

# Improving Customer Service at the Agricultural Development Banks in Ghana: An Application of the Queuing Theory

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## Abstract

Competition for customers in retail services such as the banking industry is often fierce. As such, many firms have placed new emphasis on listening to their customers in an effort to better understand them. At leading or world class firms, the voice of the customer is not treated passively or left to chance. Businesses often go the extra mile to create congenial atmosphere for their customers, particularly in the present era of competitive environment where queues are inevitable in fast growing goods and services market. This article analyses the perceptions of customers about queues build-up at the bank, using the Agricultural Development Bank (ADB) at Koforidua, Eastern Region, Ghana, as a case study. Based on the queuing theory, an analysis of the queuing system at the bank shows that the current performance of the queuing system could be improved to serve customers better when an extra service point is added, and suggests how best the bank can reduce the length of the queues. The study therefore recommends that the management of the bank considers adding an extra service point as this is a significant improvement over the current system, particularly in terms of the time spent by customers waiting in line to be served.

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**Key words:** Queuing theory, customers, competition, time, service point.

## Introduction

Waiting for a good or service in a queue is generally frustrating, demoralizing, agonizing, aggravating, annoying, time consuming and incredibly expensive (Maister, 1985). However, queues are becoming inevitable in today's fast growing goods and services market. The ultimate result has been the loss of customers. Though disturbing, few firms have really considered analysing their queuing system. The Agricultural Development Bank (ADB) Koforidua Branch has for sometime been experiencing long queues almost every day. Due to such long queues at the bank, congestion in the banking hall has also been observed, and this is usually accompanied by customer complaints. As a result there is the possibility of both customer and revenue losses to the bank (Davies, 1991).

ADB in Ghana was set up by an Act of Parliament (Act 286) in 1965 to enhance and modernize the agricultural sector through appropriate but profitable financial intermediation. Initially ADB was called the Agricultural Credit and Co-operative Bank. It assumed its present name in 1970 when a subsequent Act of Parliament (Act 352) amended the earlier legal instrument of the Bank and thereby broadened its functions to make it a fully-fledged banking institution. The Act establishing the bank provided it with a major objective which is to provide credit facilities to stakeholders in agriculture and persons involved in agricultural activities.

## Study Questions and Objectives

ADB is committed to building a strong customer-oriented Bank, run by

knowledgeable and well-motivated staff, providing profitable financial intermediation and related services for a sustained and diversified agricultural and rural development. ADB Koforidua branch which was established in 1996 has seen tremendous numerical growth of customers over its relatively short period of existence. The result has been the presence of long queues at the bank which affect quality customer service.

Customer satisfaction is a key component of competitive strategies, and keeping customers happy is critical to long-term business success. As such, many firms have placed new emphasis on listening to their customers in an effort to better understand them. At leading or world class firms, the voice of the customer is not treated passively or left to chance. Such firms actively seek customer input and guidance to better serve their interests (Stank and Lackey Jr, 1997). Customers today expect high quality products and fast, friendly services at reasonable cost. Customer service (also known as Client Service) is the provision of service to customers before, during and after a purchase. According to Turban et al, (2002), customer service is a series of activities designed to enhance the level of customer satisfaction - that is, the feeling that a product or service has met the customer expectation. Its importance varies by product, industry and customer. As an example, an expert customer might require less pre-purchase service (i.e., advice) than a novice.

In many cases, customer service is more important if the purchase relates to a "service" as opposed to a "product".

Customer service is normally an integral part of a company's customer value proposition, and may be employed to generate competitive advantage as a particular service proposition can be harder to copy by competitors (Osuna, 1985; Rubinovitch, 1985). The implementation of a particular customer service proposition must consider several elements of the organization. A company may attempt to differentiate itself from its competition through the provision of better customer service.

In today's business world, almost any operation that provides a good or service will involve queuing at some point. A queue occurs as a result of inadequate production capacity, equipment or personnel. In today's ever-increasing competitive nature of businesses, quality customer service remains paramount. Competition for customers in retail service industries such as banking are often fierce, and such competition occurs especially in perceived customer services. The key questions then are: (a) what are the major factors underlying the continual queue build-ups at the ADB branch bank at Koforidua, and what could be the possible consequences of such queues at the bank? What measures could the bank employ to address the issue of the queues and improve customer services? Are there any lessons that other banks could learn from ADB's experience with queues?

In order to address the issues raised above, the study analyses queuing development and customer service at the ADB Koforidua Branch. Specifically, the study investigates customer perceptions about queue build-up, determines the performance of the queuing system,

ascertains what improvements could be made in the performance of the system and how these affect customers.

## Method of Analysis - Applying Queuing Models

Queuing theory is the mathematical study of waiting lines and therefore ingrained in mathematics and linked extensively to probability theory. It is generally considered a branch of operations research because it is often applied in making business decisions in terms of how resources are made available to provide services. Its most direct applications are many and varied. They include production systems, transportation and stocking systems, traffic flow, communication systems, call centers, networks, and information processing systems. In particular, queuing models are useful for the design of several systems in terms of layout, capacities, and control, as well as in waiting lines for services (Cohen, 1995; Green et al. 1991; Johnson, 1993; Taylor, 1994).

In queuing theory, a queuing model is used to approximate a real queuing situation or system, so the queuing behaviour can be analysed mathematically. According to Russell and Taylor (2000 and 2006), the mathematics used in queuing theory generate measures referred to as *operating characteristics* that describe the performance of the queuing system and which management uses to evaluate the system and make decisions. The operating characteristics include:

- average number of customers in the system (waiting and being served).
- average number of customers in the

waiting line.

- average time a customer spends in the system (waiting and being served).
- average time a customer spends waiting in line.
- probability of no customers in the system.
- utilization rate (i.e. the proportion of time the system is in use).

Adan and Resing (2001) explain that relevant performance measures in the analysis of queuing models include: (i) the distribution of the waiting time and the sojourn time of a customer (where the sojourn time is the waiting time plus the service time); (ii) the distribution of the number of customers in the system (including or excluding the one or those in service); (iii) the distribution of the amount of work in the system (that is, the sum of service times of the waiting customers and the residual service time of the customer in service; and (iv) the distribution of the busy period of the server (this is a period of time during which the server is working continuously, particularly the mean performance measures, such as the mean waiting time and the mean sojourn time). They further explain that among others, a queuing model is characterized by the arrival process of customers (where it is usually assumed that the inter-arrival times are independent and have a common distribution such as a Poisson stream). In addition, customer behaviour may be that of patience and willingness to wait or that

of impatience and leaving after some time; while the service times are independent and identically distributed (Berry, 1993; Berry and Parasuraman, 1991). Also, the service discipline (e.g. customers can be served one by one or in batches) and service capacity (referring to a single server or a group of servers helping the customers) are all important (Bennett, 1990).

There are key assumptions that underlie the empirical determination of the operating characteristics of queuing models. In this study, the multiple server queuing system was applied based on the following assumptions:

1. Customer arrivals are described by Poisson distribution.
2. The service time are described by an exponential distribution.
3. Infinite calling population and queue length.
4. The queue discipline used is first-come, first served.
5. The customers are patient so there is no balking or renegeing.

Following from the assumptions and related operating characteristics, some standard formulae for estimating operating characteristics of a multiple server queue which serve as performance measures of the queuing system were used (see Stevenson, 2005; Gross and Harris, 1985; Larson, 1987). These include (where  $\lambda$  is the average arrival rate,  $\mu$  is the average service rate, and  $s$  is the number of servers):

(a) The probability that there are no customers in the system,  $P_0$  [note that  $P_0 \geq r_0$ ]

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

(b) Average number of customers in the system,  $L$

$$L \geq \frac{\lambda \mu \left( \frac{\lambda}{\mu} \right)^s}{(s-1)! (s\mu - \lambda)^2} \times \rho_0 + \frac{\lambda}{\mu} \quad (2)$$

(c) Average time a customer spends in the system,  $W$

$$W \geq \frac{L}{\lambda} \quad (3)$$

(d) The average number of customers waiting,  $L_q$

$$L_q \geq L - \frac{\lambda}{\mu} \quad (4)$$

(e) The average time a customer spends waiting in a line,  $W_q$

$$W_q \geq \frac{L_q}{\lambda} \quad (5)$$

(F) The probability that the server is busy and a customer has to wait for service,  $P_w$

$$P_w \geq \frac{1}{s!} \left( \frac{\lambda}{\mu} \right)^s \times \frac{s\mu}{(s\mu - \lambda)} \times \rho_0 \quad (6)$$

(g) The probability that the server is idle and a customer can be served,  $I$

$$I \geq 1 - P_w \quad (7)$$

## Empirical Analysis: The Case of Agricultural Development Bank (ADB) Koforidua

The ADB Koforidua Branch has three servers in the banking hall so the multiple-servers queuing model is applicable. With the multiple servers, all the customers share a common queue. If a customer arrives and at least one server is available, then the customer is immediately dispatched to that server. It is assumed that all servers are identical; thus, if more than one server is available, it makes no difference which server is chosen for the service. If all servers are busy, a queue begins to form. As soon as one server becomes free, a customer is dispatched from the queue using the dispatching discipline in force (Stalling, 2000).

In determining the current performance of the queuing system at the bank, data was collected on the arrival rate ( $\lambda$ ) and service rate ( $\mu$ ). The data was collected on five different days at the beginning, middle and ending of January and February 2008 and the average was estimated. This was done so that the average of the data will reflect periods when the bank is very busy, busy and less busy, respectively. It is also assumed appropriately that the activities at the bank are similar across months, so that it made no difference which month was chosen for the study. Data collection in January and February were therefore for convenience as the researchers were more available during those months.

The arrival rate was estimated by monitoring the number of customers that arrive at the bank in every one hour period, and the average determined for each of the five days. The service time was

computed through the monitoring activities of four people and with the help of stop watches. It was computed by finding out the time taken by each of the three servers of the bank to serve a customer that arrives at the bank. The average service time of the three servers was estimated for each day. The average number of customers served per hour was obtained by dividing 60 minutes by the average service time, i.e. service rate per hour. An average of the arrival rate and the service rate for the five days were estimated. The average arrival rate ( $\lambda$ ), average service rate ( $\mu$ ) and the number of servers ( $s$ ), were used in computing the operating characteristics which serve as measures of the performance of the queuing system at the bank.

In examining the performance of the system with an additional service point at the bank, the arrival rate, service rate and number of servers and number of customers in a waiting line system were again used but this time it was assumed that the bank had added an additional service point, hence  $s \geq 4$ . This was then used to compute the operating characteristics of the queuing system, assuming an additional service point has been added.

ADB Koforidua Branch was selected out of the numerous banks because it was expected that being an agricultural development bank, some of its customers would be farmers hence the results of the study will help the farming community as well. Also, the Branch Manager was willing to allow the bank to be used for this study. Finally, there is always a queue build-up at the bank.

In determining customer

perceptions about queue build-up at the bank, primary data was collected using structured questionnaires which included questions on customer perceptions about queues at the bank. A sample size of sixty was used. Data used in determining the performance of the queuing system was obtained through the monitoring of the arrival and the time a customer was served at the bank by four individuals each with a stop watch. For a period of one hour at the bank, the time each customer entered the bank was recorded, and the time the customer left the bank was also recorded.

## Results and Discussion

Descriptive statistics, including frequency distribution and percentages were used to identify and describe the customer perceptions about queue build-up at the bank, based on data collected from questionnaires administered to 60 customers of the bank.

Out of the 60 people interviewed, 40 of them representing 66.7 percent do foresee the presence of a queue whenever they are visiting the bank while 33.3 percent do not. For those who foresee the presence of queue at the bank, 40.5 percent expect a very long queue at the bank, 38.1 percent expect a long queue, and 21.4 percent expect a short queue. This implies that most of the customers expect very a long queue prior to visiting the bank. About 86.7 percent of the respondents indicated that they are much concerned about the presence of queues at the bank since these affect them in several ways, while the remaining 13.3 percent are not concerned about the queues at the bank. This implies that a majority of the respondents hate to see

queues at the bank

About 33.3 percent of the respondents asserted that they encounter queues at the bank mostly on Fridays which constitute the highest percentage of the respondents. About 31.7 percent however mostly encounter queues at the bank at the end of every month which can be any of the five working days. Fourteen (14) out of the 60 respondents which represent 23.3 percent indicated that Mondays are the days that there are mostly queues at the bank. This means there are often queues at the bank at the beginning and ending of the week and at the end of the month.

About 53 of the respondents representing 88.3 percent asserted that though there are always queues at the bank which in one way or the other affects them, they are very satisfied with the core service of the bank, while the remaining 7 representing 11.7 percent are not satisfied with the core service of the bank. Also, 73.3 percent of the respondents stated that the presence of queues at the bank affect their ability to do other things like going to school on time, going to work on time and also going to the market place on time. The remaining 26.7 percent point out that the queue at the bank does not affect them in any way. This implies that majority of the customers are affected by the presence of the queue at the bank. Furthermore, about 73.3 percent of the respondents have an intention of withdrawing their account from the bank while the remaining 26.7 percent specified that they will withdraw their account from the bank. This suggests that the bank is likely to lose some of its customers if nothing is done about the presence of

queues at the bank.

In terms of what customers think should be done to limit the queues at the bank, 8.3 percent point out that the bank should expand the banking hall so as to limit the queue spilling over into the area outside the banking hall. About 20 percent suggest that the bank should improve their network so as to be fast in their service. Also, 16.7 percent indicate that though the bank has ATM machine, most of the customers do not have the ATM card so the bank should provide the customers with the card so as to reduce the number of people who come and wait in the banking hall. The majority representing 55 percent suggest that the bank should provide an extra service point

so that more people can be served at a time so as to limit the queue at the bank.

Data (converted to averages as shown in table 1) were collected from the bank between January and February 2008 (as described above) to help assess the current performance of the queuing system at ADB, Koforidua branch.

It was found that the bank has three servers ( $s \geq 3$ ) that provide customers with services such as withdrawing money, depositing money into an account, checking of balance in an account, opening of a new account, ordering and collection of ATM cards, and making of enquiries. Most of the customers come to the bank to withdraw money.

**Table 1 - Data for determining the current performance of the bank**

Date	Average number of customers per hour	Average service time (Minutes)	Average number of Customers served per hour
30 <sup>th</sup> January, 2008	76	2.7	22
4 <sup>th</sup> February, 2008	68	3.0	20
8 <sup>th</sup> February, 2008	44	3.2	19
13 <sup>th</sup> February, 2008	46	3.0	20
19 <sup>th</sup> February, 2008	48	3.1	19
<b>Average</b>	<b>56</b>	<b>3.0</b>	<b>20</b>

*Source: Authors computation*

Note: The following were estimated from the data to compute the operating characteristics which serve as a measure of the current performance of the queuing system at the bank:

Mean arrival rate,  $\lambda = 56$  customers

Mean service rate,  $\mu \geq 20$  customers

As already indicated above, the performance of the queuing system at the bank was assessed by computing the

operating characteristics using the queuing formulae for the multiple server model.



(A) The probability that there are no customers in the system:

$$P_0 \geq \frac{1}{\left[ \frac{1}{0!} \left( \frac{56}{20} \right)^0 + \frac{1}{1!} \left( \frac{56}{20} \right)^1 + \frac{1}{2!} \left( \frac{56}{20} \right)^2 \right]} + \frac{1}{3!} \left( \frac{56}{20} \right)^3 \frac{3(20)}{3(20)-56}$$

$\geq 0.01623$  probability or 1.6% chance of having no customers in the system.

(B) Average number of customers in the system:

$$L \geq \frac{56(20) \left( \frac{56}{20} \right)^3}{(3-1)! [3(20)-56]} (0.016) + \frac{56}{20}$$

$\geq 15$  customers in the service department.

(c) Average time a customer spends in the department:

$$W \geq \frac{15}{56}$$

$\geq 0.27$  hour or 16.2 minutes in the service department.

(d) The average number of customers waiting:

$$L_q \geq 15 - \frac{56}{20}$$

$\geq 12.2 \geq 12$  customers waiting to be served.

(e) The average time a customer spends waiting in a line:

$$W_q \geq \frac{12}{56}$$

$\geq 0.22$  hours or 13.2 minutes waiting in the line.

(f) The probability that the server is busy and a customer has to wait for service:

$$P_w \geq \frac{1}{3!} \left( \frac{56}{20} \right)^3 \frac{3(20)}{3(20)-56} (0.016)$$

$\geq 0.878$  probability or 87.8% chance that a customer must wait for service.

(g) The probability that the server is idle and a customer can be served:

$$I \geq 1 - P_w$$

$\geq 1 - 0.878 \geq 0.122$  probability or 12.2% chance that the server is idle and a customer can be served.

From the computations, it is observed that at any point in time one goes to the bank, there is only 1.6% chance of having no customers in the queuing system. This means there is 98.4% chance of having customers in the queue. This confirms why 66.7% of the respondents expect a queue in the banking hall prior to visiting the bank. One is likely to meet 15 customers in the queuing system and each will spend about 16 minutes in the system before leaving the bank. Also, there will always be 12 customers waiting in the queue to be served, and each will spend about 13 minutes in the queue before being served. There is always 87.8% chance that a customer who goes to the bank must wait for sometime before he/she is served.

The current performance of the queuing system suggests that customers are not satisfied. The waiting line is too long, the average time a customer has to be in the system is excessive, and too many customers must wait in order to be served. As a result, customers are frustrated by the average waiting time of 13.2 minutes and the 87.8% chance of waiting. They are not happy with the current performance of the queuing system at the bank. This confirms why 86.7 percent of the respondents are much concerned about the presence of queues at the bank, and even 26.7 percent of customers intend to withdraw their account from the bank. To

try to improve matters, the bank is expected to consider an extra service representative (or a service point in the banking hall.

The operating characteristics for the system was recomputed with  $s = 4$  to ascertain whether an additional service point could improve the performance of the queuing system at the bank. Substituting  $s = 4$  along with  $\lambda$  and  $\mu$  in the queuing formulae as shown in appendix 1 resulted in the following operating characteristics:

$P_0 \geq 0.053$  probability or 5.3% chance that no customers are in the service department.

$L \geq 4$  customers are in the service department

$W \geq 0.069$  hour or 4.14 minutes in the service department

$L_q \geq 1.06 \geq 1$  customer waiting to be served

$W_q \geq 0.0189$  hour or 1.13 minutes waiting in line

$P_w \geq 0.45$  probability or 45% chance that a customer must wait for service.

$I \geq 0.55$  probability or 55% chance that the server is idle and a customer can be served.

**Table 2: Comparing the performance of the queuing system with the number of servers,  $s = 3$  and  $s = 4$** 

Operating characteristics	Number of servers, $s$	
	$s = 3$	$s = 4$
Probability that there are no customers in the system, $P_0$	0.016	0.053
Average number of customers in the system, $L$	15 customers	4 customers
Average time a customer spends in the system, $W$	16.2 minutes	4.14 minutes
Average number of customers waiting, $L_q$	12 customers	1 customer
Average time a customer spends waiting in a line, $W_q$	13.2 minutes	1.13 minutes
Probability that the server is busy and a customer has to wait for service, $P_w$	0.878	0.45
Probability that the server is idle and a customer can be served, $P_s$	0.122	0.55

Source: Author's computation

The results from adding another server is significantly better for all the operating characteristics computed. Waiting time is reduced from 13.2 minutes to 1.13 minutes; average number of customers waiting in the line is reduced from 12 customers to 1 customer, and the probability of 0.878 or 87.8% chance to 0.45 probability or 45% chance of waiting to be served. Taylor III (2007) and Russell and Taylor III (2003) have illustrated this improvement using three servers and four servers. The interesting issue here though is the magnitudes of these changes as the model is applied to real data under different contexts. The magnitudes of these improvements are large and therefore prompted further

analysis to ascertain the robustness of the changes observed. A selective analysis of the data was subsequently done separating the busy and non-busy days/periods.

As was observed from the survey, longer queues usually formed at the bank at the beginning and ending of the week and at the end of the month.” Indeed, column 2 of Table 1 shows that on January 30<sup>th</sup> and February 4<sup>th</sup>, 2008, the average number of customers per hour was 76 and 68 respectively, while on the other three days the average number of customers only varied between 44 and 48 with a mean of 46. Thus, different days of the week or periods of the month are different in terms of mean arrival rates

even if the assumption of Poisson distribution holds. Further analysis was therefore done by separating the more busy and less busy days/periods at the bank.

If for the non-busy days  $\lambda = 46$ ,  $\mu = 20$ , and  $s = 3$ , based on the queuing formula used the average waiting time is 2.5 minutes. This is a reasonable waiting time suggesting that during the non-busy days or periods, it may not be necessary to increase the number of servers to four. However, when the busy days are considered then  $\lambda = 68$  or  $\lambda = 76$ . If  $\lambda = 76$ ,  $\mu = 20$ , and  $s = 3$ , then  $\lambda = 76 > s\mu = 60$ , implying that the customers arrive at a faster rate than the total rate at which the three servers can serve them. In this case, the queuing formulae are not applicable because the stability condition inherent in the model is violated. Averaging the data over five days for both busy and non-busy days thus tends to make the analysis rather simplistic, especially when the stability condition consistently fails to hold during the busy days/periods.

Although the queuing model is not applicable when the stability condition fails, we nevertheless know that the waiting time will be very high because the queue never reaches a steady state, and keeps growing. If the number of servers is increased to 4, then now  $\lambda = 76 < s\mu = 80$  (the stability condition is satisfied). The waiting time is 13.37 minutes with  $s = 3$  which is high but better than it otherwise would be, and so justifies the introduction of a 4<sup>th</sup> server. And if a 5<sup>th</sup> server is introduced during those busy days/periods, that reduces the waiting time to 1.19 minutes. Thus whereas no new server may be introduced at the bank

on non-busy days, two more servers (4<sup>th</sup> and 5<sup>th</sup>) may be introduced to improve service at the bank on busy days.

## Conclusions and Recommendations

The study was undertaken with the general view of analysing the relationships between queue development and customer service provision at the Agricultural Development Banks in Ghana, using the ADB Koforidua Branch as a case study. Specifically, the study describes the customer perceptions about queue build-up, the current performance of the queuing system, and improvement in the queuing system with additional service points particularly during busy days/periods at the bank.

Most of the respondents expect a queue before going to the bank. Majority of them are affected by waiting in line and are not happy, so 26.7% intend to withdraw their account from the bank as a result of the queue. There is often queue build-up at the beginning and ending of the week and at the ending of the month. Most of the respondents are satisfied with the core services of the bank despite the queue at the bank. Most of them suggest providing extra service point as a way of limiting the queue. Others suggest that the provision of ATM cards, improving network and expansion of the banking hall will help to limit queue build-up at the bank.

On the average, 56 customers go to the bank per hour and a customer arrives in every 3 minutes. This indicates that the bank is busy. If the non-busy and busy days at the bank are separated, an average of 46 customers and 68 or 76 customers

go to the bank every hour on non-busy and busy days respectively. Each service point is able to serve an average of 20 customers in an hour.

Most customers seem not to be satisfied with the current performance of the system. There is 87.8% probability that a customer must wait to be served and this confirms why 66.7% of the respondents always foresee a queue before going to the bank. There is always an average of 12 customers waiting to be served and a customer spends about 13 minutes waiting.

Adding a fourth server is a significant improvement over the previous system as the operating characteristics are better with four servers than with three servers. Waiting time and average number of customers waiting in the line are reduced significantly from 13.2 minutes to 1.13 minutes and 12 customers to 1 customer, respectively. However, when non-busy and busy days at the bank are analysed separately, it is observed that customer waiting time on non-busy days/periods is only 2.5 minutes, and the current 3 servers seem adequate. On the other hand, customer waiting time is still high at 13.37 minutes with the introduction of a 4<sup>th</sup> server, but this reduces to only 1.19 minutes when a 5<sup>th</sup> server is introduced.

It was observed that the ADB Koforidua Branch is concerned with the queue so it is trying to make waiting more attractive by providing a psychological solution. The bank has provided diversions by placing a television above the tellers to entertain customers waiting in the line. This practice seems to be the case in most banks in Ghana, particularly

those in large cities and towns. As a way of providing more concrete solutions to improve the queuing system at the banks and thereby improve the banking services in Ghana, the following general recommendations are made based on the results of the case study.

Customers often link long waiting periods to poor quality service and one option is for them to change their banks. Banks should therefore improve server efficiency in order to increase the number of customers that can be served in a period of time since the time spent by people waiting in a line is a valuable resource loss. One clear way to achieve this is to identify busy days at the bank and the addition of one or more extra service points whenever queues build up or during such busy days as this results in a significant improvement of service delivery to customers.

Customers must be served faster than they arrive at the banking hall hence the arrival rate must always be less than the total service rate, that is,  $\lambda < \mu$ . The case study shows that during peak periods, such as during the month ending, the total service rate is less than the arrival rate, that is,  $\mu < \lambda$ , which means that the waiting line for this period would eventually grow infinitely long. Banks should therefore commit additional resources and add extra service points during these periods so that they can maintain their customers and even attract new ones.

In addition, banks should improve their networks and provide ATM cards to more customers and encourage its usage so as to reduce queuing at the banking halls as most of the customers come to the bank to withdraw money most of which

can be done with ATM cards. Also, since opening a new account and making certain enquires may take more time than depositing money or withdrawing money (which is what most customers go to the

bank for) the creation of specialized windows for some of these different functions or services is recommended to reduce the average waiting time for most customers.

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## Appendix 1

### Computing the operating characteristics to ascertain the performance of the queuing system with an additional service point. (s = 4)

(a) Probability that no customer are in the service department

$$P_0 \geq \frac{1}{\left[ \frac{1}{0!} \left( \frac{56}{20} \right)^0 + \frac{1}{1!} \left( \frac{56}{20} \right)^1 + \frac{1}{2!} \left( \frac{56}{20} \right)^2 + \frac{1}{3!} \left( \frac{56}{20} \right)^3 \right] + \frac{1}{4!} \left( \frac{56}{20} \right)^4 \frac{4(20)}{4(20)-56}}$$

$P_0 \geq 0.053$  probability or 5.3% chance that no customers are in the service department.

(b) Average number of customers in the system, L

$$L \geq \frac{56(20) \left( \frac{56}{20} \right)^4}{(4-1)! [4(20)-56]} (0.053) + \frac{56}{20}$$

$L \geq 4$  customers are in the service department

(c) Average time a customer spends in the department, W

$$W \geq \frac{4}{56}$$

$W \geq 0.069$  hour or 4.14 minutes in the service department

(d) The average number of customers waiting,  $L_q$

$$L_q \geq 4 - \frac{56}{20}$$

$L_q \geq 1.06 \geq 1$  customer waiting to be served

(e) The average time a customer spends waiting in a line,  $W_q$

$$W_q \geq \frac{1}{56}$$

$W_q \geq 0.0189$  hour or 1.13 minutes waiting in line

(f) The probability that the server is busy and a customer has to wait for service,  $P_w$

$$P_w \geq \frac{1}{4!} \left( \frac{56}{20} \right)^4 \frac{4(20)}{4(20) - 56} \quad (0.053)$$

$P_w \geq 0.45$  probability or 45% chance that a customer must wait for service.

(G) The probability that the server is idle and a customer can be served,  $I$

$$I \geq 1 - 0.45$$

$I \geq 0.55$  probability or 55% chance that the server is idle and a customer can be served.