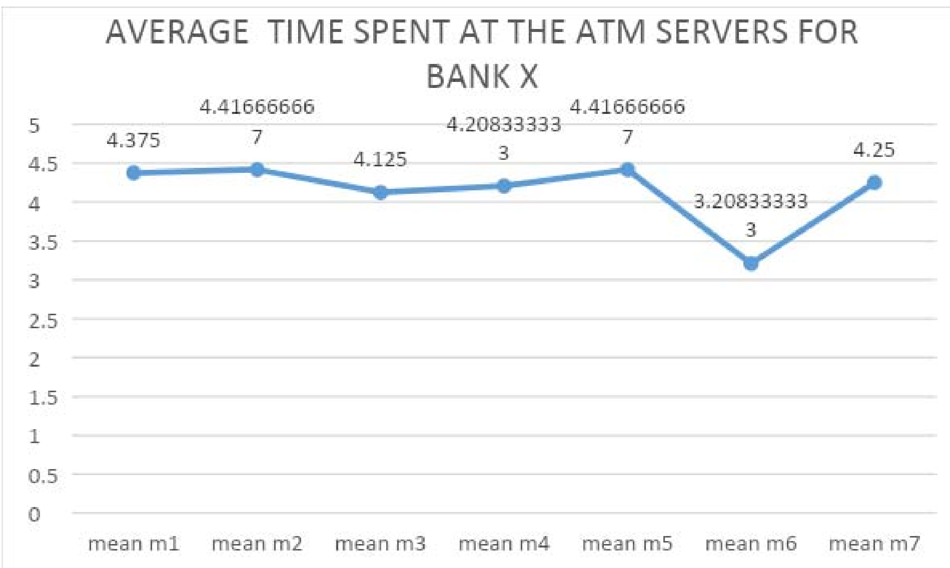

Figure 2B: Average Time Spent at the ATM servers for Bank X

From the above figures, Bank X has 7 servers, that is, 7 ATMs, which is also referred to as the m1, m2, …m7 respectively. Thus, where figure 2a depicts the time in minutes spent in front of the ATMs otherwise referred to as the service time. It can be seen that server M2 has the highest number of time spent on service rendered to customers with a total of 10 minutes followed by 9 minutes by server M1 and the least time were seen on servers M1, M3, M4, M5, M6 and M7 respectively excluding server M2 with 2 minutes across board.

The average time spent on service rendered to customers at the bank's servers ranges from 3.2 mins to 4.4 minutes. Thus, approximately, one can say 3 to 4 mins on servers M6 to M5 respectively. It is thus more convenient to say that the service time at the ATMs ranges from 3 minutes to 4 minutes on an average for Bank X (First Bank Plc).

The Figures below, that is, Figures 2C and 2D respectively depicts the frequencies and average time spent at the ATM servers for Bank Y by customers. The highest time spent at the server (service time) for Bank Y is 12 minutes which was observed at servers M4, M3 and 2 minutes at M1, M2, M3, M4, M5 i.e. it was observed on all the servers. Thus the average shows that the ranges of service time spent on the server lies between 5 to 7 minutes on the whole at Bank Y (Diamond Bank Plc).

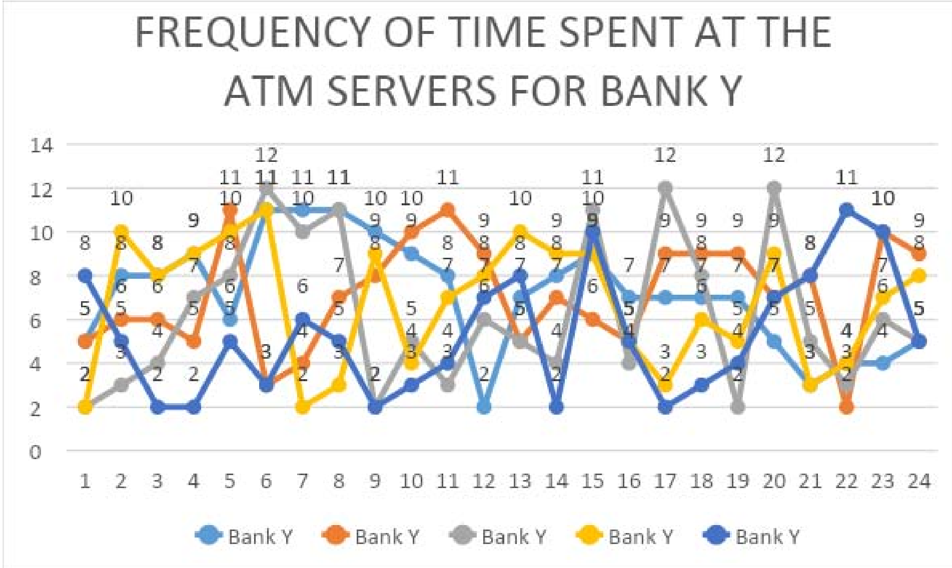

Figure 2C: Frequency of Time Spent at the ATM servers for Bank Y

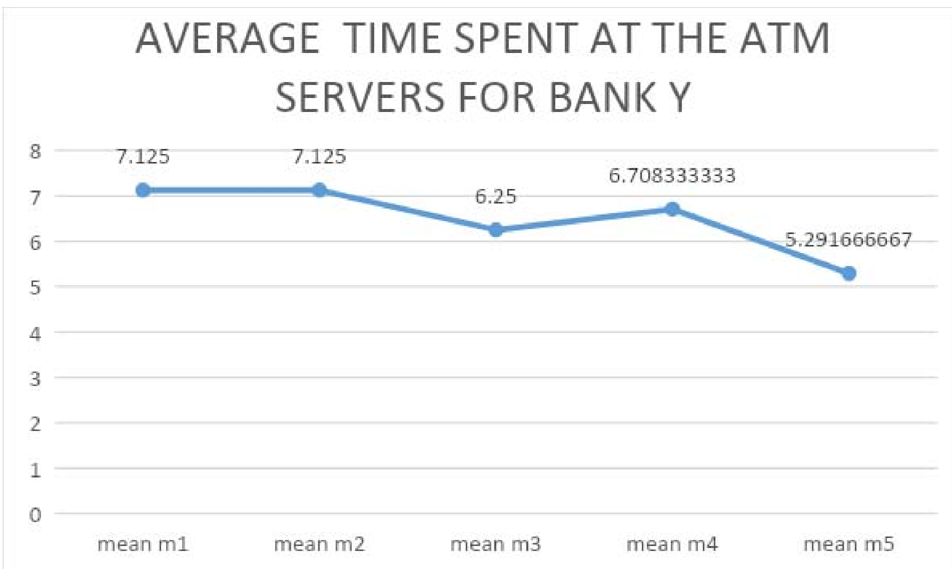

Figure 2D: Average Time Spent at the ATM servers for Bank Y

The figures E and F below show the frequencies and averages of time spent in front of the ATM servers for Bank Z. the time spent renges from 2minutes to 11 minutes which can be observed on servers M1, M2, M3, M4, M5 and 11 minutes for M5, M3 and M2 respectively. On the average, one can deduce that the minutes of service time lies between 4.91 approximately 5 minutes to 5.54minutes approximately 6 minutes on the whole for Bank Z (Fidelity Bank Plc).

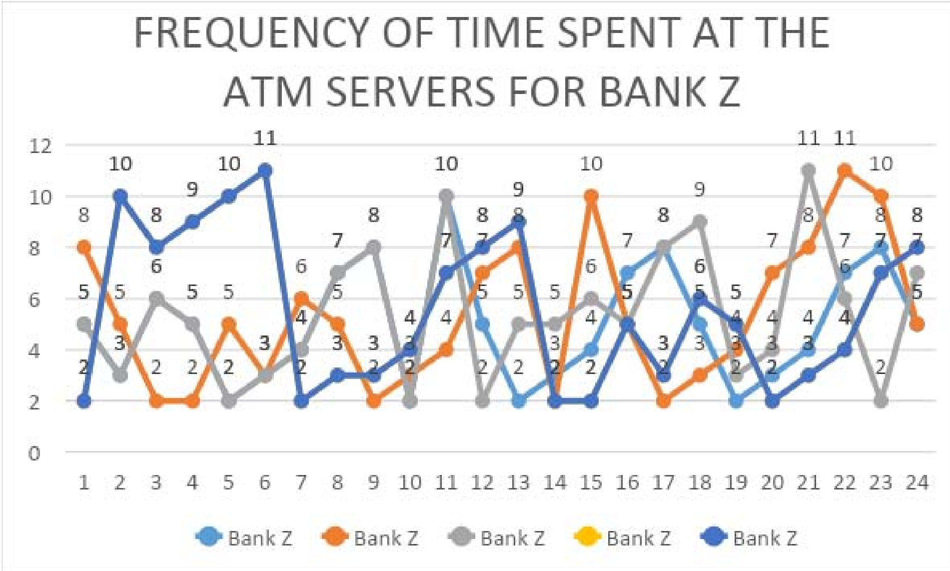

Figure 2E: Frequency of Time Spent at the ATM servers for Bank Z

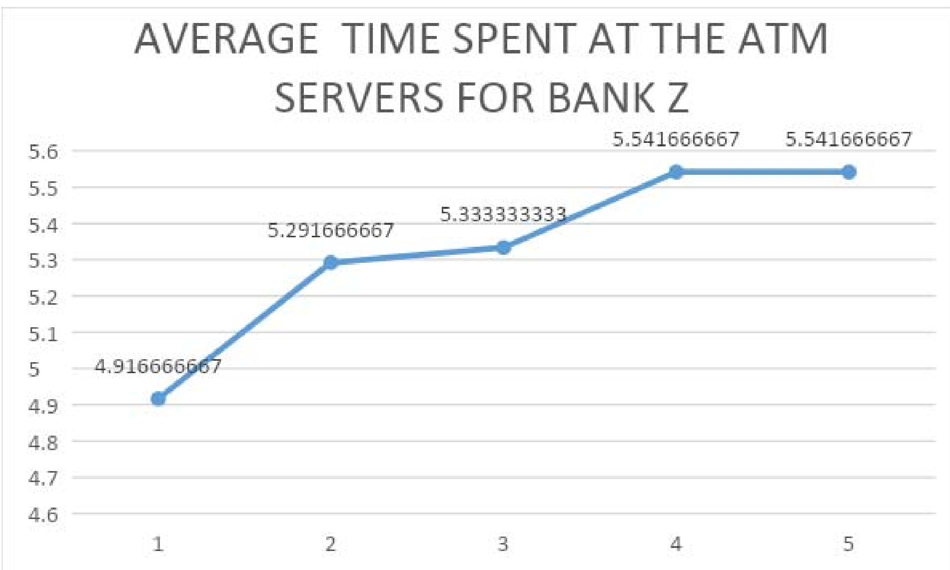

Figure 2F: Average Time Spent at the ATM servers for Bank Z

Table 1: Optimization and Efficiency Table for Bank X

Number of queues	Number of servers (ATMs)			L_s	L_q	W_s	W_q	P_0
1	1	31	7	14.32658	7.48965	0.52387	0.27387	0.00009
	7	4	7	1.00001	0.00001	0.25000	0.00002	0.36788
	7	4	7	1.00001	0.00001	0.25000	0.00002	0.36788
	7	4	7	1.00001	0.00001	0.25000	0.00002	0.36788
	7	4	7	1.00001	0.00001	0.25000	0.00002	0.36788
	7	4	7	1.00001	0.00001	0.25000	0.00002	0.36788
	7	4	7	1.00001	0.00001	0.25000	0.00002	0.36788
	7	4	7	1.00001	0.00001	0.25000	0.00002	0.36788

From table 1 on optimization and efficiency table for Bank X, if the bank were to maintain one server (ATM) and of course 1 queue, the waiting time in the system would increase but with multiple servers (7 ATMS), it was seen that the waiting time on the queue would reduce. The waiting time in the system by customers is reduced from 0.52387 hours to 0.2500 hours and the waiting time on the queue before service is also reduced from 0.27387 hours to almost 0hours, which implies that with the introduction of more servers (ATMs), it was discovered that customers stand the chances of wasting their precious time if it was just 1 ATM and would spend almost 0 hours if it were for the multiple ATMs. The probability that there exist zero (0) customers in the system i.e. P_0 from table 1 is 0.00009. This value shows that the chances or probability of 0 customers on the queue or in the system is very slim, that is actually what is used to measure the idle time. In a 1 queue scenario, it is usually impossible for the server to be without queue but when it was compared to 7 servers (ATMs), it was seen that a value of 0.36788 show that at some time, the system would experience idle time and the chances or probability of having 0 customers on the queue is about 36%. For L_q, the average number of customers waiting for service is 7.48965 which is approximately 8 customers on the average for a single queue, single server (ATM) but for the 7 ATMs case, the average number of customers waiting for service is very insignificant in value (0.00001). For L_s, the average number of customers in the system is 14.32658 approximated as 14 customers for single scenario and 1 customer for multiple servers. The overall average arrival rate for single scenario is 31 customers per hour and 4 per hour to go round for multiple scenario.

Table 2: Optimization and Efficiency Table for Bank Y

Number of queues	Number of servers (ATMs)			L_s	L_q	W_s	W_q	P_0
1	1	25	7	4.57381	1.00238	0.18295	0.00003	0.02366
	5	5	7	0.71443	0.00015	0.14289	0.04010	0.48953
	5	5	7	0.71443	0.00015	0.14289	0.04010	0.48953
	5	5	7	0.71443	0.00015	0.14289	0.04010	0.48953
	5	5	7	0.71443	0.00015	0.14289	0.04010	0.48953
	5	5	7	0.71443	0.00015	0.14289	0.04010	0.48953

Table 3: Optimization and Efficiency Table for Bank Z

Number of queues	Number of servers (ATMs)			L_s	L_q	W_s	W_q	P_0
1	1	29	6	2.74647	1.75351	0.46099	0.00007	0.00704
	5	6	6	0.85755	0.00041	0.14293	0.29432	0.42434
	5	6	6	0.85755	0.00041	0.14293	0.29432	0.42434
	5	6	6	0.85755	0.00041	0.14293	0.29432	0.42434
	5	6	6	0.85755	0.00041	0.14293	0.29432	0.42434
	5	6	6	0.85755	0.00041	0.14293	0.29432	0.42434

For Banks Y and Z from tables 2 and 3 respectively, the probability of 0 customers in the system is 0.02366 and 0.48953; 0.00704 and 0.42434, implying that having 0 customers on queue is very slim or almost impossible for single server for banks Y and Z and values of 0.48, that is, 48% and 42% are significantly showing that there are higher chances of having 0 customers in the system thereby giving room for idle time. For L_q and L_s; 4.57381 to 0.71443, that is, approximately 1 customer for multiple servers and 2.74 approximated to 3 customer per single server to 0.85755 approximated to 1 customer Z.

Table 4: Comparison Table for Banks X, Y, Z

	Bank X	Bank Y	Bank Z
Single Scenario	31	25	29
multiple scenario	4	5	6
	4	7	6
M (ATMs)	7	5	5
P_0	0.36788	0.48953	0.42434
Efficiency value	4.000	5.000	5.95778
L_s	1.00001	0.71443	0.85755
L_q	0.00001	0.00015	0.00041
W_s	0.25000	0.14289	0.14293
W_q	0.00002	0.04010	0.29432

Global Journal of Human-Social Science (G) Volume XXI Issue VIII Version I Year 2021

Average time spent at the ATM servers for banks X, Y, Z are 4, 5 and 6. Bank X is better off in rendering services efficiently and in discharging her services with a minimal time of 4 minutes unlike bank Z with 6 and bank Y with 5. Although, the differences in time spent on an average is not really significant. The little difference may be as a result of bad banking network, which could trigger her slow movements or slow network. The probabilities of 0.36788 (37)%, 0.48953 (49%) and 0.42434 (42%) show that bank Y have higher chances of having an idle time or periods to compare to the other banks and bank X having higher chances of having 0 customers in the system. Thus, this implies that bank Y needs to reduce her servers (ATMs) to about 4 ATMs to increase her efficiency and optimization level. The efficiency value of 4, 5 and 5.95778 approximately 6 respectively shows that the bank with the lowest value is the best as regards efficiency.

V. Conclusion and Recommendation

Queueing system was presented at the banking premises and it was discovered that bank X, followed by Bank Z and bank Y. The queuing analysis performed above shows that for optimality to be achieved, more servers were required except for bank Y which displayed higher chances of exhibiting idle times in the system. Thus, the recommendation is that customer's satisfaction is paramount and a long time on the queue isn't the best. Customers would value banks that discharge their services efficiently.

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