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STATEMENT OF THE PROBLEM
OBJECTIVES
HYPOTHESIS (ES)
RESEARCH METHODOLOGY
RESULTS & DISCUSSION
FINDINGS
RECOMMENDATIONS/SUGGESTIONS
CONCLUSIONS
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- Kumar S. (2011): "Customer Value: A Comparative Study of Rural and Urban Customers," Thesis, Kurukshetra University, Kurukshetra.

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ASSESSMENT QUEUING THEORY AND ITS APPLICATION: ANALYSIS OF THE COUNTER CHECKOUT OPERATION IN BANK (A CASE STUDY ON DASHEN DILLA AREA BANK)

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ABSTRACT
This paper contains the analysis of Queuing systems for the empirical data of bank checkout service unit. In any service system, a queue forms whenever current demand exceeds the existing capacity to serve. This occurs when the checkout operation unit is too busy to serve the arriving costumers, immediately. One of the expected gains from studying queuing systems is to review the efficiency of the models in terms of utilization and waiting length, hence increasing the number of queues so customers will not have to wait longer when servers are too busy. In other words, trying to estimate the waiting time and length of queue(s) is the aim of this research paper. We may use queuing simulation to obtain a sample performance result and we are more interested in obtaining estimated solutions for multiple queuing models. This paper describes a queuing simulation for a multiple server process as well as for single queue models. This study required an empirical data which includes the variables like, arrival time in the queue of checkout operating unit (server), departure time, service time, etc. A questionnaire is developed to collect the data for such variables and the reaction of Dashen Dilla area bank from the customers separately and the researchers observe the trend of queue in the bank. This model is developed for a counter checkout operation in the bank, Dilla. The models designed for this example are both single server single queue and single queues multiple-server model. The model contains two servers (with one additional model server which is server 3 to compare with the existing servers).

KEYWORDS
Queue Model, bank efficiency, customer satisfaction.

INTRODUCTION
Waiting for service is part of our daily life. We wait to eat in restaurant, we 'queue up' at the checkout counters in grocery stores, and we 'line up' for service in post offices and banks. And the waiting phenomenon is not an experienced limited to human beings only: jobs wait to be processed on a machine, planes circle in stack before given permission to land at an airport, and cars stop at traffic lights. Waiting cannot be eliminated completely without incurring inordinate expenses, and the goal is to reduce its adverse impact to ''tolerable" levels (Taha, 2007).

Queuing theory is the formal study of waiting in line and is an entire discipline within the field of operations management. Queuing theory has been used in the past to assess such things as staff schedules, working environment, productivity, customer waiting time, and customer waiting environment (Nosek and Wilson, 2001)

Today banks are one of the most important units of the public. Since the foundational work of banks, many researchers try to get full advantage of any new technology to increase customer satisfaction. Therefore an active research has focused on analyzing the queues to optimize their operations and to reduce waiting time for customers.

This paper focuses on the bank lines system and the different queuing algorithms that used in banks to serve the customers. Most banks used standard queuing models. To avoid standing in a queue for a long time or in a wrong line, most banks use automatic queue system to give tickets to all customers. The customer can push a specific button in a tickets supplier device according to their needs (www.ijacsa.thesai.org).

The main purpose of this study is to assess the application of queuing theory and to evaluate the parameters involved in the service unit for the counter checkout operation in Dashen bank. Therefore, a mathematical model is developed to analyze the performance of the checking out service unit. Three important results need to be known from the data collected in the bank by the mathematical model: one is the 'service rate' provided to the customers during the checking out process, and the second, is the gaps between the arrival times (inter-arrival time) of each customer per hour, and the other is cost efficiency of servers. In order to get an overall perspective of the customer's quality of service, the questionnaires which indicate the result in percentages, are also used to get the evaluation from the counters directly.

There were two counters in Dashen bank at the time of the study, which means consisting of two servers with multiple queues (infinite calling population) in terms of Queuing Theory. A queue forms whenever current demand exceeds the existing capacity to serve when each counter is so busy that arriving customers cannot receive immediate service facility. So, each server process is done as a queuing model in this situation.

STATEMENT OF THE PROBLEM (MANAGEMENT SCIENCE PROBLEM)
Waiting causes not only inconvenience, but also frustration to people's daily lives. Often, customers may be discouraged from pursuing valuable services by a sheer length of the waiting line. At other times, waiting might even cause the customer to delay or miss important events because Peoples spend their golden time on queue so as to get service in different organization.

Since waiting involves people, time, and environment, it is vital to also incorporate issues related to both the social and psychological perspectives in order to reduce the negative impact of waiting on customer satisfaction and perceived quality. Outstanding problems on waiting line (queue) are Queue affects the quality service, Customer dissatisfaction and it consumes time and add cost

If the manager is not on the position to solve the above problem it will lead to losing of customers to competitors.

OBJECTIVES OF THE STUDY
The main aim of the study is to assess of queuing theory and its application: analysis of the counter checkout operation in Bank which is confined to Dashen Dilla area bank. On top of this the following are Specific objectives of the study.

1. To review Queuing Theory and its empirical analysis based on the observed data of checking out sales service unit.
2. To measure the expected queue length in each server and the service rate provided to the customers while checking out by using mathematical model.
3. To give insight view of the steady-state behavior of queuing processes and running the simulation experiments to obtain the required statistical results.
4. To find out the relative cost contribution of each servers in assuring quality service

LITERATURE REVIEW

OVERVIEW OF QUEUING MODEL THEORY

The word *queue* comes, via French, from the Latin *cauda*, meaning tail. The spelling "queuing" over "queuing" is typically encountered in the academic research field. In fact, one of the flagship journals of the profession is named "Queuing Systems".

Queuing theory is generally considered a branch of operations research because the results are often used when making business decisions about the resources needed to provide service. It is applicable in a wide variety of situations that may be encountered in business, commerce, industry, healthcare, public service and engineering. Applications are frequently encountered in customer service situations as well as transport and telecommunication (William III, 2006).

EVOLUTION OF QUEUING THEORY

Queuing Theory had its beginning in the research work of a Danish engineer named Erlang. In 1909 Erlang experimented with fluctuating demand in telephone traffic. Eight years later he published a report addressing the delays in automatic dialing equipment. At the end of World War II, Erlang's early work was extended to more general problems and to business applications of waiting lines

QUEUES

Queues (waiting lines) are a part of everyday life. We all wait in queues to buy a movie ticket, make a bank deposit, pay for groceries, mail a package, obtain food in a cafeteria, start a ride in an amusement park, etc. We have become accustomed to considerable amounts of waiting, but still get annoyed by unusually long waits (madang.ajou.ac.kr)

Queuing is a situation familiar to everyone is waiting in a line. A typical example might be the line of customers that forms in front of the service windows at any organization. The number of customers in the line grows and shrinks with time, and, as anyone who has had the experience knows, the wait can be highly unpredictable. Because the number in line is a random variable that changes with time, the system of customers and servers fits the definition of a stochastic process.

Basically, a queue results whenever existing demand temporarily exceeds the capacity of the service facility; i.e., whenever an arriving customer cannot receive immediate attention because all servers are busy. This situation is almost always guaranteed to occur at some time in any system that has probabilistic arrival and service patterns. Tradeoffs between the cost of increasing service capacity and the cost of waiting customers prevent an easy solution to the design problem. If the cost of expanding a service facility were no object, then theoretically, enough servers could be provided to handle all arriving customers without delay. In reality, though, a reduction in the service capacity results in a concurrent increase in the cost associated with waiting. The basic objective in most queuing models is to achieve a balance between these costs.

One of the key insights gained from studying queuing systems is that they may not be very efficient in terms of resource utilization. Queues form and customers wait even though servers may be idle much of the time. The fault is not in the model or underlying assumptions. It is a direct consequence of the variability of the arrival and service processes. If variability could be eliminated, systems could be designed economically so that there would be little or no waiting, and hence no need for queuing models.

OBJECTIVE OF QUEUING

The objective of queuing model is to offer a reasonably satisfactory service to waiting customers. Unlike other tools of management science or operational research, queuing theory is not an optimization technique; rather, it determines the measure of performance of waiting lines, such as the average waiting time in queue and the productivity of the service facility, which can then be used to design the service installation (Taha, 2007).

Now, let us see some interesting observation of human behavior in queues:

Balking – Some customers even before joining the queue get discouraged by seeing the number of customers already in service system or estimating the excessive waiting time for desired service decide to return for service at a later time. In queuing theory this is known as balking.

Reneging - customers after joining the queue wait for some time and leave the service system due to intolerable delay, so they renege.

For example, a customer who has just arrived at a grocery store and finds that the salesmen are busy in serving the customers already in the system, will either wait for service till his patience is exhausted or estimates that his waiting time may be excessive and so leaves immediately to seek service elsewhere.

Jockeying - Customers who switch from one queue to another hoping to receive service more quickly are said to be jockeying.

QUEUE MODELS

There are two possible models for multiple-server system: *Single-Queue Multiple-Server model*, and *Multiple-Queue Multiple-Server model*.

Using the same concept of model, the sales checkout operating units are all together taken as a series of servers that forms either single queue or multiple queues for sales checkout (single service facility) where the arrival rate of customers in a queuing system and service rate per busy server are constants regardless of the state of the system (busy or idle). For such a model the following assumptions are made:

ASSUMPTIONS

a) Arrivals of customers follow a Poisson process

1. The number of the customers that come to the queue of sales checkout server during time period [t, t+s) only depends on the length of the time period 's' but no relationship with the start time 't'
2. If 'S' is small enough, there will be at most one customer arrives in a queue of a server during time period [t, t+s)

BASIC STRUCTURE OF QUEUING MODELS

THE BASIC QUEUING PROCESS

The basic process assumed by most queuing models is the following. *Customers* requiring service are generated over time by an *input source.* These customers enter the *queuing system* and join a *queue.* At certain times, a member of the queue is selected for service by some rule known as the *queue discipline.* The required service is then performed for the customer by the *service mechanism,* after which the customer leaves the queuing system. Many alternative assumptions can be made about the various elements of the queuing process; they are discussed next (madang.ajou.ac.kr)

QUEUE IN THE OPERATIONS RESEARCH PERSPECTIVE

Why then is there waiting? The simplest answer to this is that when the demand for a particular product or service exceeds the available capacity, a waiting line forms. Reasons for this may be a shortage of available products in stock or servers, or there may be limitations to the available space where the service or product is provided. To understand the true problems behind, one must know how much service or products should be made available that is reflected by factors such as the average length of waiting, number of people in a waiting line, service rate, …etc. All these factors can be taken into account with the use of the queuing theory, which will be discussed in the following section.

QUEUING THEORY

Every queue takes place within a system that involves processes including customers arriving for a service or product, waiting when the service is not immediate, and eventually leaving the system once being served. The word 'customers' does not necessarily infer a true human being, but rather, it is used in a general sense, say, it could represent an airplane waiting to take off. The queuing theory is essentially the study of a queue through the use of mathematical modeling to evaluate the efficiency of queues. It is the basis to finding the optimal solution to queue management.

CHARACTERISTICS OF QUEUING PROCESSES

The queuing theory considers mainly six general characteristics of any queuing processes: (1) arrival pattern of customers, (2) service pattern, (3) system capacity, (4) queue disciplines (5) service capacity and (6) behavior of arrival.

1. **Arrival Pattern of Customers**

   Customer arrivals are the input processes of a queuing system that is defined by:

- ***Number of arrivals at a given time period***. Single arrivals vs. bulk arrivals
- ***Statistical distribution of customers' inter-arrival times***. This is the pattern that infers the times between successive customer arrivals. The Poisson process is the most commonly used in situations when the distribution of the time until the next customer arrival is independent of the last arrival.

- ***Other unusual aspects***. Stationary (time-dependent) vs. non-stationary arrival patterns (non time-dependent).

2. Service Pattern

The service pattern is the output process that depends upon the followings:

- ***The distribution of the service time***. This refers to the time elapsed during the service process from the beginning of service to its completion, assuming that it is independent of the number of customers present. The exponential distribution is most commonly used in this regard.
- ***Number of servers.*** This number directly affects the arrangement of a waiting line, which could be either in parallel or in series.

3. Service Capacity

The service capacity is the available room for waiting that is defined into 2 categories:

- ***Finite service capacity***. A customer finds the waiting area full upon arrival, and he/she cannot join the system, so he/she leaves and never return.
- ***Infinite.*** When the maximum permissible number of customers of the waiting area is significantly large, it is assumed to be infinite. This is a standardized assumption for most queuing system.

4. **Queuing Disciplines**

I. **Order of Service**

This specifies the order in which customers were chosen for service within a queue.

Among the disciplines under this category:

FCFS: First Come, First Served. This is the most commonly used discipline applied in the real world situations, such as check-in counters at the airport.

LCFS: Last Come, First Served**.** This illustrates a reverse order service given to customer versus their arrival.

SIRO: Service in Random Order.

PD: Priority Discipline. Under this discipline, customers will be classified into categories of different priorities

II. **STRUCTURE OF THE QUEUE**

This specifies the physical setup of the queue, which combines two main factors: the number of servers and lines available. Among the disciplines under this category:

Type 1: Single line and single server

This is one of the most prevalent forms of queuing, which customers enter a system, get priority in terms of their arrival and get served by one single server.

With proper enforcement, a high level of social justice will be maintained, while the higher ability of making social comparisons will be emphasized, particularly in the situations where queues are visible to the customers, such as queuing at a bus stop.

Type 2: Single line and multiple servers

In this situation, customers enter the system and line up in a single queue based on their arrival. However, there are multiple servers available in this case, where each of the customers is served by the next available server among all. Examples of such a situation can be found in airline check-in areas, or some fast-food restaurants, where customers follow a single line waiting to check in luggage or purchase food respectively, and the customer at the front of the line is called by the next available (Sheu and Babbar, 1996).

Slightly more complex than the single-server queuing system is the single waiting line being serviced by more than one server (i.e., multiple servers). Examples of this type of waiting line include an airline ticket and check-in counter where passengers line up in a single line, waiting for one of several agents for service, and a post office line, where customers in a single line wait for service from several postal clerks.

In multiple-server models, two or more independent servers in parallel serve a single waiting line. These formulas, like single-server model formulas, have been developed on the assumption of a first-come, first-served queue discipline, Poisson arrivals, exponential service times, and an infinite calling population. The parameters of the multiple-server model are as follows:

λ= the arrival rate (average number of arrivals per time period)

μ= the service rate (average number served per time period) per server (channel)

C= the number of servers

cμ= the mean effective service rate for the system, which must exceed the arrival rate

The formulas for the operating characteristics of the multiple-server model are as follows.

$c\mu > \lambda$ the total number of servers must be able to serve customers faster than they arrive.

The probability that there are no customers in the system (all servers are idle) is

$$Po = \frac{1}{\sum_{n=0}^{n=c-1} \frac{1}{n!}\left(\frac{\lambda}{\mu}\right)^n + \frac{1}{c!}\left(\frac{\lambda}{\mu}\right)^c \left(\frac{c\mu}{c\mu-\lambda}\right)}$$

The probability of n customers in the queuing system is

$p_n = \frac{1}{c!c^{n-c}}\left(\frac{\lambda}{\mu}\right)^n p_0$, for $n > c$; $p_n = \frac{1}{n}\left(\frac{\lambda}{\mu}\right)^n p_0$, for $n \le c$

The average number of customers in the queuing system is

$$L = \frac{\lambda\mu(\lambda/\mu)^c}{(c-1)!\,(c\mu-\lambda)^2} p_0 + \frac{\lambda}{\mu}$$

The average time a customer spends in the queuing system (waiting and being served) is

$$W = \frac{L}{\lambda}$$

The average number of customers in the queue is

$$Lq = L - \frac{\lambda}{\mu}$$

The average time a customer spends in the queue, waiting to be served, is

$$Wq = W - \frac{1}{\lambda} = \frac{Lq}{\lambda}$$

The probability that a customer arriving in the system must wait for service (i.e., the probability that all the servers are busy) is

$$Pw = \frac{1}{c!}\left(\frac{\lambda}{\mu}\right)^c \left(\frac{c\mu}{c\mu-\lambda}\right) p_0$$

Notice in the foregoing formulas that if c = 1 (i.e., if there is one server), then these formulas become the single-server formulas (Taylor III, 2006).

Type 3: Multiple line and single server

This situation involves only one server attending multiple waiting lines. An example to this would be car washing service, where only one washing area is available for cars lining in two queues.

Type 4: Multiple lines and multiple servers

This is the case involving multiple servers and multiple waiting lines, in which each line is served by a single server. This situation can commonly be found in

Supermarket check-out queues or Immigration Custom queues, where customers arrive at the system, join in one of the waiting lines and wait until they move towards the front of their chosen line (Mandia,)

In these models, three various sub-processes may be distinguished:

• **Arrival Process**: includes number of customers arriving, several types of customers, and one type of customers' demand, deterministic or stochastic arrival distance, and arrival intensity. The process goes from event to event, i.e. the event "customer arrives" puts the customer in a queue, and at the same time schedules the event "next customer arrives" at some time in the future.

• Waiting Process: includes length of queues, servers' discipline (First In First Out). This includes the event "start serving next customer from queue" which takes this customer from the queue into the server, and at the same time schedules the event "customer served" at some time in the future.

• **Server Process**: includes a type of a server, serving rate and serving time. This includes the event "customer served" which prompts the next event "start serving next customer from queue". (Troitzsch, 2006)

5. Service Mechanism

The service mechanism consists of one or more *service facilities,* each of which contains one or more *parallel service channels,* called **servers.** If there is more than one service facility, the customer may receive service from a sequence of these (*service channels in series*). At a given facility, the customer enters one of the parallel service channels and is completely serviced by that server. A queuing model must specify the arrangement of the facilities and the number of servers (parallel channels) at each one. Most elementary models assume one service facility with either one server or a finite number of servers (http://faculty.ks u.edu.sa/72966/Documents/chap17.pdf).

6. **Behavior of arrivals**

Another thing to consider in the queuing structure is the behavior or attitude of the customers entering the queuing system.

On this basis, the customers may be classified as being

(a) Patient, or

(b) Impatient.

If a customer, on arriving at the service system stays in the system until served, no matter how much he has to wait for service is called *a patient customer*.

Whereas the customer, who waits for a certain time in the queue and leaves the service system without getting service due to certain reasons such as a long queue in front of him is called an *impatient customer* (http://businessmanagementcourses.org/Lesson21QueuingTheory.pdf).

QUEUING ANALYSIS

Providing quick service is an important aspect of quality customer service. Like decision analysis, queuing analysis is a probabilistic form of analysis, not a deterministic technique. Thus, the results of queuing analysis, referred to as operating characteristics, are probabilistic. These operating statistics (such as the average time a person must wait in line to be served) are used by the manager of the operation containing the queue to make decisions (Taylor III, 2006)

DECISION MAKING

Queuing-type situations that require decision making arise in a wide variety of contexts.

For this reason, it is not possible to present a meaningful decision-making procedure that is applicable to all these situations. Instead, this section attempts to give a broad conceptual picture of a typical approach.

Designing a queuing system typically involves making one or a combination of the following decisions:

1. Number of servers at a service facility

2. Efficiency of the servers

3. Number of service facilities.

When such problems are formulated in terms of a queuing model, the corresponding decision variables usually are s (number of servers at each facility), μ (mean service rate per busy server), and λ (mean arrival rate at each facility). The *number of service facilities* is directly related to λ because, assuming a uniform workload among the facilities, λ equals the total mean arrival rate to all facilities divided by the number of facilities. decisions regarding the amount of service capacity to provide usually are based primarily on two considerations: (1) the cost incurred by providing the service, (hil61217_ch26.qxd 5/15/04 11:51 Page 26-3) shown in Fig. 9, and (2) the amount of waiting for that service, as suggested in Fig. 10.

Figure 10 can be obtained by using the appropriate waiting-time equation from queuing theory. (For better conceptualization, we have drawn these figures and the subsequent two figures as smooth curves even though the level of service may be a discrete variable.)

These two considerations create conflicting pressures on the decision maker. The objective of reducing service costs recommends a minimal level of service. On the other hand, long waiting times are undesirable, which recommends a high level of service. Therefore, it is necessary to strive for some type of compromise. To assist in finding this compromise,

Figs. 9 and 10 may be combined, as shown in Fig. 11. The problem is thereby reduced to selecting the point on the curve of Fig. 26.3 that gives the best balance between the average delay in being serviced and the cost of providing that service.

Obtaining the proper balance between delays and service costs requires answers to such questions as, how much expenditure on service is equivalent (in its detrimental impact) to a customer's being delayed 1 unit of time? Thus, to compare service costs and waiting times, it is necessary to adopt (explicitly or implicitly) a common measure of their impact. The natural choice for this common measure is cost, which then requires estimation of the cost of waiting.

Given that the *cost of waiting* has been evaluated explicitly, the remainder of the analysis is conceptually straightforward. The objective is to determine the level of service that minimizes the total of the expected cost of service and the expected cost of waiting for that service. This concept is depicted in Fig. 12, where WC denotes *waiting cost,* SC denotes *service cost,* and TC denotes *total cost.* Thus, the mathematical statement of the objective is to: Minimize $E(\text{TC}) = E(\text{SC}) + E(\text{WC})$ (http://faculty.ksu.edu.sa/72966/Documents/chap17.pdf)

RESEARCH METHODOLOGY

RESEARCH DESIGN

Study is descriptive in nature because it describe the existing customer service capacity of the bank and customer arrival and banks efficiency. And also it is cross sectional study with one week data collection period (observation) which both data approach (qualitative and quantitative) were employed.

The researchers used convenience sampling method. Convenience sampling is a non-probability sampling technique where subjects are selected because of their convenient accessibility and proximity to the researchers. The researchers used not only for his convenience they are the only respondents who have relevant data for the study.The selected respondents are those employees who are confronted with customers (serving on the counter) and their number is two.

The data used in the Queuing model is collected for an arrival time of each customer in five days by the observation form. The observations for number of customers in a queue, their arrival-time and departure-time were taken without distracting the employees. The whole procedure of the service unit each day was observed and recorded using a time-watch during the same time period for each day.

The collected data are analyzed by using queue model

QUEUING MODELS WITH SINGLE STAGE (FACILITY)

The term queuing system is used to indicate a collection of one or more waiting lines along with a server or collection of servers that provide service to these waiting lines. The example of Dashen bank is taken for queuing system discussed in this chapter the researchers used a single waiting line and a single server, and multiple server. All results are presented in data analysis and discussion assuming that FIFO is the queuing discipline in all waiting lines and the behavior of queues is jockey and the queue is infinite.

A. BASIC QUEUING PROCESS

Customers requiring service are generated over time by an input source. The required service is then performed for the customers by the service mechanism, after which the customer leaves the queuing system. We can have two types of models: Single-queue single- Servers model and the second one is Multiple-Queues single-Servers model (Sheu, C., Babbar S. (Jun 1996)).

ASSUMPTIONS

Assumptions of the basic single-server model

1. An infinite calling population
2. A first-come, first-served queue discipline
3. Poisson arrival rate
4. Exponential service times

PARAMETERS IN QUEUING MODELS (SINGLE SERVERS, SINGLE QUEUES MODEL)

p_n The probability that n customers are in the queuing system is
$Pn= (\lambda/\mu)^n xPo$

L The average number of customers in the queuing system (i.e., the customers being serviced and in the waiting line) is
$L=\lambda/\mu-\lambda$

Lq The average number of customers in the waiting line is
$Lq= \lambda^2/\mu(\mu-\lambda)$

W The average time a customer spends in the total queuing system (i.e., waiting and being served) is
$W= L/\lambda$

Wq The average time a customer spends waiting in the queue to be served is
$Wq= \lambda/\mu(\mu-\lambda)$

U The probability that the server is busy (i.e., the probability that a customer has to wait), known as the utilization factor, is
$U= \lambda/\mu$

***p*o** The probability that no customers are in the queuing system (either in the queue or being served) is
$Po= (1-\lambda/\mu)$

λ Arrival rate (1 / (average number of customers arriving in each queue in a system in one hour))

μ Serving rate (1 / (average number of customers being served at a server per hour))

(Taylor III, 2006)

The data collected from questionnaires were tabulated in a spreadsheet in order to calculate the required parameters of queuing theory analysis.

ANALYSIS AND DISCUSSION

A counter checkout service has single waiting line in a form of parallel cash counters. Customers are served on a first-come, first-served (similar with FIFO in accounting) basis as a counter of checkout operation unit becomes free. It is possible that some of the counter checkout units are idle. The data collected from observation were tabulated in a spreadsheet in order to calculate the required parameters of queuing theory analysis. Firstly, the confidence intervals are computed to estimate service rate and arrival rate for the customers. Then the later first part of the analysis is done for the model involving one queue and single servers, whereas the second part is done by queuing model for second model involving single queues for each corresponding parallel server.

We can estimate confidence intervals for average service rate and average arrival rate. Assuming the 95% confidence interval for arrival rate.

CONFIDENCE INTERVALS FOR WEEKDAYS

We have,

Mean (service time) = 01:06 minutes per customer (read clock as min:sec)
SD (service time) = 00:06 min
Mean (arrival time) = 00:37 min per customer
SD (arrival time) = 00:06 min
And n = 41 customers

95% Confidence Intervals for Service Time:

Mean (service time) - 1.96 (SE (service time)) = 54 sec/customer
Mean (service time) + 1.96 (SE (service time)) = 78 sec/customer
$SE = SD/\sqrt{n}$

INTERPRETATION OF CONFIDENCE INTERVALS

The confidence interval shows that 73 to 150 customers arrive in 2-server system within an hour whereas 46 to 67 customers are served. That means there are still some customers not being served and are waiting for their turn in a queue to be served. This is due to a service time provided by a server to the customers. The service time can vary between 54 sec to 78 sec per customer.

EXPECTED QUEUE LENGTH

We can find the expected length of queue by using empirical data. In survey, the number of customers waiting in a queue was observed. The average of that number in a system is (1+1+3+…+2+0)/41 = 2.07 customers per minute on average waiting in a queue in a system within 25 min of data collection time.

QUEUING ANALYSIS

Customers arrive at an average of 98 customers per hour, and an average of 55 customers can be served per hour by a banker.

TABLE 1: RESPONDENTS PROFILE

Items	Respondents	
1. Gender	number	percentage
Male	2	100
Total	2	100
2. Age	number	percentage
23-27	1	50
28-32	1	50
Total	2	100
3. educational background		
1st degree	2	100
Total	2	100

Source: questionnaires 2012.

From the above table 1, all (100%) of the respondents are male. And most of the respondents or counter workers are youth. In top of that their educational background shows they are first degree holders and competent to the position.

RESULTS FOR WEEKDAY APPLYING QUEUING MODEL 1

The parameters and corresponding characteristics in Queuing Model 1, assuming system is in steady-state condition, are:

C number of servers = 1
λ Arrival rate = 49 customers per hour
μ serving rate = 55 customers per hour
The probability that no customers are in the queuing system (either in the queue or being served) is
Po= 1-(λ/μ)
Po=1-(49/55)
Po= 0.11 the probability of no customers in the queuing system
The average number of customers in the queuing system (i.e., the customers being serviced and in the waiting line) is
L= λ/μ-λ
49/(55-49)
L= 8.17 customers, on average, in the queuing system
The average number of customers in the waiting line is
Lq= ^{2}**/(**μ(μ-λ))
49^2/(55(55-49))
Lq= 2401/330= 7.28 customers, in the waiting line
The average time a customer spends in the total queuing system (i.e., waiting and being served) is W= L**/**λ
W= 8.17/49
W= 0.17 (10 min) average time in the system per customer
The average time a customer spends waiting in the queue to be served is
Wq= λ/(μ(μ-λ))
Wq= 49/(55(55-49)
Wq= 0.15 (9 min) average time in the waiting line per customer
The probability that the server is busy (i.e., the probability that a customer has to wait), known as the utilization factor, is
U= λ/μ
U= 49/55
U= 0.89 probability that the server will be busy and the customer must wait
I= 1-U
I= 1-0.89
0.11 probability that the server will be idle and customer can be served

INTERPRETATION OF RESULTS FOR QUEUING MODEL 1

The performance of the counter checkout service on weekday is sufficiently good. We can see that the probability for servers to be busy is 0.8909, i.e. 89.09%. The average number of customers waiting in a queue is Lq = 7.28 customers per server. The waiting time in a queue per server is Wq = 9 min which is normal time in a busy server. This estimate is based on probabilistic nature as the model shows that the customers make a single queue and choose an available server. Hence we can consider each server with a queuing model as a single-server single-queue model to get the correct estimate of the length of queue. Model 1 queue is a useful approximate model when service times have standard deviation approximately equal to their means.

RESULTS FOR WEEKDAY APPLYING QUEUING MODEL 2

The parameters and corresponding characteristics in Queuing Model 2, assuming system is in steady-state condition, are:
c number of servers = 2
λ Arrival rate = 98 customers per hour
μ serving rate = 55 customers per server per hour
cμ (55x2) = 110 service rate for servers)
P λ/(cμ) = 98 / 110 = 0.8909= 89.09%
I λ /μ = 1.7818
Overall system utilization = P = 89.09 %
The probability that all servers are idle (Po) = 0.5769
The probability that there are no customers in the system (all servers are idle) is

$$Po = \frac{1}{\sum_{n=0}^{n=c-1} \frac{1}{n!}\left(\frac{\lambda}{\mu}\right)^n + \frac{1}{c!}\left(\frac{\lambda}{\mu}\right)^c \left(\frac{c\mu}{c\mu-\lambda}\right)}$$

$$\frac{1}{\left(\frac{1}{0!}\left(\frac{98}{55}\right)^0 + \frac{1}{1!}\left(\frac{98}{55}\right)^1\right) + \frac{1}{2!}\left(\frac{98}{55}\right)^2 \left(\frac{2x55}{2x55-98}\right)}$$

Po= 0.058 probability that no customers are in the bank

The average number of customers in the queuing system is

$$L = \frac{\lambda\mu(\lambda/\mu)^c}{(c-1)!\,(c\mu-\lambda)^2} p_0 + \frac{\lambda}{\mu}$$

$$L = \frac{98x55(98/55)^2}{(2-1)!\,(2x55-98)^2}(0.058) + \frac{98}{55}$$

L= 8.66≈ 9 customers, on average, in the bank

The average time a customer spends in the queuing system (waiting and being served) is

$$W = \frac{L}{\lambda}$$

$$W = \frac{9}{98}$$

W= 0.092 hr. (5.5 min.) average time in the bank per customer

The average number of customers in the queue is

$$Lq = L - \frac{\lambda}{\mu}$$

$$Lq = 9 - \frac{98}{55}$$

Lq= 7.2≈ 7 customer, on average, waiting to be served

The average time a customer spends in the queue, waiting to be served, is

$$Wq = W - \frac{1}{\lambda} = \frac{Lq}{\lambda}$$

$$Wq = \frac{7}{98}$$

Wq= 0.07hr. (4.3 min.) Average time waiting in line per customer

The probability that a customer arriving in the system must wait for service (i.e., the probability that all the servers are busy) is

$$Pw = \frac{1}{c!}\left(\frac{\lambda}{\mu}\right)^{c}\left(\frac{c\mu}{c\mu - \lambda}\right)p_0$$

$$Pw = \frac{1}{2!}\left(\frac{98}{55}\right)^{2}\left(\frac{2x55}{2x55 - 98}\right)0.058$$

Pw= 0.85 probability that a customer must wait for service

If the bank management has decided that customers are frustrated by the relatively long waiting time of 9 minutes and the .89 probability of waiting. To try to improve matters, if management has decided to consider the addition of an extra counter checkout the operating characteristics for this system must be recomputed with c = 3 counter checkout but it may be less in reducing cost than server 2.

The parameters and corresponding characteristics in Queuing Model 3, assuming system is in steady-state condition, are:

c number of servers = 3

λ arrival rate = 98 customers per hour

µ serving rate = 55 customers per server per hour

cµ (55x2) = 110 service rate for servers)

The probability that there are no customers in the system (all servers are idle) is

$$Po = \frac{1}{\sum_{n=0}^{n=c-1} \frac{1}{n!}\left(\frac{\lambda}{\mu}\right)^{n} + \frac{1}{c!}\left(\frac{\lambda}{\mu}\right)^{c}\left(\frac{c\mu}{c\mu-\lambda}\right)}$$

$$\frac{1}{\left(\frac{1}{0!}\left(\frac{98}{55}\right)^{0} + \frac{1}{1!}\left(\frac{98}{55}\right)^{1}\frac{1}{2!}\left(\frac{98}{55}\right)^{2}\right) + \frac{1}{3!}\left(\frac{98}{55}\right)^{3}\left(\frac{3x55}{3x55-98}\right)}$$

Po= 0.060 probability that no customers are in the bank

The average number of customers in the queuing system is

$$L = \frac{\lambda\mu(\lambda/\mu)^{c}}{(c-1)!\,(c\mu-\lambda)^{2}}p_0 + \frac{\lambda}{\mu}$$

$$L = \frac{98x55(98/55)^{3}}{(3-1)!\,(3x55-98)^{2}}(0.060) + \frac{98}{55}$$

L= 2 customers, on average, in the bank

The average time a customer spends in the queuing system (waiting and being served) is

$$W = \frac{L}{\lambda}$$

$W = \frac{2}{98}$

W= 0.02 hr. (1.2 min.) average time in the bank per customer

The average number of customers in the queue is

$$Lq = L - \frac{\lambda}{\mu}$$

$$Lq = 2 - \frac{98}{55}$$

Lq=0.22 ≈ 0 customer, on average, waiting to be served

The average time a customer spends in the queue, waiting to be served, is

$$Wq = W - \frac{1}{\lambda} = \frac{Lq}{\lambda}$$

$$Wq = \frac{0.22}{98}$$

Wq= 0.002hr. (0.13 min.) Average time waiting in line per customer

The probability that a customer arriving in the system must wait for service (i.e., the probability that all the servers are busy) is

$$Pw = \frac{1}{c!}\left(\frac{\lambda}{\mu}\right)^{c}\left(\frac{c\mu}{c\mu - \lambda}\right)p_0$$

$$Pw = \frac{1}{3!}\left(\frac{98}{55}\right)^{3}\left(\frac{3x55}{3x55 - 98}\right)0.060$$

Pw= 0.20 probability that a customer must wait for service.

COMPARISON OF THE RESULTS FOR QUEUING MODEL 1 AND MODEL 2

The actual structure of our survey example Dashen bank has queuing model 2. A queuing model with single queue and multiple servers is not effective when we evaluate performance for each server. For instance, the utilization factor for both servers varies in each analysis, i.e. for model 1 its 89% whereas for model 2 its 94.2%. A simulation process shows the performance of each server with their corresponding queues. For instance, in server 2 each customer has to wait for 4.3 minutes in a queue, in server 1 each customer has to wait for 9 minutes in a queue, and in server 3 each customer has to wait only 0.13 minutes in a queue for being served.

However, server 3 is effective saving of customer's time but it saves cost of serving less as compared to that of server 2. When we see server 2 it seems inefficient in saving of customer's time, but this comes from in efficient utilization of resources.

CONCLUSION AND RECOMMENDATION

The empirical analysis of queuing system of Dashen bank is that they may not be very efficient in terms of resources utilization. Queues form and customers wait even though servers may be idle much of the time. The fault is not in the model or underlying assumptions. It is a direct consequence of the variability of the arrival and service processes. If variability could be eliminated, system could be designed economically so that there would be little or no waiting, and hence no need for queuing model.

With the increasing number of customers coming to the bank for different services either for usual saving, opening account, loan etc. there is a competent employee serving at each service unit. Counter checkout service has sufficient number of employees (2 servers) which is helpful during the peak hours of weekdays. Increasing more than sufficient number of servers may not be the solution to increase the efficiency of the service by each service unit. As we (researchers) have tried to indicate in appendix C (cost analysis) server 2 is efficient if it is used well (saves 260 birr than installing server 3 which saves 127 birr) and only natural line (queue) may be created which have no harm in the normal functioning of the bank.

The result also shows us if the bank use server 3 almost there may not be queue and this make create idleness of servers indirectly it is costly. Nevertheless, server 2 is more feasible because such kind of idleness may not be appear, thereby resources are efficiently employed in top of that customers will be delighted by the service provided, and the quality of service is affirmed.

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