# HiMCM 2013 Problem B

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November 3, 2013

# Summary

Customer service is one of the major financial activities banks around the world carry out. High-quality and efficiency of customer service are not only indispensable for ensuring a satisfactory banking experience for customers, but also crucial for helping the bank earn profits and enhance reputation. However, the problem of long lines continues to bother many commercial banks despite their great efforts to improve the situation. In this paper, our task was to determine whether the current customer service of the bank in Problem B was at the ideal level proposed by the manager. If it turned out to be dissatisfactory, we would have to consider the most efficient ways to optimize the current system and put forward our recommendations to the manager.

Our models were all based on the famous Queuing Theory. Before constructing models, we calculated the average arrival rate of customers and the average service rate of servers using data provided by the problem. After obtaining the two necessary parameters, we were able to start on our first model—$M/G/1$ Queuing Model to compute the average waiting time and average queue length. The results we obtained from computation were 6.599 persons for average queue length and 17.504 minutes for average waiting time. Because these values obviously exceeded the ideal results, we found that the current service system was far from satisfactory and it definitely needed appropriate improvements.

Therefore, our next step was to construct models that would help identify the minimal changes to the current system. Keeping the notion of optimum and profit maximization in mind, we altogether proposed three recommendations. First, we used $M/G/2$ Queuing Model to determine the effect of adding an additional service station, and results showed that service efficiency could be greatly increased, especially during rush hours. For both recommendations two and three, we applied $M/G/1$ Queuing Model again. We proposed that the average service time should be reduced to 1.695 minutes from the original 2.450 minutes and the average arrival time should be increased to 4.219 minutes from the original 2.650 minutes, respectively. We also provided some qualitative suggestions.

Moreover, we also introduced two alternative models to further verify the need to improve customer service. Although the results given by the $G/G/1$ and $M/M/1$ Queuing Models deviated from what we obtained using $M/G/1$ Model, they were still much larger than the manager's desired values. At this point, the importance of improvement was beyond doubt.

To test the universality of our three recommendations, we did case studies of three banks from different regions in the world: TD Bank, Bendigo Bank and Banca Comerciala and Romana (BCR). We found that each bank either reduced customer arrival rate or increased service rate to achieve high-quality customer

service. This implied that Recommendations Two and Three are the most widely adopted approaches. We also learned what these banks did specifically to deal with improving customer service and found that these methods matched what we proposed in the recommendations section.

In our letter to the manager of the bank, we eventually listed all the potential techniques the manager could use to improve customer service, including: 1) Providing staff training; 2) Establishing online service programs to educate customers and set up online transactions; 3) Creating more ATM machines; 4) Establishing and improving bank branches; 5) Adding one service station during rush hours. These approaches should prove successful in helping the bank retain its customer base and make profits.

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# 1 Introduction

The issue of customer service has always been crucial for every financial sector in the world. Improving customer satisfaction is one of the major goals of responsible banks. As banks continue to provide more and more services and products, they must manage to organize the structure of their operation system in order to ensure both a great banking experience for customers and sufficient profits for themselves.

When engaging in financial transactions at banks, customers always have to wait in long lines. The most common category of queuing systems we face in our daily lives is customer service queuing system. Many commercial banks have been striving for methods to increase the efficiency and quality of customer service, but most of them are still facing the serious problem of long lines. In terms of economics, long line means shortage of demand, creating negative externality. It reflects the slow service rate of a system and inefficient coordination. Long lines always exist because the service for a customer may not be available immediately due to the limited facilities and resources. As waiting queues tend to discourage customers from engaging in financial activities at the bank, the most important and the only technique to meet the service demand is to increase the number of useful resources and the efficiency of operation.

# 2 Problem Restatement

In this paper, we will build a mathematical model (queuing model) based on the data of a bank provided by the problem to find out whether the current customer service is satisfactory. If the current service can enable customers to wait less than 2 minutes and the average length of the queue can be no more than 2 persons, it can be considered appropriate and ready for application. If not, we have to determine the minimal changes the staff have to make in order to realize the manager's goal.

Also in this paper, we will analyze and compare the quality of the customer services of banks from different regions in the world to find out the extent to which banks need to improve their services and what some banks do to achieve the optimal goal. Moreover, by gathering enough data and information, we will be able to write a non-technical letter to the bank's management team to provide our suggestions.

# 3 Assumptions/Justifications

**Assumption 1.** The working time of the service stations is approximately 8 hours per day, including the time for breaks and lunches.

Justification: We can compute that the average arrival time per customer is $0 \times 0.1 + 1 \times 0.15 + 2 \times 0.1 + 3 \times 0.35 + 4 \times 0.25 + 5 \times 0.05 = 2.65$. Then the total average arrival hours for 150 customers is $150 \times 2.65/60 = 6.625$ hours. Moreover, in the real world, the average working time for employees is about 8 hours a day. We assume that the working time of service stations in this model is also around 8 hours.

**Assumption 2.** We assume that the bank can have one or more than one service station placed in parallel to serve a single waiting line.

Justification: Servers are staff members who are capable of performing a service task in the bank. We assume that the bank has more than one service station so that the same service can be carried on for multiple customers at the same time.

**Assumption 3.** The banking system follows the ordinary queueing discipline/ scheduling, that is, service in the order of arrivals–FCFS (First Come First Served) or FIFO (First In First Out).

Justification: We assume that the bank keeps track of the order in which the requests are placed. Thus, the customers will engage in their financial activities in the order they request the service. This assumption is made to ensure relative efficiency of banking service.

**Assumption 4.** The customers do not arrive at a constant rate nor are they served in an equal amount of time. But the bank has an average rate of customer arrivals and an average service time.

Justification: This is obvious by the given data. We will give the detailed calculation in the next section.

**Assumption 5.** There are no financial depressions or natural disasters that may render the bank unable to operate.

Justification: It is essential that the bank continues to operate and provide its financial products and services properly. If the bank goes into bankruptcy, our model will definitely become meaningless.

# 4 Main models: Queuing System Models

## 4.1 Introduction

Basically, the goal of our model is to evaluate the quality of the current customer service. We will try to find out whether the average waiting time for customers is no more than the desired 2 minutes and whether the average length of the queue (the length of the waiting line) will not exceed 2 persons.

It is well known that queueing theory is the mathematical study of waiting lines, or queues. Waiting lines form because people arrive at a service faster than they can be served. Queueing models can be constructed to predict queue lengths and waiting times. Therefore, we will use the queuing system models to analyze the given data and determine if the current customer service is satisfactory according to the manager guidelines. After analyzing the model, we try to determine if the minimal changes are needed to improve customer service and to achieve the greatest effectiveness of the banks.

Our motive is based on the notion of optimum and profit maximization. Improving customer service is the most important means to ensure a bank's success. Unlike other industries, the banking industry is relatively homogeneous, with all the banks providing nearly the same financial services and products. As a result, customers have a lot of choices. If they are not satisfied with one bank, they can easily turn to another bank that offers better service; so the quality of customer service is what distinguishes successful banks from unsuccessful ones.

Figure 1 demonstrates the notion of optimum. The increasing line of Figure 1 represents Supply and the decreasing line represents Demand. When supply of financial service equals demand for financial service, the bank achieves an optimum in which it satisfies every customer's material and psychological needs and gets the desired profits in the end. However, when demand exceeds supply, the shortage of financial service tends to discourage customers from engaging in the financial activities provided by the bank. This not only results in an unpleasant banking experience for customers but also fewer profits for the bank. Thus, our final aim is to ensure the optimal situation.

Figure 2 is another way to prove the importance of improving customer service in terms of profit maximization. The figure illustrates the relationship among Average Total Cost(ATC), Average Variable Cost(AVC), Average Fixed

Cost(AFC) and Marginal Cost(MC). As the total fixed cost of the bank is always constant, the average fixed cost when there are only a few customers is relatively high and it decreases as the number of customers increases. The average variable cost changes only a little throughout the course. Therefore, the bank needs to attract more customers in order to minimize its average total cost. However, when there are too many customers, the average total cost will increase and the marginal cost even exceeds average total cost. All in all, we conclude that the bank should strive to retain a customer size where the graph of marginal cost intersects the lowest points of average total cost and average variable cost to maximize profits.

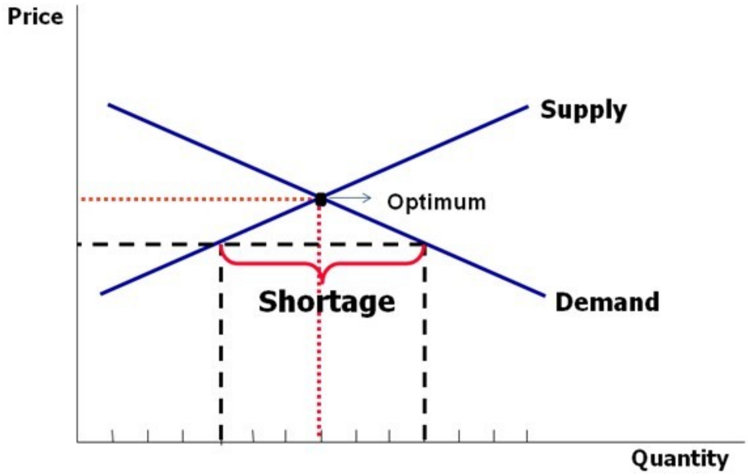


Figure 1: Supply–Demand Model

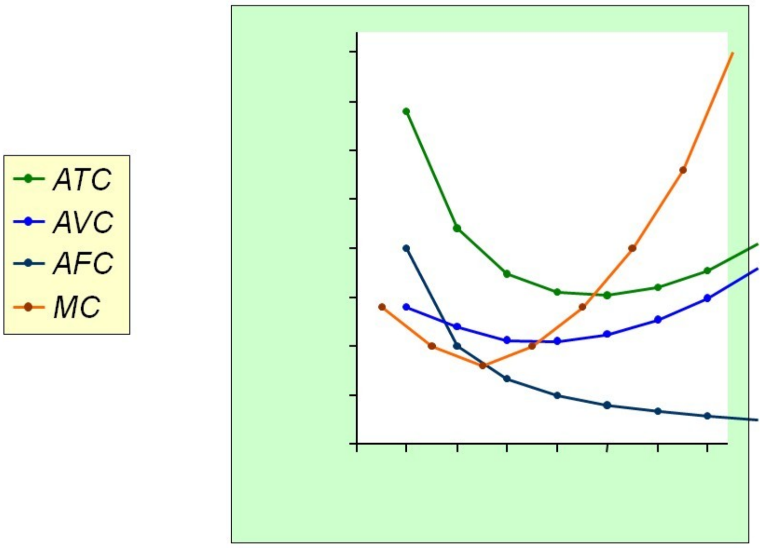


Figure 2: Cost Analysis

Now we turn to the queuing theory. First, what is a queuing system? For a unique definition of queueing systems, the following notation is usually used: $A/S/m/c/p$, where $A$ represents the arrival process, $S$ is the service process, $m$ the number of service stations, $c$ number of system places, $p$ size of customer population.

Usually, $A$ and $S$ are substituted by one of the commonly used symbols as the case may be. The term queue length refers to the total number of customers in the system (including both waiting customers and those in service). The parameter $c$ includes both waiting places and service places ( may be omitted from the notation, whence by default its value is infinite). The size of the customer population $s$ is also on optional parameter (may be omitted from the notation, whence by default its value is infinite).

$A$ (arrival process) defines the type of arrival process. Often it is thought that the interarrival times are independent (renewal process), whence the process is determined by the type of interarrival distribution. Commonly used symbols are $M$ (exponential interarrival distribution ($M$ = Markovian, memoryless), Poisson process); $D$ (deterministic, constant interarrival times); $G$ (general (unspecified) distribution); etc.

$S$ (service process) defines the distribution of the customer's service time. The service time is affected by two factors: the required work requested by the customer and the service rate of the server. The service time is the ratio of these. The type of the service time distribution is indicated by substituting an appropriate symbol for $S$. Commonly the same symbols ($M, D, G$, etc.) are being used as for defining the type of the interarrival time distribution.

**Example 1.** The queue $M/M/1$

Poisson arrival process, exponential service time distribution, single service station, unlimited number of waiting places.


Figure 3: M/M/1 Model

**Example 2.** The queue $M/M/m/m$

Poisson arrival process, exponential service time distribution, $m$ service stations and $m$ system places.

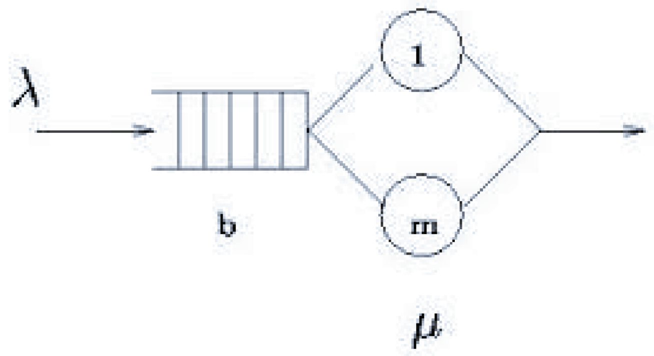


Figure 4: M/M/m Model

## 4.2 Parameters

**A. Average Arrival Rate $\lambda$**

From the problem statement, we see that the customers do not arrive at a constant rate nor are they served in an equal amount of time. Then we need to compute the average rate of customer arrivals and the average service time. First we decide the average arrival rate ($\lambda$). From the given Table 1, we obtain the expected value of the arrival time for per person is $0 \times 0.1 + 1 \times 0.15 + 2 \times 0.1 + 3 \times 0.35 + 4 \times 0.25 + 5 \times 0.05 = 2.65$. Hence the average arrival rate is $\lambda = 1/2.65 = 0.377$ customers per minute.

Assumption: Poisson arrival process.

Justification: Figure 5 shows the cumulative distribution function (pdf) of the customers' arrival time, while Figure 6 shows the cumulative distribution function of exponential distribution with parameter $\lambda = 0.377$. Comparing the two figures, we conclude that approximately we can assume the Poisson arrival process with exponential interarrival distribution.

**B. Average Service Rate $\mu$**

According to the given service time in Table 2, we can get that the average service time of the servers is $1 \times 0.25 + 2 \times 0.20 + 3 \times 0.4 + 4 \times 0.15 = 2.45$ minutes. Thus the average service rate is $\mu = 1/2.45 = 0.408$ customers per

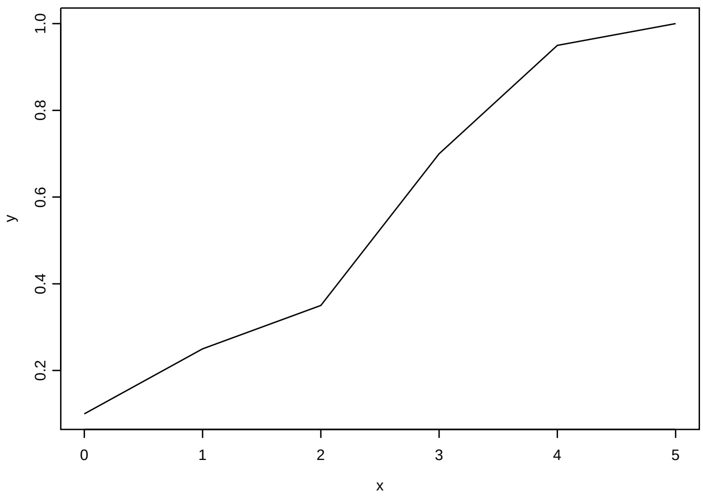


Figure 5: Pdf of the arrival times

minute. Moreover, the standard deviation of the service times is

$\sigma = \sqrt{(1-2.45)^2 \times 0.25 + (2-2.45)^2 \times 0.20 + (3-2.45)^2 \times 0.4 + (4-2.45)^2 \times 0.15}.$

That is,

$$\sigma = \sqrt{1.048} = 1.023.$$

Here we do not need to assume exponential service time distribution, because we can use the $M/G/1$ queuing model to analyze the data even if the given service time distribution is not exponential. In Section 6.2 we will try the $M/M/1$ model based on the exponential service time assumption.

## 4.3 $M/G/1$ Queuing Model

Because $\lambda < \mu$, customers are served faster than they arrive. We can use the Single-Service station Waiting Line System (Single-Service station Model) with undefined general service time distribution, that is, $M/G/1$ queuing system.

For this model, we have the following queuing formulas and results:

1. Probability that no customers are in the waiting line: $p_0 = 1 - \lambda/\mu = 0.076$.

**2. Average length of the waiting line:**

$$L_q = \frac{\lambda^2\sigma^2 + \rho^2}{2(1-\rho)} = 6.599 \gg 2,$$

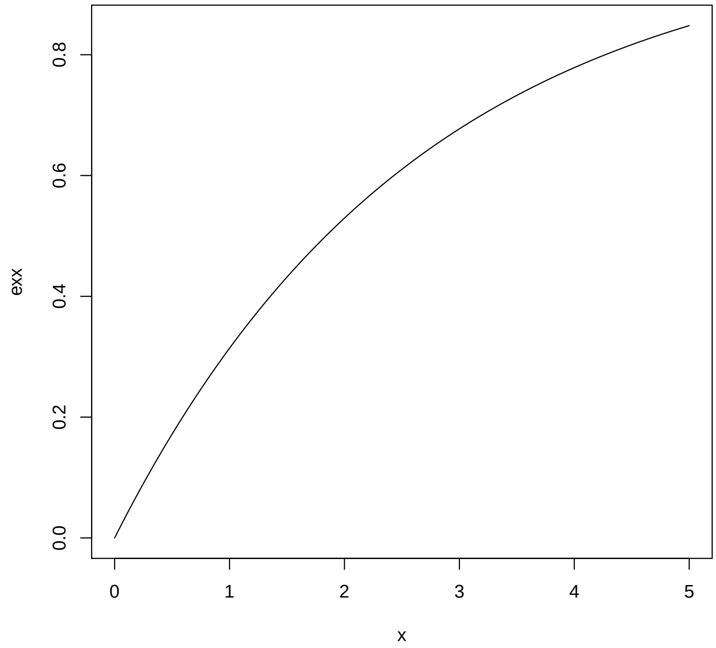


Figure 6: Pdf of exponential distribution

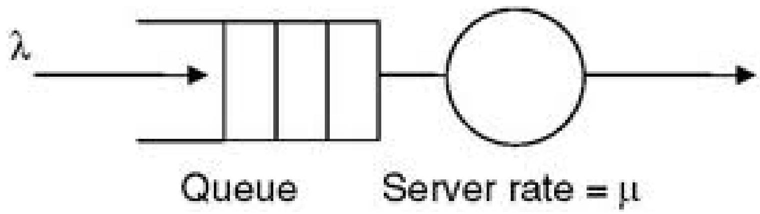


Figure 7: M/G/1 Model

**where** $\rho = \frac{\lambda}{\mu} = 0.924$**.**

3. Average number of customers in system:

$$L = L_q + \rho = 7.523.$$

**4. Average time customer spends waiting in the queue:** $W_q = L_q/\lambda = 17.504 \gg 2$ **minutes.**

5. Average time customer spends waiting and being served: $W = W_q + 1/\mu = 19.955$.

6. Probability that service station is busy (utilization factor): $U = \rho = 0.924$.

7. Probability that service station is idle: $I = p_0 = 1 - U = 0.076$.

From the above computation results, we conclude that the average waiting time for customers is far bigger than the desired 2 minutes and the average length of the queue also exceeds 2 persons. Therefore, the current customer service is not satisfactory according to the manager guidelines.

# 5 Analysis of the Problem and Recommendations

In this section, we will try to determine, through modeling, the minimal changes for servers required to accomplish the manager's goal and to improve customer satisfaction by offering better service.

## 5.1 Recommendation 1–Adding one service station

To reduce the average waiting time and the average length of the queue, one effective way is to increase the number of the service stations. Hence we suggest that the manager add one service station. Now we can use the $M/G/2$ **Queuing Model** with two service stations in parallel serving a single waiting line. First-come first-served queue discipline is assumed. We also assume Poisson arrivals and exponential service times. Again, arrival rate (average number of arrivals per minute) is $\lambda = 0.377$, the service rate (average number served per minute) per service station (channel) is $\mu = 0.408$, the number of service stations is $c = 2$ and the mean effective service rate for the system is $2\mu = 0.816$.

Then we have the following queuing formulas and results:

1. Probability that no customers are in the waiting line:

$$p_0 = \frac{1}{1 + \rho + \frac{1}{2}\rho^2 \frac{2\mu}{2\mu - \lambda}} = 0.368, \quad \rho = \frac{\lambda}{\mu} = 0.924.$$

**2. Average length of the waiting line:**

$$L_q = \frac{\lambda\mu\rho^2}{(2\mu - \lambda)^2} p_0 = 0.251 \ll 2.$$

3. Average number of customers in system:

$$L = L_q + \rho = 1.175.$$

**4. Average time customer spends waiting in the queue:** $W_q = L_q/\lambda = 0.666 \ll 2$ **minutes.**

5. Average time customer spends waiting and being served: $W = W_q + 1/\mu = 3.116$.

6. Probability that customer must wait for service:

$$p_W = \frac{1}{2}\rho^2 \frac{2\mu}{2\mu - \lambda} p_0 = 0.292.$$

7. Probability that service stations are idle: $I = p_0 = 0.368$.

Obviously, if the manager adds one service station, the customer service will be much satisfactory according to the manager guidelines. However, with two service stations in the system, the idleness of the service stations will be increased to 36.8% from the original 7.6%. Moreover, only about 29% of the customers needs to wait for service. This will increase the total cost of providing service. Actually, whether to add a service station depends on the number of customers.

## 5.2 Recommendation 2–Reducing service time

Still using $M/G/1$ queuing model with only one service station, we recommend speeding up the service station's service time by training staff members so that the average time customer spends waiting in the queue and the average length of the waiting line can be reduced to the desired 2 minutes and 2 persons, respectively.

We assume that the average arrival rate is still $\lambda = 0.377$, and the standard deviation of the service times is still $\sigma = 1.023$. Now we want to find an appropriate $\mu$ such that

$$W_q = L_q/\lambda = \frac{1}{\lambda} \frac{\lambda^2\sigma^2 + (\lambda/\mu)^2}{2(1 - \lambda/\mu)} \leq 2.$$

By solving this inequality, we obtain

$$3.64\mu^2 - 1.508\mu - 0.377 \geq 0.$$

Hence we arrive at

$$\mu \geq \frac{1.508 + \sqrt{1.508^2 + 4 \times 3.64 \times 0.377}}{2 \times 3.64} = 0.590.$$

Thus the average service time for one customer is $1/\mu = 1.695$ minutes. This implies that **the service station's average service time should be reduced to 1.695 minutes** from the original 2.450 minutes.

Next we give an example to verify our $M/G/1$ model with the new larger $\mu$. Suppose the distribution of the service time is changed to

| Service Time (min.) | Probability |
|---|---|
| 1 | 0.5 |
| 2 | 0.35 |
| 3 | 0.1 |
| 4 | 0.05 |

In this case, the average service time is 1.7, the service rate $\mu = 1/1.7 = 0.588$ and the standard deviation of the service times is $\sigma = 0.897$. Computing the queuing formulas again, we get

1. **Average length of the waiting line:**

$$L_q = \frac{\lambda^2\sigma^2 + \rho^2}{2(1-\rho)} = 0.732 < 2,$$

**where** $\rho = \frac{\lambda}{\mu} = 0.641$**.**

**2. Average time customer spends waiting in the queue:** $W_q = L_q/\lambda = 1.942 < 2$ **minutes.**

## 5.3 Recommendation 3–Reducing the arrival rate

Still using $M/G/1$ queuing model with only one service station, we recommend reducing the customer's arrival rate so that the average time customer spends waiting in the queue and the average length of the waiting line can be reduced to the desired 2 minutes and 2 persons, respectively.

We assume that the average service rate is still $\mu = 0.408$, and the standard deviation of the service times is still $\sigma = 1.023$. Now we want to find an appropriate $\lambda$ such that

$$W_q = L_q/\lambda = \frac{1}{\lambda}\frac{\lambda^2\sigma^2 + (\lambda/\mu)^2}{2(1-\lambda/\mu)} \leq 2.$$

By solving this inequality, we obtain

$$1.048\lambda + 6.024\lambda + 9.804\lambda \leq 4.$$

Hence we arrive at

$$\lambda \leq 0.237.$$

Thus the average arrival time for one customer is $1/\lambda = 4.219$ minutes. This implies that **the customer's average arrival time should be increased to 4.219 minutes** from the original 2.650 minutes.

Next we give an example to verify our $M/G/1$ model with the new smaller $\lambda$. We suppose the distribution of the arrival time is changed to exponential distribution with parameter $\lambda = 0.237$ (the average arrival time is $1/\lambda = 4.219$ minutes.) In this case, the arrival rate $\lambda = 0.237$. Computing the queuing formulas, we get

1. **Average length of the waiting line:**

$$L_q = \frac{\lambda^2\sigma^2 + \rho^2}{2(1-\rho)} = 0.473 < 2,$$

**where** $\rho = \frac{\lambda}{\mu} = 0.581$**.**

2. **Average time customer spends waiting in the queue:** $W_q = L_q/\lambda = 1.995 < 2$ **minutes.**

Usually, the management can not control the customer's arrival time. So a nature question is how to reduce the arrival rate. There are two ways we can suggest. First the bank can take advantage of ATMs and online service in which it provides customers with easily accessible answers to their banking questions via email so that the bank can reduce the arrival rate. Another suggestion is to re-design its branch network to enhance customer service and productivity. In this way the arrival rate at each branch will be reduced.

## 5.4 Summary of Recommendations

The application of Recommendation One should be paid attention to. We must take into account the idleness and additional costs that might be the results of adding another service station. Therefore, we recommend that the bank provides another service station only during rush hours to increase the service rate. Such change during slack hours is unnecessary and the profits of the bank will not be able to cover the costs of adding another service station.

Recommendations Two and Three can be accomplished through means that can serve to reduce service time or customer arrival rate. The applications of the two recommendations are dependent on the specific region of the bank and the age group of its customers. If the bank is located in a busy city or its customers are mainly young busy people, we think the bank should make improvements strictly according to our recommendations. However, if the bank is situated in a small county or has customers that are retired citizens, the scale of such improvements can be made smaller.

# 6 Alternative models

## 6.1 $G/G/1$ Queue

If the assumption of Poisson arrival process can not be satisfied in this bank service problem, then we can use $G/G/1$ queuing model to analyze the data. For $G/G/1$ queue, Kingman's formula can be applied to approximate the mean customer waiting time:

$$\tilde{W}_q \approx \frac{\rho}{1-\rho}\left(\frac{C_\lambda^2 + C_\mu^2}{2}\right)\frac{1}{\mu},$$

where $C_\lambda^2 = \sigma_\lambda^2 \lambda^2 =$ and $C_\mu^2 = \sigma_\mu^2 \mu^2$, where $\sigma_\lambda^2$ is the variance of the arrival times and $\sigma_\mu^2$ is the variance of the service times.

Using the data in Tables 1 and 2, we obtain $\rho = 0.924$, $\sigma_\lambda^2 = 1.928$ and $\sigma_\mu^2 = 1.048$, and hence

$$\tilde{W}_q \approx 6.684 \gg 2$$

which is much smaller than $W_q = 17.504$ in $M/G/1$ queue. But $\tilde{W}_q$ is still larger than the desired 2 minutes. Therefore we still need some changes to improve customer satisfaction. The analysis in Section 5 with small revisions can still be applied for the $G/G/1$ model.

## 6.2 $M/M/1$ Queue

Alternatively, for simplicity we can assume Poisson arrival process, exponential service time distribution and single service station. That is, we model the data using $M/M/1$ queue. Then standard queue formulas for this simple model yield the following results:

1. Probability that no customers are in the waiting line: $p_0 = 1 - \lambda/\mu = 0.076.$

2. Probability that $n$ customers are in the waiting line: $p_n = \rho^n(1-\rho) = 0.076(0.924)^n$.

3. Average length of the waiting line:

$$L_q = \frac{\rho^2}{1-\rho} = 11.237 \gg 2,$$

where $\rho = \frac{\lambda}{\mu} = 0.924$.

4. Average number of customers in system:

$$L = L_q + \rho = 12.161.$$

5. Average time customer spends waiting in the queue: $W_q = L_q/\lambda = 29.806 \gg 2$ minutes.

6. Average time customer spends waiting and being served: $W = W_q + 1/\mu = 32.256$.

Since $L_q$ and $W_q$ are much larger than the desired 2 persons and 2 minutes, respectively, we need some changes to improve customer satisfaction. The analysis in Section 5 with some revisions can still be applied for the $M/M/1$ model.

# 7 Case Studies-Customer services of banks around the world

In this section we will briefly analyze and compare the quality of the customer services banks from different regions in the world to find out the extent to which banks need to improve their services and what some banks do to achieve the optimal goal.

**A. TD Bank**

TD Bank took advantage of online service in which it provided customers with easily accessible answers to their banking questions via email. The project team made use of a search engine with a true knowledge base to optimize the online self-service facilities. In this way, customers could have a thorough understanding of the specific steps for banking transactions. The search engine TD Bank used was RightNow, which provided the integrated email and web accesses and strong customization and XML-based integration tools. As a result, customers became well-informed before they decided to engage in financial activities. This reduced the time required for the bank to conduct service because the servers didn't have to spend time explaining the specific terms and steps to those ignorant customers.

**B. Bendigo Bank**

The Bendigo Bank improved its customer service by training staff members. All the employees took part in a special training program based on a model called Whole Brain. Trainers introduced a group activity which challenged the servers to think from the perspective of customers and determine customers' thinking preferences. They started out by understanding how relationship works. Each group was then divided into sub-groups to consider dealing with potential customers with four main thinking preferences. They were expected to work out the specific needs of different groups of customers. One of the most important applications for the Whole Brain Model was to teach employees effective communication with customers. By defining the needs and demands of customers, staff members could easily provide appropriate services without wasting too much time on asking them unnecessary questions. Another significant application of this training program was to help employees develop listening skills. Oftentimes, a single customer might have multiple preferences. Thus, the servers should listen carefully to understand what the customer means. The team also trains staff to keep in mind that most people don't have a single dominance; therefore, listening skills are very important. The whole training proved to be a huge success. Because of Bendigo Bank's efficiency and high-quality in dealing with customer service, its reputation was gradually enhanced and it became one of the leading banks in Australia.

**C. Banca Comerciala Romana (BCR)**

BCR sought to re-design its branch network to enhance customer service and productivity. The managers determined that it was very important to keep disruption to a minimum, while also protecting IT investment. Their innovation plan was Cisco-based. By designing Cisco Borderless Network Architecture, the managers of BCR made it easier for employees to communicate between different branches and laid the foundations for more collaboration between employees in terms of telephony, data and video services. The whole architecture also renovated online custom services with more efficient tools of financial transactions and created more automated teller machines (ATMs).

The new plan also introduced skills-based rooting. Clients were able to be connected with the right financial experts, thereby accelerating negotiations and decision-making. "We can provide our customers with quicker, convenient access to knowledgeable advisors who are best placed to deal with their enquiries," says one of the managers.

**What can we derive from the above cases?**

The three banks discussed above improved their respective customer service mainly by 1) Reducing the number of customers that arrive at each bank or 2) Reducing the service time. TD Bank in Case Study A made use of the second method by educating the customers; Bendigo Bank in Case Study B also applied the second method by providing necessary training for servers; BCR in Case Study C used the first method by modernizing branch network as well as providing online service and ATMs. As a result, we can conclude that the suggestions for the bank in the problem should basically involve these two approaches.

# 8 Strengths and weaknesses

Like any model, the ones presented above have their strengths and weaknesses. Some of the major points are listed below.

## 8.1 Strengths

- **Our models can apply to virtually every scenario that has the problem of long lines**

  Queuing theory basically deals with mathematical models to analyze long lines. Formulae for each model can be applied to different scenarios of queuing systems, whether long lines at retail stores, at barber shops or at commercial banks. Thus, we can use the same models to determine the situation of a variety of queuing systems.

- **Our models can improve the customer service efficiently in an exact way**

  Our models can not only test the effectiveness of the queuing system, but also help improve the current situation. In this paper, we used $M/G/1$, $M/G/2$, $G/G/1$ and $M/M/1$ Queuing Models to determine the minimal changes the servers can make to reach the manager's goals. Thus, the queuing models are very powerful tools for finding out how to manage a queuing system in the most effective way.

## 8.2 Weaknesses

1. We do not take into account the more complicated queuing systems due to the lack of time.

2. With more time, we could construct a testing procedure to check and estimate the distributions of the arrival times and the service times. Then, based on these distributions we can choose a proper queuing model to analyze the dataset in a more accurate way.

3. With more information, we could also consider some more factors in the proposed queuing models to improve the efficiency of the customer services, e.g. determining the optimal service rate which minimizes the total cost of providing service and waiting for that service.

# 9 Conclusions

By constructing the $M/G/1$ Queuing Model, we found that the current customer service system is far below the manager's expectations since average waiting time is 17.504 minutes and average queue length is 6.599 persons. Therefore, we used $M/G/1$ and $M/G/2$ Queuing Models to find out and test the minimal changes required for the servers to reach the desired goal. The bank can: 1) add one service station; 2) reduce service time; 3) reduce the arrival rate to bring the quality of its service closer to the manager's goal. We also introduced two alternative models, which are the $G/G/1$ Queuing Model and $M/M/1$ Queuing Model. The numbers obtained further verify the need to improve service.

In addition to applying mathematical models, we also analyzed case studies of several banks in the world to test the universality of the above applications for improvement of customer service. The three banks applied methods such as educating customers, training servers, establishing and improving branches, providing online service and ATMs, and so forth. Through case studies, we found out that options 2) and 3) are the most widespread approaches. Based on all our analysis, we were able to write a letter to the bank's manager voicing our opinions and suggestions.

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# 10 Letter to the bank's manager

Dear Sir/Madam,

As a high school student concerned about the operation of today's banking system, I have always hoped that I could provide suggestions to help improve the quality of customer service to the optimum level. As a result, I constructed several models and analyzed various sources of data. After careful and thorough research, I was able to come up with a couple of ideas that could help enhance customer satisfaction. If the quality of customer service is ensured, the bank will be able to attract enough customers that might serve to increase the profits of the bank. If not, the customers may instead switch to other banks due to the similarity of the types of financial service conducted by different banks.

According to my analysis, the current customer service is not desirable enough. Although your goal is to confine the average waiting time of customers to within 2 minutes and the average queue length to within 2 persons, the results showed that the current situation of customer service is far from satisfactory. Therefore, I strongly suggest that you make some changes to the current system.

First, you can consider ways to reduce the service time of the service stations. Staff training is the most important method to increase the efficiency of service. By learning the thinking preferences and common demands of customers, servers will be able to understand customers better and provide the services that best suit their needs. Another approach is to establish online service programs. This gives customers the opportunity to learn about finance and investment. With multiple links and web pages at their disposal, customers will gradually become familiar with the specific terms and steps that are required for efficient financial transactions.

Second, you should also reduce the number of customers that arrive at the bank by lowering the arrival rate. This goal can also be accomplished through online service which enables customers to conduct financial activities online without having to wait in lines at the bank. In addition, creating more Automated Teller Machines(ATMs) will also help reduce arrival rate of customers. Moreover, the bank can establish branches throughout the region so that the customers can be scattered in different places. This approach will significantly lower the number of customers that wait in line at the bank. If the bank already has branches, you can think about ways that will improve the communication and collaboration between different branches in order to make sure that every branch gets its desired number of customers.

The scale of the above two revisions to the banking system depends on the specific region of the bank and the age group of customers. As is clearly demonstrated in my analysis, the average waiting time of customers and the average queue length far exceed the desired values. These data show that this bank is located in a busy city, which implies that the majority of customers are busy young people and the scale of such improvements should therefore be relatively large. In my opinion, if thoroughly conducted, the above two methods are sufficient enough to reach your goal. However, if the bank has high-quality staff and a responsible management team, I suggest that you occasionally add one service station to help increase the speed of service. The management team of the bank should collect data on the numbers of customers in different time periods during a day. During rush hours, one more service station is definitely needed to help conduct financial service, and the huge profits generated from efficient operation will be able to cover the cost of adding another server. If an additional service station is added when the bank has only a few customers, the idleness of staff will even lower the efficiency of service.

In brief, the current customer service of the bank surely needs improvement. I hope you could consider my suggestions because they are all based on careful and comprehensive model testing. Only through enhancing service can the bank firmly retain its customer base and ensure profitability.

Hope my suggestions could prove valuable for the bank!

Sincerely,

A high school student

11/03/2013