CBN Journal of Applied Statistics (JAS)

Volume 6 | Number 1 Article 5

6-2015

Queue Modelling for Successful Implementation of the Cash-less Policy in Nigeria

Amos N. Dauda
National Bureau of Statistics Lafia, Nassarawa State,

Kenneth N. Korve
National Health Insurance Scheme Headquarters, Abuja, Nigeria

Onuche P. Agada
University of Agriculture Makurdi, Benue State, Nigeria

Queue Modelling for Successful Implementation of the Cash-less Policy in Nigeria

Amos N. Dauda[1], Kenneth N. Korve[2] and Onuche P. Agada[3]

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, the M/G/1 model, a single-channel queuing model with Poisson arrivals, General distribution service time has been applied in modelling the ATM queuing system across three commercial banks: Guarantee Trust Bank (GTB), Diamond bank and Ecobank all located in Lafia, Nasarawa State Nigeria, in order to reveal the associated queuing problems and proffer solutions via an empirical approach of distribution fitting to real time data of inter arrival and service times. The result revealed problems of long queue length, long waiting time and ATM (Server) over utilization to be common in all the three banks. The result of sensitivity analysis established that, an upgrade of ATM processor speed such that customers spend one (1) minute on the average in service, will ensure that no customer wait in queue and an average utilization of the ATM to check breakdown.

Keywords: Cash-less, queue, service

JEL Classification: C53, C63

1.0 Introduction

The governor of Central Bank of Nigeria (CBN), Mallam Sanusi Lamido Sanusi, during the three-day Cash-less Lagos Fair, explained that the cash-less economic policy was designed to promote financial intermediation, financial inclusion, minimise revenue leakages, eliminate incidence of robbery and also to reduce the amount of cash payment and encourage electronic payment, stating that cost of cash and associated risk of cash-driven economy to Nigeria's financial system was high and increasing. He further stated that the cash-less economic policy recently introduced in Lagos State has recorded success, with banks so far deploying over 9,000 Automated Teller Machines

[1] National Bureau of Statistics Lafia, Nassarawa State, Nigeria.
[2] National Health Insurance Scheme Headquarters, Abuja, Federal Capital Territory, Nigeria
[3] Department of Mathematics/Statistics/Computer Science, University of Agriculture Makurdi, Benue State, Nigeria.

(ATMs), (Nigerian Tribune, 2012). In view of this, a few deposit money banks in partnership with the CBN had tried to key into the process by updating their technology and imputing systems such as point of sale (POS) terminals and increasing the number of ATM outlets within and outside the banking halls. Deposit-taking ATMs were also introduced in the process as a means of reducing the stress of customers having to queue for hours in the banking hall to make cash deposits.

The Deputy Governor, CBN, Mr. Tunde Lemo, added that deposit taking ATM was part of the strategies aimed at strengthening available modes of e-payment as well as boosting the cash-less initiative, adding that efforts were being made by the regulators to encourage more of such into the country. According to him, about 60,000 Nigerians currently depend on one ATM, whereas the ideal situation should be 15,000 people to one ATM. He added that this was one of the reasons why the banks were trying to inject 75,000 ATMs, including deposit-taking ATMs, into the system between now and 2015 (Punch Newspaper, 2012). This has established the fact that the ATM is indisputably an indispensable piece of machinery in actualizing the dream of cash-less economy in Nigeria but certainly not without challenges.

This paper has been able to identify the challenges of congestion, usual long waiting time of customers and machine over utilization that has characterized the ATM queuing systems across commercial banks in the country. It has been able to point out that, the problem of congestion, long waiting time and staff over-utilization experienced by customers and staff in the banking hall instead of being solved, seemed to have been successfully transferred to the ATM queuing systems outside the banking hall, due to high influx of customers demanding for ATM services. This is indeed traceable to the recent upsurge in the customer base of most banks without equivalent increase in service capacity It has also been identified to be against the initial objective of changing the face of banking in Nigeria, so as to provide efficient services at reduced cost and customer convenience (Solo, 2008).

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), Famule (2010), 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.

This paper has been able to address this problem from a different angle, first, by employing a more empirical approach of collecting data as regards arrival and service times of customers and fitting appropriate probability distributions in order to ascertain the actual distribution fit, as this will guide the selection of the best queuing model for better results. Secondly, it proposes that a reduction in service time of the ATMs which can be achieved by the installation of high speed ATMs or an upgrade of the existing ones can translate into reduced waiting time, queue length, busyness of the ATM machines and eventually save the cost of multiplying the number of slow ATMs. The success of the cash-less policy depends on the improved efficiency of the ATMs since they would be largely employed. These results if implemented are hoped to be able to solve the associated problems of long waiting time, long queue length and ATM over utilization before the full implementation of the policy in Nassarawa state by the year 2015.

2.0 Methodology

This section presents the method of data collection, distribution fits and the mathematical details of the M/G/1 queue model employed in the study.

2.1 Method of Data collection and distribution fits

Data on customer arrival times, service start and finish times were collected for each ATM facility selected across the selected banks over the period of one month including all the days of the week, from 7 am to 6 pm it is important to mention that the congestion at the ATMs during festive periods is not captured in the data. This is because the period of data collection does not include these periods. The Easyfit professional version 5.5 distribution software is employed in fitting probability distributions of inter arrival and service times to the collected data. This is summarized in Table 1 and for graphical details, displayed in histogram and distribution fit for the selected ATM in each bank (Figures 1-6).

Table 1: Summary of Distribution Fits for Inter arrival and Service time

Bank	ATM identification number	Distribution of Inter Arrival Time	Parameter (λ)	Distribution of Service Time	Parameter
GTB	I	Exponential	0.5053	Log-Logistic	α=3.3501, β=1.4433
Diamond Bank	II	Exponential	0.5175	Log-Pearson 3	α=6.2341,β =0.1887
Ecobank	II	Exponential	0.5528	Gamma	α=2.4151, β=0.7195

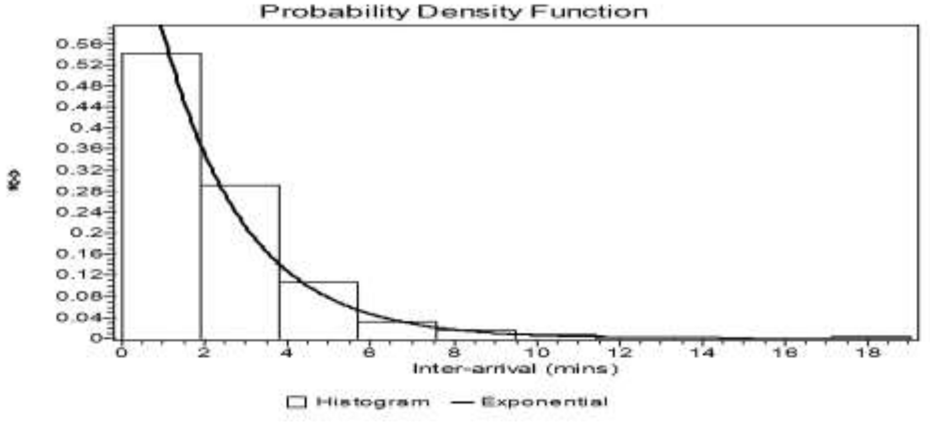

Figure 1: Exponential Probability Density Function of Inter arrival times for GTB ATM I

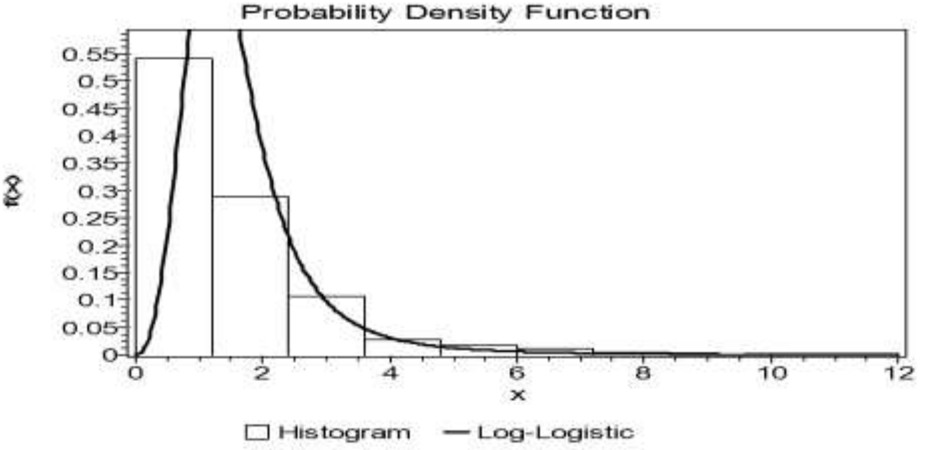

Figure 2: Log-Logistic Probability Density Function of Service time for GTB ATM (I)

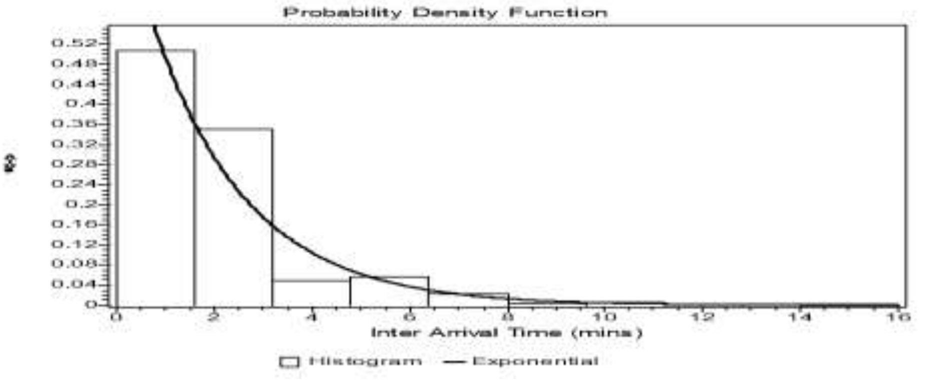

Figure 3: Exponential Probability Density Function of Inter arrival times for Diamond Bank ATM II

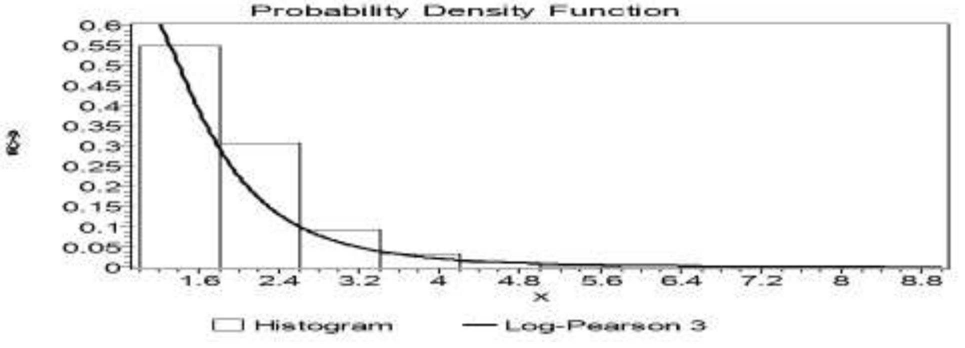

Figure 4: Log-Pearson 3 Probability Density Function of Service Time for Diamond Bank ATM II.

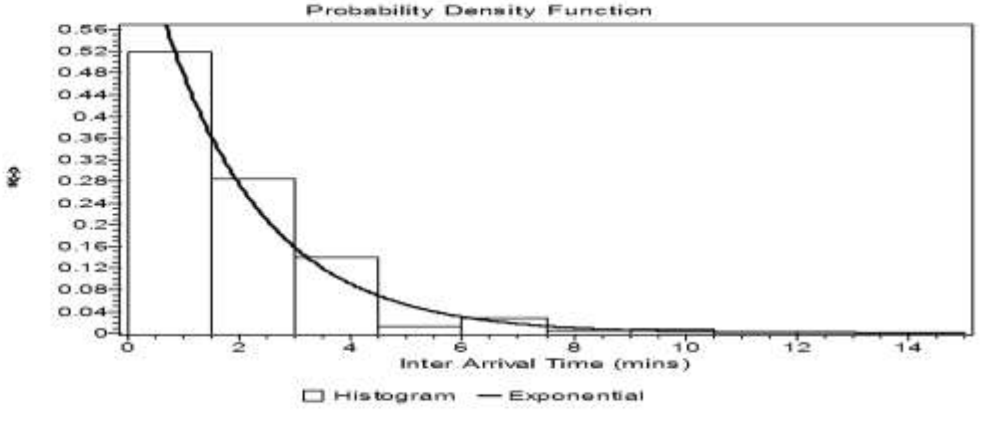

Figure 5: Exponential Probability Density Function of Inter arrival time for Ecobank Server (II)

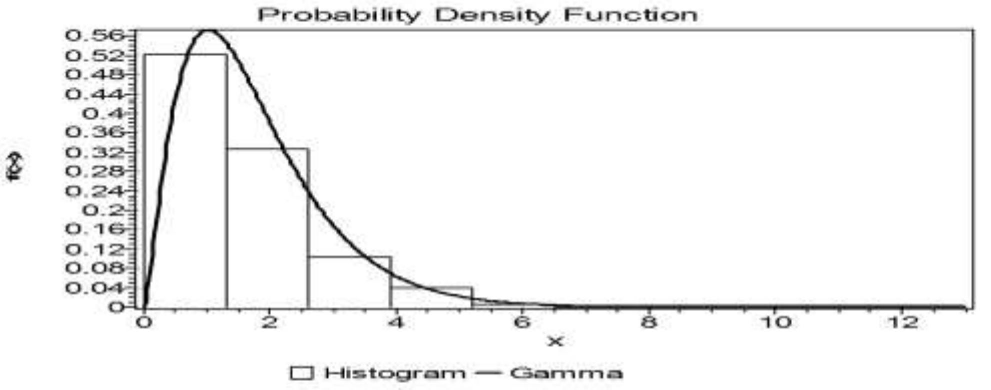

Figure 6: Gamma Probability Density Function Service of time for Ecobank ATM II

2.2 The M/G/1 queue model

Queuing models in which the arrivals and departures do not follow the Poisson distribution are complex. In general, it is advisable in such cases to use simulation as an alternative tool for analyzing them. However there are few non-Poisson queues for which analytic result can be available; the M/G/1 a single channel Poisson arrival, General Service time distribution, First-Come-First-Serve queuing discipline models are examples. The service time t, is represented by any probability distribution with mean, $E\{t\}$, and variance, $var\{t\}$. The results of the model include the basic queue performance measures of average number of customers in the system and in the queue, L_s and L_q, respectively, the average waiting time in the system and queue, W_s and W_q , respectively and the server utilization

$$\rho = \lambda E\{t\} \quad (1)$$

The model does not provide a closed form expression for probability of having n number of customers in queue, p_n, because of analytic intractability.

Let λ be the arrival rate of a single server facility. Given $E\{t\}$ and $var\{t\}$ of the service time distribution and that $\lambda E\{t\} < 1$, it can be shown using probability/ Markov chain analysis that

$$L_s = \lambda E\{t\} + \frac{\lambda^2 E^2\{t\} + var\{t\}}{2(1 - \lambda E\{t\})}, \; \lambda E\{t\} < 1 \quad (2)$$

The probability that the facility is empty (idle) is computed as

$$p_0 = 1 - \lambda E\{t\} = 1 - \rho\lambda \tag{3}$$

Since $\lambda_{eff} = \lambda$, the remaining measures of performance are derived using L_s Taha (2002).

Note: λ_{eff} is the effective arrival rate, it equals the nominal arrival rate λ since all arriving customers can join the system.

2.3 Model Validation

In this study, one sample T-Test is used to test whether the model value of mean waiting time in queue, W_q (Test Value) differs from the actual mean value at 5% level of significance and this is done using the Predictive Analytical Software (PASW). Table 2 displays the result of the model validation for the selected ATM across the banks.

Table 2: Model Validation using One Sample T Test

Bank	ATM ID number	Day of the month	Actual value of Wq	Model value of Wq	P-Value
GTB	I	13	11.13	11.27	0.885
	I	25	10.83	11.27	0.667
Diamond	II	5	6.33	7.14	0.285
	II	23	7.77	7.14	0.112
Ecobank	II	30	7.93	8.2	0.575
	II	2	12.53	13.4	0.346

3.0 Results

The data collected on arrival and service times at the ATM machine of the three selected banks were used to fit probability distributions of inter arrival and service times which enhance the selection of the appropriate queuing model. Model results were eventually used in computing the values of the queue performance measures for each ATM. The fitted probability distributions are shown in Table 1 as earlier mentioned. Model Validation is carried out using the one sample T-test to determine whether the calculated mean waiting time in queue differs significantly from that of the observed or actual value during a day’s ATM service session (Table 2). Computed values of arrival and service rate with mean and variance of service time is shown in

Table 3 for each ATM while the computed performance measure for each ATM which reflects the current queue system at each bank is displayed in Table 4. Finally, the result of the Sensitivity analysis of the queue performance measures to a reduction in average service time is displayed in Tables 5, 6 and 7 for GTB, Diamond and Ecobank ATMs respectively, while the respective graphs are shown in figures 7 - 12

Table 3: Computed values of arrival and service rate with mean and variance of service time Distribution

Bank	ATM identification number	Arrival Rate λ	Service Rate μ	Mean of Service time Distribution (mins)	Variance of Service time Distribution (mins)
GTB	I	0.5053	0.5642	1.7722	1.5198
Diamond	II	0.5175	0.5980	1.6722	0.9169
Ecobank	II	0.5272	0.5755	1.7378	1.2504

Table 4: Tabular Presentation of Computed Performance Measures for each ATM across the three Banks

Performance Measures	GTB	Diamond Bank	Ecobank
	ATM I	ATM II	ATM II
ATM utilization (%)	89.56	86.54	91.62
L_s	6.5885	4.5593	7.9968
L_q	5.6929	3.6939	7.0806
W_s (mins)	13.0388	8.8102	15.1683
W_q (mins)	11.2664	7.1380	13.4305
E[t] (mins)	1.7724	1.6722	1.7378

L_s: Average number of customer in the service system, L_q: Average number of customers waiting in line

W_s : Average time Spent waiting in the system (mins), W_q: Average time Spent waiting in the line (mins),

E[t]: Average service time, Var{t}: variance of service time

Table 5: Result of Sensitivity Analysis of Queue Performance measures to Variation in average Service Time (E(t)) for GTB ATM I

E(t)	L_S	L_q	W_q	W_s	ρ
1.8	5.48	4.57	9.05	10.85	0.91
1.7	3.48	2.62	5.18	6.88	0.86
1.6	2.51	1.71	3.38	4.98	0.81
1.5	1.94	1.19	2.35	3.85	0.76
1.4	1.56	0.86	1.69	3.09	0.71
1.3	1.29	0.63	1.24	2.54	0.66
1.2	1.07	0.47	0.92	2.12	0.61
1.1	0.90	0.35	0.69	1.79	0.56
1	0.76	0.26	0.51	1.51	0.51

Table 6: Result of Sensitivity Analysis of Queue Performance measures to Variation in average Service Time (E(t)) for Diamond Bank ATM II

E(t)	L_S	L_q	W_q	W_s	ρ
1.8	7.27	6.33	12.24	14.04	0.93
1.7	4.10	3.22	6.22	7.92	0.88
1.6	2.82	1.99	3.85	5.45	0.83
1.5	2.12	1.35	2.60	4.10	0.78
1.4	1.68	0.95	1.84	3.24	0.72
1.3	1.36	0.69	1.34	2.64	0.67
1.2	1.13	0.51	0.98	2.18	0.62
1.1	0.95	0.38	0.73	1.83	0.57
1	0.80	0.28	0.54	1.54	0.52

Table 7: Result of Sensitivity Analysis of Queue Performance measures to Variation in average Service Time(E(t)) for Ecobank Bank ATM II

E(t)	L_S	L_q	W_q	W_s	ρ
1.8	9.77	8.82	16.73	18.53	0.95
1.7	4.77	3.87	7.34	9.04	0.90
1.6	3.12	2.27	4.31	5.91	0.84
1.5	2.29	1.49	2.84	4.34	0.79
1.4	1.78	1.04	1.97	3.37	0.74
1.3	1.43	0.75	1.42	2.72	0.69
1.2	1.18	0.54	1.03	2.23	0.63
1.1	0.98	0.40	0.76	1.86	0.58
1	0.82	0.29	0.56	1.56	0.53

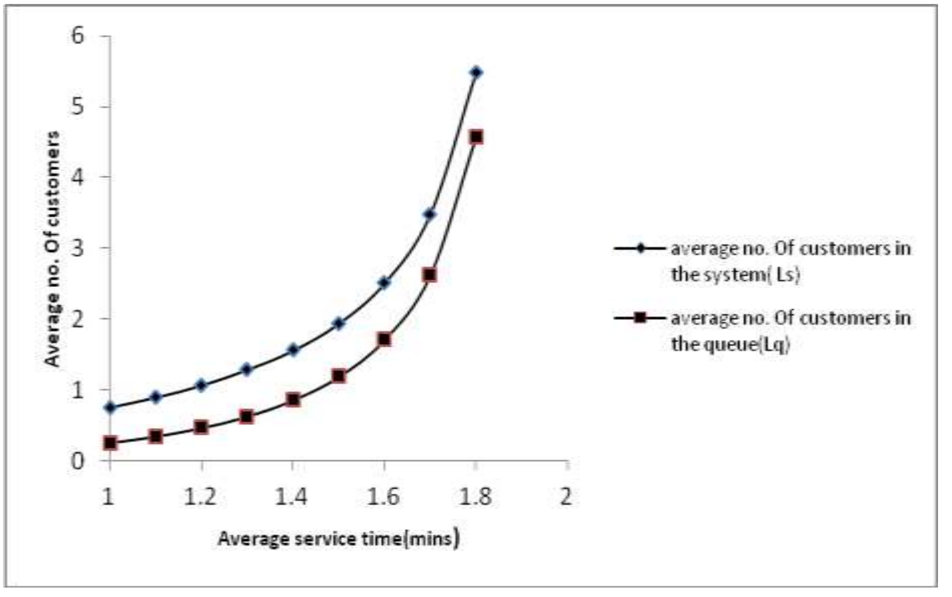

Figure 7: Graph of Average number of customers (L_s and L_q) against Average service time (E[t]) for GTB ATM I

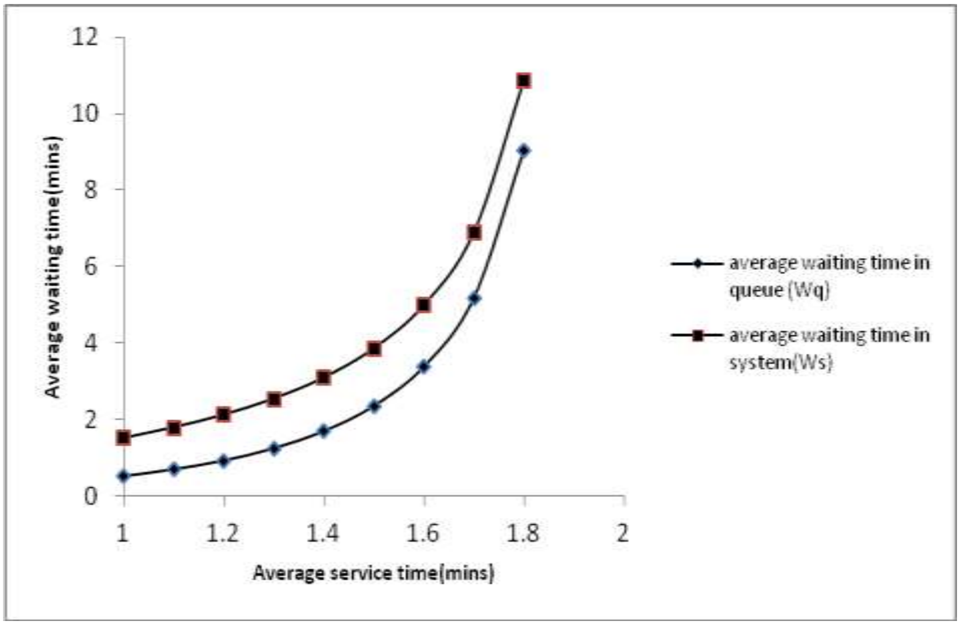

Figure 8: Graph of Average waiting time (W_s and W_q) against Average service time (E[t]) for GTB ATM I

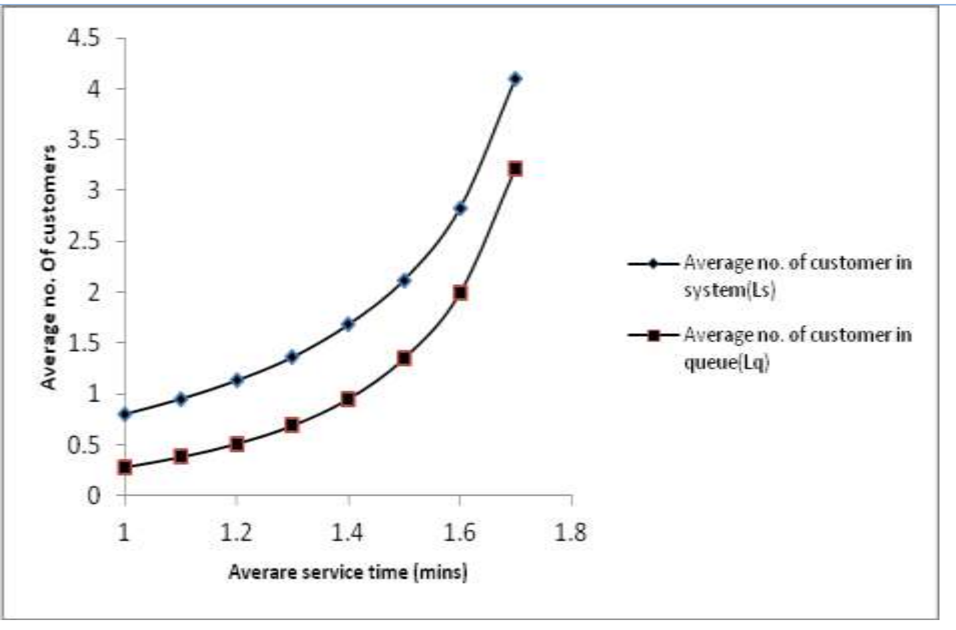

Figure 9: Graph of Average number of customers (L_s and L_q) against Average service time (E[t]) for Diamond Bank ATM II

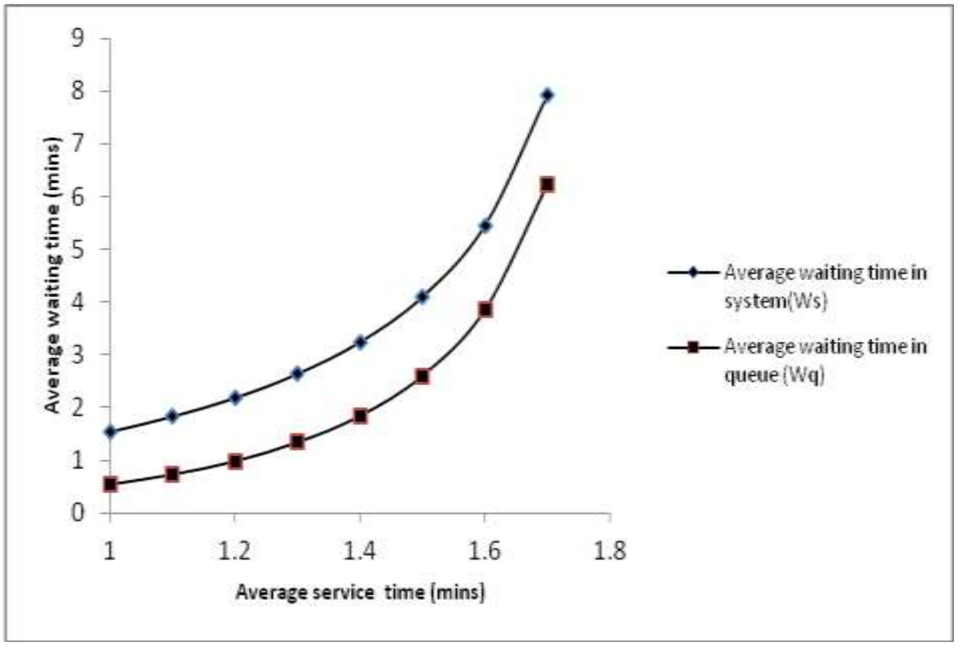

Figure 10: Graph of Average waiting time (W_s and W_q) against Average service time (E[t]) for Diamond Bank ATM II

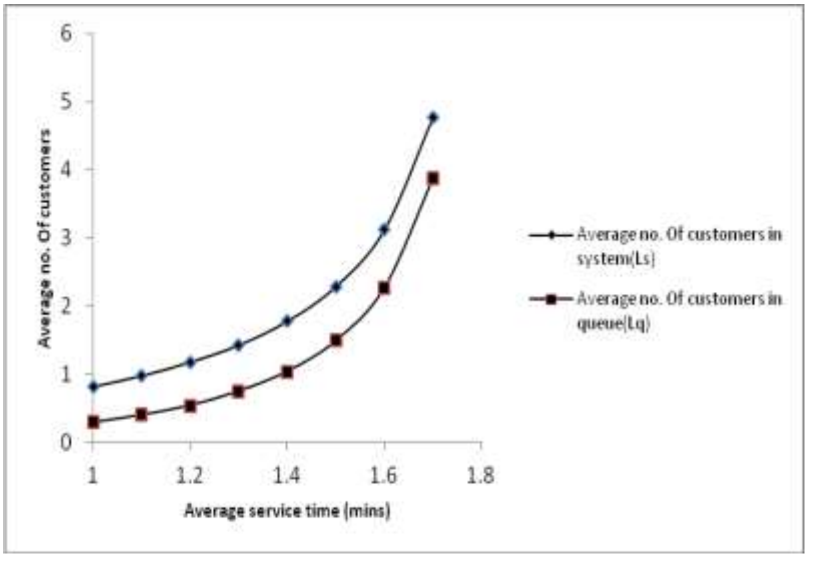

Figure 11: Graph of Average number of customers(L_s and L_q) against Average service time (E[t]) for Ecobank ATM II

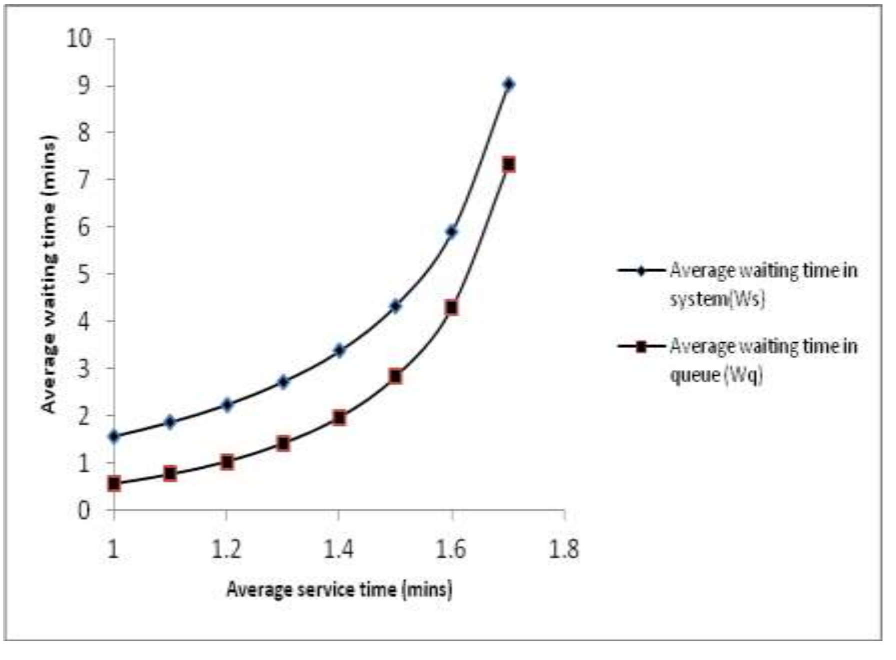

Figure 12: Graph of Average waiting time(W_s and W_q) against Average service time (E[t]) for Ecobank ATM II

4.0 Discussion and Recommendation for further research

4.1 The appropriateness of the M/G/1 queue model

Queuing situations in which the inter-arrival time follow the exponential distribution and the service time follow a general distribution can best be approached using the M/G/1 model also known as Pollaczek-Khintchine (P-K) formula (Taha, 2012). The summary in Table 1 and the histograms of the distribution fits (Figures 1-6) shows that the inter-arrival times fit the exponential distribution and the service times are not exponentially distributed for all ATMs, hence the appropriateness of the M/G/1 model for this study and not the popular M/M/1 or M/M/c model. In this model (M/G/1), no restrictions are imposed on what the service-time distribution should be; in fact it is only necessary to estimate its mean and variance.

4.2 Model Validation

In this study, one sample T-Test is used to test whether the model value of mean waiting time in queue, W_q (Test Value), differs from the actual mean values at 5% level of significance and this is done using the Predictive Analytical Software (PASW). Table 5 displays the result of the model validation for each server across the banks. The result shows no significant difference between the observed mean waiting time and that of the model estimate. This is because the P-values exceed the α-value of 0.05.

4.3 The current state of the ATM queuing system across the banks

Result of the ATM I in GTB shows that customers spent 1.77 minutes on the average in service after waiting for 11 minutes on the average in queue. It was also found that an average of 6 customers wait in queue while the ATM utilization is 89.56%. Result of ATM II in Diamond bank shows that customers spent 1.67 minutes on the average in service after waiting for 7 minutes on the average in queue. It was also found that an average of 4 customers wait in queue while the ATM utilization is 86.54%. Result of ATM II in Ecobank shows that customers spent 1.74 minutes on the average in service after waiting for 13 minutes on the average in queue. It was also found that an average of 7 customers wait in queue while the ATM utilization is 91.62%. The results show a high ATM utilization across the banks which can eventually cause machine breakdown, it also reveal that customers spent much time waiting in queue for service but less time in service across the ATMs.

4.4 Result of Sensitivity Analysis

In this study, the value of the Average service time, E(t) for each ATM was reduced from 1.8 minutes to 1 minute with a step size of 0.1 minute. The queue performance measures were computed at zero variance for ease of matching the average service time to specific ATM processor speed for further research. The results are tabulated in Tables 5, 6 and 7 and graphically displayed in Figures 7-12. The result shows that the average queue length (L_s and L_q) and average waiting times (W_s and W_q) reduce significantly with a reduction in the average service time, E[t] for each ATM. In particular, if an ATM processor speed is upgraded such that a customer spends 1 minute in service on the average, then no customer would be found waiting in queue across the ATMs and ATM utilization becomes optimal to check breakdowns.

4.5 Implication of research findings to the success of the cash-less policy

This study asserts that the installation of faster ATMs will reduce the average service time and consequently reduce the values of the queue performance measures considerably across ATMs of the selected banks in Nassarawa state. The ATM is indisputably an indispensable piece of machinery for actualizing the dream of cash-less economy in Nigeria. Problems of long queue lengths, long waiting times and high ATM utilization have been identified in this study; these problems are not desirable if the cash-less policy is to be successful. The result of the sensitivity analysis suggests that an upgrade of the ATM processor speed such that a customer spends 1 minute in service on the average, ensures that no customer would be found waiting in queue and that the ATM would be averagely utilized to check breakdowns. On-going is a further research work to match specific ATM processor speed to actual service times in order to determine the processor speed that will achieve a 1 minute average service time.

4.6 Recommendation for further research

1. The extension of the M/G/1 model to other major cities In the country as well as specific modelling of peak business periods, specific months

of the year and festive periods should be considered for further research.

2. The use of the M/G/c, (c > 1) model should be considered for further research since the multiplications of efficient and fast ATM machines will go a long way to reducing over utilization of a particular machine.

3. Other issues associated with availability of network service on the part of the network provider are also vital points for further investigation.

References

Al-Jumaily, S.A and Al-Jabori, K.T. (2012). "Automatic Queuing Model for Banking Applications". *International Journal for Advanced Computer Science Applications*, 2(7):11-15.

Famule, F. D. (2010)." Analysis of M/M/1 Queuing Model with Application to Waiting Time in Banks". *Global Journal of Computer Science and Technology* 10(13): 28-34.

Taha, H.A., (2002). "Operations Research, an Introduction". 7th Edition. University of Arkansas, Fayetteville. pp 579-625.

Nigerian Tribune (2012). "Cash-less policy: banks deploy 9,000 ATMs", Thursday, 10 May 2012

Ogunwale, O.D. and Olubiyi, O.A. (2010). "A Comparative Analysis of Waiting Time of customers in Banks". *Global Journal of Science Frontier Research* 10(6): 97-99

Olatokun, W.M. and Igbinedion, L.J. (2009). "The Adoption of ATMs in Nigeria: An Application of the Theory of Diffusion of Innovation". *Issues in Information Technology*, **6**:373-393.

Punch Newspaper (2012). "Cash-less policy: Bank customers seek improved ATM services". Saturday September 8, 2012.

Solo, B., (2008). "Automated Teller Machine (ATM) in Nigeria: The present, The Future" www.OPPapers.com.

Vasumathi, A., and Dhanavanthan, P., (2010). "Application of Simulation Technique in Queuing Model for ATM Facility". *International Journal of Applied Engineering Research*, Dindigul.1(3):469-482.