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Minimizing Waiting Time in ATM Services by Applying Queuing Model: Hands on and Hands off Perspectives

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Abstract: *Bank ATMs would avoid losing their customers due to a long wait on the line. The bank initially provides one ATM. And, one ATM would not serve a purpose when customers withdraw to use ATM and try to use other bank's ATM. Thus, to retain the customers, the service time needs to be improved. This paper shows that the queuing theory may be used to resolve this problem. We obtained the data from a bank's ATM in Sylhet city in Bangladesh whilst applying little's Theorem and M/M/1 queuing model in the process. This paper applied queuing theory to determine optimal service level for a case ATM base on a customer-defined criterion of wait time not exceeding eight (8) minutes. Direct non-participatory observation and questionnaire were engaged to record time measurements and primary data. The research revealed that although queuing theory is applicable in finding optimal service levels, waiting time might still be lengthy because of external factors. Service unavailability was observed to be a contributory factor to queue formation in the case of ATM.*

Keywords: *Waiting line, ATM, M/M/1 queuing model, waiting time, terminal*

1. Introduction

The mainstay of this research paper is to solve waiting line problems by harnessing hands-on and hands-off approach in order to optimize the service operations designed to satisfy the end user. We explore a dummy dimension here to pin point the areas that have potential bottlenecks and then deploying some mathematical modeling to figure out the bottlenecks and ultimately streamlining the system itself.

Queue is a common word that means a waiting line or the act of joining a line. Queuing theory was initially proposed by A.K. Erlang in 1903. It optimizes the number of service facilities and adjusts the times of services [1]. Queuing theory is the study of queue or waiting lines. Some of the analysis that can be derived using queuing theory include the expected waiting time in the queue, the average time in the system, the expected queue length as well as the probability of the system to be in certain states, such as empty or full.

The study of waiting lines, called queuing theory, is one of the oldest and most widely used quantitative analysis techniques [2]. Waiting lines are an everyday occurrence, affective people shopping for groceries buying gasoline, making a bank deposit, or waiting on the telephone for the first available airline reservationists to answer. Queues, another term for waiting lines, may also take the form of machines waiting to be repaired, trucks in line to be unloaded, or airplanes lined up on a runway waiting for permission to take off. The three basic components of a queuing process are arrivals, the actual waiting line and service facilities. This paper uses queuing theory to study the waiting lines in Dutch Bangla BANK ATM, at Sylhet city, Bangladesh.

The bank provides one ATM in every branch. In ATM, bank customers arrive randomly and the service time is also random. We used Little's theorem and M/M/I queuing model to derive the arrival rate, service rate, utilization rate, waiting time in the queue. On average, 500 customers are served on weekdays (Sunday to Thursday) and 300 customers are served on weekends (Friday & Saturday) monthly. Generally, on Sundays, there are more customers coming to ATM, during 10am. to 5pm.

The body of knowledge about waiting lines, often called queuing theory, is an important part of operations and a valuable tool. Waiting lines are a common situation. Waiting-line models are useful in both manufacturing and service areas. Analysis of queues in terms of waiting-line length, average waiting time, and other factors helps us to understand service systems (such as bank teller stations), maintenance activities (that might repair broken machinery), and shop-floor control activities [14,15]. Indeed, patients waiting in a doctor's office and broken drill presses waiting in a repair facility have a lot in common from an OM perspective. Both use human and equipment resources to restore valuable production assets (people and machines) to good condition.

2. Literature Review

Technology has changed not only the way we do business but has also changed virtually all sphere of human life. Baxtex et al. (2008) [17] cited in Musara and Fatoki (2010) opine that technology provides enhanced insight into handling old and new tasks [10]. Abor (2005) affirms that technology affects even the direction of an economy and its capacity for continued growth. Human beings consciously or unconsciously interact with products of technology in almost all their daily activities [11].

These products have made the performance of activities which hitherto were carried our stressfully and unproductively much more convenient, faster, easier and more accurate. In the banking industry, information and communication technology is playing a major role in addressing operational challenges such as quicker exchange of data, information processing, record storage and retrieval and many more. The Automated Teller Machine (ATM) is one of the several electronic banking channels used in the banking industry.

According to Aldajani and Alfares (2009), automated teller machines are among the most important service facilities in the banking industry [12]. In a survey conducted by Abor (2005), more than half of respondents revealed their preference for ATM as a conduit to conducting transactions. ATMs particularly when installed off-site serve to keep customers away from bank halls. Unfortunately most ATMs are on-site operating very much as another department of the bank [8].

The issue of queue control in bank halls via ATM is essentially defeated because ultimately access to these facilities is limited to customers going to the bank. ATMs themselves have as a result become subjects of large service demands which directly translate to queues for services when these demands cannot be quickly satisfied. This situation becomes compounded and more evident during festive periods and month endings, around which time demand for cash is high.

Queuing theory known by various other names such as the traffic theory, congestion theory and the theory of mass service (Copper, 1981) is a mathematically based technique for analyzing waiting lines (queues) [13]. It has been used successfully in the studies of queue behavior problems, optimization problems and the statistical inference of queuing system (Xiao and Zhang, 2009) [7].

Queues abound. There is queuing at petrol or gas or diesel filing stations if too many customers await service. Vehicles waiting to cross a major road create congestion. There is also queuing in bank halls when customers wait to be attended to by a cashier or to utilize an ATM facility and many other similar situations. A queue is synonymous to a waiting line because of the waiting involved. According to Ford (1980) "Waiting lines develop when "clients" arriving for "service" are delayed prior to being served"[16]. If customers are scheduled to visit service facilities, and the scheduling rule strictly adhered to, queues can be avoided.

A slow response would greatly affect the speed at which service is provided to customers. As a results service providers may loss customers who grow impatient and leave the system. The business order now is the ability to acquire and retain customers. This centrally lies in the ability of firms to satisfy and provide better service experiences. As such managers of service systems need to design apt strategies to tackle challenges brought about as a result of lengthy queues.

3. Problem Statement

On the basis of the literature review, we came to the conclusion that ATM services here in Sylhet city are unable to reach its competency level. The performance is below par. At times, there are less numbers of booths with customers' demand ever increasing and at times, there are scenarios where the queuing length is so large that customers are bound to Balk or Renege. The target here is to reduce the utilization factor and make the ATM service more rewarding and enjoying for the end-user which culminates into the efficiency optimization of the service provider.

4. Expected Outcomes

- This research can help bank ATM to increase its Quality of Service, by anticipating, if there are many customers in the queue.
- The result of this paper is helpful to analyze the current system and improve the next system. Because the bank can now estimate the number of customers waiting in the queue and the number of customers going away each day.
- By estimating the number of customers coming and going in a day, the bank can set a target that, how many ATMs are required to serve people in the main branch or any other branch of the bank.

5. Research Question / Hypothesis

By estimating the number of customers wait in the queue and the numbers of customers going away each day, the bank can set a target as in installing the right number of ATMs.

6. Research Method

Depending on research questions and orientation of the researcher, a choice is made in setting out the research plan. Robson (1993) divides experimental design, longitudinal design, cross-sectional design and case study design [18]. Others have referred to this distinction as quantitative research designs and qualitative research designs respectively. The case study design is applied appropriately in this paper. Case study as an empirical inquiry is chosen because it allows focus to be placed on the queue phenomenon within its real-life context. The design here is particularly a single case where we considered the two ATMs of the main branch bank of DBBL in Sylhet City. In this paper, two types to data were collected and used. These are primary data and secondary data. Secondary data was obtained through an intensive review of relevant literature on the queuing problem from journal articles, textbooks and many usable electronic sources. Primary data was collected through field studies via observation and questionnaire.

Convenient sampling as a non-probability sampling technique was utilized in administering research questions. This technique was employed not only because respondent were necessarily easy to recruit, but also because of their convenient accessibility. Participants were the most willing and available to be engaged at the material moment. By so doing data was collected faster, easier and inexpensively without requiring the practical details of using randomize sampling techniques. We administered questionnaires to the other group members in a face-to-face fashion. We read out questions and best-fit choices and answers made by individual respondents in this group. Participants for the time studies were also ATM users who arrived at the ATM terminal between the hours of 9:00 AM and 6:00 PM each of the study period.

7. Theoretical Framework

7.1. Characteristics of Queuing System

We take a look at the three part of queuing system

(1) The arrival or inputs to the system (sometimes referred to as the calling population),
(2) The queue or the waiting line itself, and
(3) The service facility. These three components have certain characteristics that must be examined before mathematical queuing models can be developed.

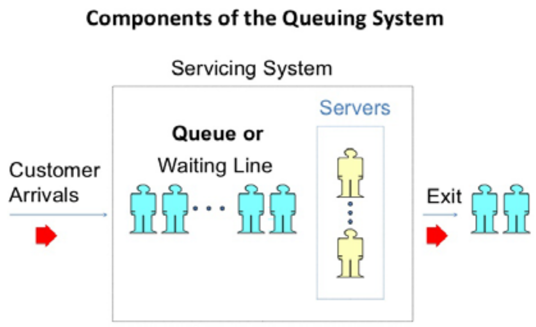

Fig: 1 Components of the queuing system [20]

The input source that generates arrivals or customers for the service system has three major characteristics. It is important to consider the size of the calling population, the pattern of arrivals at the queuing system, and the behavior of the arrivals.

7.2. Size of the Calling Population

Population sizes are considered to be either unlimited (essential infinite) or limited (finite). When the number of or arrivals on hand at any customers given moment is just a small portion of potential arrivals, the calling population is considered unlimited. For practical purpose, in our examples the limited customers arriving at the bank for deposit cash. Most queuing models assume such an infinite calling population. When this is not the case, modeling becomes much more complex. An example of a finite population is a shop with only eight machines that might deposit cash break down and require service [3].

7.3. Pattern of arrivals at the system

Customers either arrive at a service facility according to some known schedule customers or else they arrive randomly [9]. Arrivals are considered random when they are independent of one another and their occurrence cannot be predicted exactly. Frequently in queuing problems, the number of arrivals per unit of time can be estimated by a probability distribution known as the Poisson distribution., For any given arrival rate, such as two passengers per hour, or four airplanes per minute, a discrete, Poisson distribution can be established by using the formula:

$$\rho(n;t) = \frac{(\lambda t)^n}{n!}e^{-\lambda t} \text{ for, n=0,1,2,…..}$$

Where,

$\rho(n;t)$ = probability of n arrivals

λ = average arrival rate

e = 2.18
n = number of arrivals per unit of time

7.4. Behavior of the Arrival

Most queuing models assume that an arriving passenger is a patient traveler. Patient customer is people or machines that wait in the queue until they are served and do not switch between lines. Unfortunately, life and quantitative analysis are complicated by the fact that people have been known to balk or renege. Balking refers to customers who refuse to join the waiting lines because it is to suit their needs or interests. Reneging customers are those who enter the queue but then become impatient and leave the need for queuing theory and waiting line analysis. How many times have you seen a shopper with a basket full of groceries, including perishables such as milk, frozen food, or meats, simply abandon the shopping cart before checking out because the line was too long? This expensive occurrence for the store makes managers acutely aware of the importance of service level decisions.

7.5. Waiting Line characteristics

The waiting line itself is the second component of a queuing system. The length of a line can be either limited or unlimited. A queue is limited when it cannot, by law of physical restrictions, increase to an infinite length. Analytic queuing models are treated in this article under an assumption of unlimited queue length. A queue is unlimited when its size is unrestricted, as in the case of the tollbooth serving arriving automobiles.

A second waiting line characteristic deals with queue discipline. The refers to the rule by which passengers in the line are to receive service., Most systems use a queue discipline known as the first in, first out rule (FIFO). This is obviously not appropriate in all service system, especially those dealing with emergencies. In most large companies, when computer-produced pay checks are due out on a specific date, the payroll program has highest priority over other runs [7].

The third part of any queuing system is the service facility. It is important to examine two basic properties: (1) the configuration of the service system and (2) the pattern of service times.

7.6. Basic Queuing System Configurations

Service systems are usually classified in terms of their number of channels, or number of servers, and number of phases, or number of service stops, that must be made. The term FIFS (first in, first served) is often used in place of FIFO. Another discipline, LIFS (last in, first served), is common when material is stacked or piled and the items on top are used first. A single-channel system, with one server, is typified by the drive in bank that has only one open teller. If, on the other hand, the bank had several tellers on duty and each customer waited in one common line for the first available teller, we would have a multi-channel system at work. Many banks today are multi-channel service systems, as are most large barbershops and many airline ticket counters. A single-phase system is one in which the customer receives service from only one station and then exits the system. Multiphase implies two or more stops before leaving the system.

7.7. Service Time Distribution

Service patterns are like arrival patterns in that they can be either constant or random. If service time is constant, it takes the same amount of time to take Care of each customer. More often, service times are randomly distributed in many cases it can be assumed that random service times are described by the negative exponential probability distribution. This is a mathematically convenient assumption if arrival rates are Poisson distributed. The exponential distribution is important to the process of building mathematical queuing models because many of the models " theoretical underpinning are based on the assumption of Poisson arrivals and exponential services. Before they are applied, however, the quantitative analyst can and should observe, collect, and pilot service time data to determine if they fit the exponential distribution.

8. Mathematical Modeling

Single-Channel Queuing Model with Poisson Arrivals and Exponential service times (M/M/1): We present an analytical approach to determine important measures of performance in a typical service system. After these numerical measures have been computed, it will be possible to add in cost data and begin to make decisions that balance desirable service levels with waiting line service costs [5].

8.1. Assumptions of the Model

The single-channel, single-phase model considered here is one of the most widely used and simplest queuing models. It involves assuming that seven conditions exits:

1. Arrivals are served on a FIFO basis.

2. Every arrival waits to be served regardless of the length of the line; that is, there is no balking or reneging.

3. Arrivals are independent of preceding arrivals, but the average number of arrivals (the arrival rate) does not change over time.

4. Arrivals are described by a Poisson probability distribution and come from an infinite or very large population.

5. Service time also varies from one passenger to the next and is independent of one another, but their average rate is known.

6. Both the number of items in queue at anytime and the waiting line experienced by a particular item are random variables.

7. Service times occur according to the negative exponential probability distribution.

8. The average service rate is greater than the average arrival rate.

9. The waiting space available for customers in the queue is infinite. [4]

8.2. Little's Theorem

Little's Theorem describes the relationship between throughput rate (i.e. arrival and service rate), cycle time and work in process (i.e. number of customers/jobs in the system). The theorem states that the expected number of customers (n) for a system in steady state can be determined using the following equation:

$$L = \lambda T \dots\dots\dots\dots\dots.(1)$$

Here λ is the average customer arrival rate and T is the average service time for a customer [4].

8.3. ATM Model (M/M/1 queuing model)

M/M/1 queuing model means that the arrival and service time are exponentially distributed (Poisson process). For the analysis of the ATM M/M/1 queuing model, the following variables will be investigated:

$\lambda =$ Mean number of arrivals per time period (for example, per hour)

$\mu =$Mean number of people or items served per time period.

When determining the arrival rate and the services rate, the same time period must be used. For example, if the λ is the average number of arrivals per hour, then μ must indicate the average number that could be served per hour [6].

8.4. The Queuing equations

1. The average number of customers or units in the system, L_s, that is: $L_s = \frac{\rho}{1-\rho} = \frac{\lambda}{\mu - \lambda}$

2. The average time a customer's spends in the system, Ws, that is, the time spent in line plus the time spent being served : $W_s = \frac{L_s}{\lambda} = \frac{1}{\mu - \lambda}$

3. The average number of customers in the queue, $L_q = L_s\rho = \frac{\rho\lambda}{\mu(\mu-\lambda)} = \frac{\rho^2}{1-\rho}$

4. The average time a customer's spends waiting in the queue, $W_q = \frac{\lambda}{\mu(\mu-\lambda)} = \frac{L_q}{\lambda}$

5. The utilization factor for the system , ρ that is, the probability that the service facility is being used : $\rho = \frac{\lambda}{\mu}$

6. The present idle time, ρ_0, that is, the probability that no one is in the system:

$$\rho_0 = 1 - \frac{\lambda}{\mu}$$

7. The probability having n customers in the ATM/BANK:
$\rho_n = \rho_0 \rho^n =(1-\rho)\rho^n$ [19].

9. Data Analysis & Findings

We have collected the one month daily customer data by observation during banking time, as shown in Table-1.

Table-1 Monthly Customer counts

Day	Weekend	Weekdays					Weekend
Week no.	Saturday	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday
Week 1	70	139	140	138	116	119	94

Week 2	70	155	128	113	83	112	119
Week 3	40	96	111	70	108	78	70
Week 4	71	110	90	113	87	60	72
Total	251	500	469	396	394	369	355
Average	62.75	125	117.25	99	98.5	93.25	88.75

Source: Author

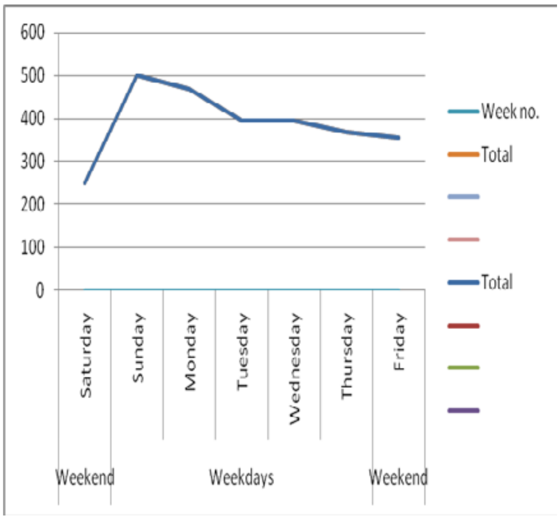

Fig: 2 One Month daily customer count

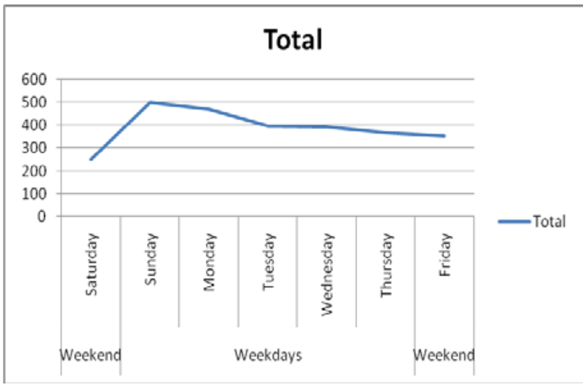

Fig: 3 ***One Month total customer count***

From the above figure –2, we observe that, the number of customers on Sundays is double the number of customers on Saturdays during a month. The busiest period for the bank ATM is Sundays and Mondays during banking time (10am. to 5pm.). Hence, the time period is very important for the research.

Also, we observed from the figure – 3 that, after Sunday, the number of customers start decreasing slowly as the week progresses. On Saturdays it is least and on Thursdays & Fridays it stays slightly more than Saturdays. This is because the Fridays and Saturdays will be holiday.

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10. Calculation

We have observed that, after Wednesday, during first three days of a week, there are, on average 60 people coming to the ATM in one hour time period of banking time. From this we can derive the arrival rate as:

$$\lambda = \frac{60}{60} = 1 \text{customer per minute}$$ (cpm)

We also found out from observation that each customer spends 3 minutes on average in the ATM (

$$\rho_n = \rho_0 \rho^n = (1-\rho)\rho^n = (1-0.67)(.67)^n = 0.33\ (0.67)^n$$

We assume that impatient customers will start to balk when they see more than 3 people are already queuing for the ATM. We also assume that the maximum queue length that a patient customer can tolerate is 10 people. As the capacity of the ATM is 1 people, we can calculate the probability of 4 people in the system (i.e. in the ATM).

Therefore, the probability of customers going away = (more than 3 people in the queue) = (more than 4 people in the ATM) is

$$p_{5-11} = \sum_{5}^{11} p_n = 0.127 = 12.7\%$$

11. Evaluation

- The utilization is directly proportional with the mean number of customers. It means that the mean number of customers will increase as the utilization increases.

- The utilization rate at the ATM is at 0.60. However, this is the utilization rate during banking time on Fridays and Saturday s. On weekend, the utilization rate is almost half of it. This is because the number of people on weekends is only half of the number of people on weekdays.

- In case of the customers waiting time is lower or in other words, we waited for less than 30 seconds, the number of customers that are able to be served per minute will increase. When the service rate is higher the utilization will be lower, which makes the probability of the customers going away decreases.

12. Further Research

Most of the queuing models are very complex and cannot be easily understood. The element of uncertainty is there in almost all queuing situations. Uncertainty arises due to:

(i) We may not know the form of theoretical probability distribution which applies.
(ii) We might not know the parameters of the process even when the particular distribution is known.
(iii) We would only know the probability distribution of out-comes and not the distribution of actual outcomes even when (i) and (ii) are known.

In many cases, the observed distributions of service times and time between arrivals cannot be fitted in the mathematical distributions of usually assumed in queuing models. For example, the Poisson distribution which is generally supposed to apply may not fit many business situations. So, availability of better methods would yield greater result.
In multi-channel queuing, the departure from one queue often forms the arrival of another. This makes the analysis more difficult.

13. Conclusion

This paper has discussed the application of queuing theory to the Bank ATM. From the result, we have obtained that, the rate at which customers arrive in the queuing system is 1 customer per minute and the service rate is 1.33 customers per minute. The probability of buffer flow if there are 3 or more customers in the queue is 7 out of 100 customers. The probability of buffer overflow is the probability that, customers will run away, because may be they are impatient to wait in the queue. This theory is also applicable for the bank, if they want to calculate all the data daily and this can be applied to other branch ATM also.
We hope that this research can contribute to the betterment of a bank in terms of its functioning through ATM. As our future work, we will be developing a simulation model for the bank ATM. By developing a simulation model we will be able to confirm the results of the analytical model that we develop in this paper. By this model, it can mirror the actual operation of the ATM more closely.

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