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APPLICATION OF QUEUEING THEORY IN BANK SECTORS

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ABSTRACT

This paper contains the analysis of M/M/s Queuing model and its application in Bank sectors. The different services in bank are discussed in this paper. They are (i) A single waiting line and a single server (ii) Multiple waiting line and multiple servers and (iii) a single waiting line and multiple servers. We establish the waiting time and length of queue(s) which may include the variables like, arrival, waiting and departure time of customers, service time of servers, etc. One of the expected gains from studying queuing systems is to review the efficiency of the models in terms of utilization and waiting length.

INTRODUCTION

A queueing system consists of inputs, queue and servers as service centres. Generally, it consists of one or more servers for serving customers arriving in some manner and having some service requirements. The customers represent users, jobs, transactions or programmes. They arrive at the service facility for service, waiting for service if there is a waiting room, and leave the system after being served (Abryen *et al*., 2002). Sometimes customers are lost.

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. The queueing systems are described by distribution of inter-arrival times, distribution of service times, the number of servers, the service discipline and the maximum capacity etc.

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Queueing models are essential for designing and monitoring of several communication systems (Idzikowska, 2000 and Lavenberg and Shedler, 1975). The queueing models provide the optimum operating policies of the several systems. They are essential for performance evaluation of a wide variety of systems in communication networks, production manufacturing process, data/voice transmission, Nero physiological systems, cargo handling, and ATM scheduling (Abolnikov *et al*., 1990). Starting from the first queueing model by Erlang (1909) much work has been reported in literature regarding queueing models and their applications.

Queueing systems by Cooper, (1981), Gross, Donald and Carl M. Harris (1998), Hillier and Lieberman, (2001), Jensen, Paul (2004), Karlin and Taylor, (1998), Taha, Hamdy (1997) have pioneered the queueing models. These models are formed with suitable assumptions on arrival, service processes. It is an abstract description of a system. Typically, a queueing models represents the system's physical configuration by specifying the number and arrangement of the servers, which provide service to the customers and the stochastic nature of the demands by specifying the variability in the arrival process and in the service process.

The elements of a queue are

1. Arrivals that need service of some kind
2. Service facilities that take care of the arrivals
3. Where the arrivals wait until they can be served.

Queueing models are very useful to provide basic framework for efficient design and analysis of several practical situations including various technical systems (Filipowicz, 1999 and Kleinrock, 1975). Queueing systems have also found wide applicability in bank sectors, computer and communication network and several other engineering systems. Such queueing situations may arise in many real time systems. Delays and queuing problems are most common features not only in our daily-life situations such as at a bank or postal office, at a ticketing office, in public transportation or in a traffic jam but also in more technical environments, such as in manufacturing, computer networking and telecommunications (Abryen *et al*., 2002).

They play an essential role for business process re-engineering purposes in administrative tasks etc., Queuing theory is the study of waiting in all these various situations. It uses queuing models to represent the various types of queuing systems that arise in practice. The models enable finding an appropriate balance between the cost of service and the amount of waiting. The purpose of this study is to review Queuing Theory and its empirical analysis based on the observed data of service in Bank. The main idea in the application of a mathematical model is to measure the expected queue length and the service rate provided to the customers. Descriptions of events are given i.e. the arrivals and service rate in each queue and how they can be generated for any amount of working hour.

The other important factor analyzed is about the comparison of two different queuing models: single-queue multiple-server and multiple-queue multiple-server model. This paper is to review the application of queuing theory and to evaluate the parameters involved in the bank service unit. Therefore, a mathematical model is developed to analyze the performance of the service unit. Two 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 service process, and the other is the gaps between the arrival times (inter arrival time) of each customer per hour.

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. This approach is trying to detect the variability in a quality of service due to queues in bank service units, find the average queue length before getting served in order to improve the quality of the services where required, and obtain a sample performance result to obtain time-dependent solutions for complex queuing models. The present investigation an attempt has been made to analyze the service in Bank sectors. The study of queueing model is organized as follows. The services are categorized in to three models. The mathematical model is described in Section 2. Section 3 provides the formulation and notations. Analysis of service behavior in Bank, results and comparison of the models are outlined in Section 4. The discussion of queueing theory in Bank application have been obtained in Section 5. The conclusion and notable features of investigation done are highlighted in Section 6.

Mathematical model

By means of the queuing theory, the bank queuing problem is studied as the following aspects: In these models, three various sub-processes are 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".

Model 1. Queuing Model with Single Stage and a single server

The unit of bank may consist single server in cash counter, enquiry, and issues of Cheque etc. These units have and single waiting line of customers (M/M/1/K queueing model). For such a model the following assumptions are made:

(i) Inter arrival of the customers during time period [t, t+ Δt) only depends on the length of the time period's'. Where the arrival rate of customers and service rate of server are constants regardless of the state of the system (busy or idle).
(ii) Service times are exponentially distributed.
(iii) Customers are served FIFO (First in First Out) basis.

No customer leaves the queue without being served. All customers arriving in the queuing system will be served approximately equally distributed service time, whereas customer choose a queue randomly, or choose or switch to shortest length queue.

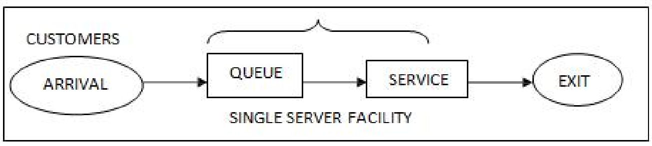

Fig. 1. **Single waiting line and a single server**

Parameters in Queuing Models

(i) n = Number of total customers in the system (in queue plus in service).

(ii) λ = Arrival rate (1 / (average number of customers arriving in each queue in a system in one hour))
(iii) μ = Serving rate (1 / (average number of customers being served at a server per hour))
(iv) ρ = System intensity or load, utilization factor (the expected factor of time the server is busy). $\rho = \lambda/\mu$.

Model 2. Queuing Model with Single Stage waiting lines with multiple servers

The bank may consist of multiple units to give service to customers. Some of the units like loan sanction, identity verification, etc., have multiple servers with single queue or multiple waiting lines of customers (M/M/s/K queueing model). For such a model the following assumptions are made:

(i) Inter arrival of the customers during time period [t, t+Δt) only depends on the length of the time period's'. Where the arrival rate of customers and service rate of server are constants regardless of the state of the system (busy or idle).
(ii) Service times are exponentially distributed.
(iii) Customers are served FIFO (First In First Out) basis. No customer leaves the queue without being served. All customers arriving in the queuing system will be served approximately equally distributed service time.

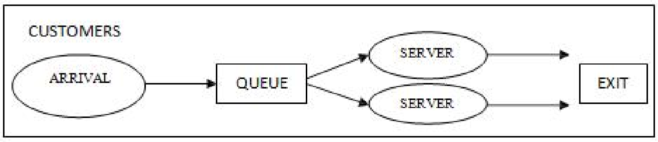

Fig. 2. Single waiting line with multiple parallel servers

Model 3. Queuing Model with Multi Stage waiting lines with multiple servers

In bank some of the units like money transaction, Cheque transacation, etc., have multiple servers with multiple waiting lines of customers. For such a model the following assumptions are made:

Inter arrival of the customers during time period [t, t+ Δt) only depends on the length of the time period's'. Where the arrival rate of customers and service rate of server are constants regardless of the state of the system (busy or idle).

(ii) Service times are exponentially distributed.
(iii) Customers are served FIFO (First In First Out) basis. No customer leaves the queue without being served.

All customers arriving in the queuing system will be served approximately equally distributed service time, whereas customer choose a parallel queue randomly, or choose or switch to shortest length queue.

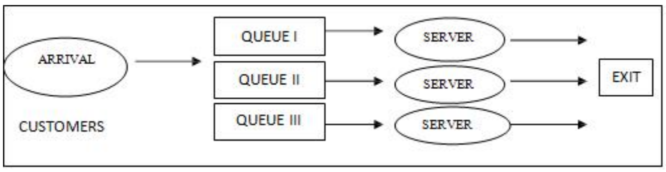

Fig. 3. Multiple waiting lines with multiple parallel servers

Parameters in Multi server Queuing Models

n = Number of total customers in the system (in queue plus in service)
s = Number of parallel servers (service units in Bank)
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))
sμ = Serving rate when s > 1 in a system
ρ = System intensity or load, utilization factor (= λ/(sμ)) (the expected factor of time the server is busy that is, service capability being utilized on the average arriving customers)
Departure and arrival rate are state dependent and are in steady-state (equilibrium between events) condition.

Notations & their Description

For single queue and single server model (fig.1) assuming the system is in steady-state condition

For this queueing model average number of customers in the system [N(s)], expected number of customers waiting for service in the queue [N(q)], average waiting time of a customer in the system [T(s)] and in the queue [T(q)] are calculated respectively, we analysis from a technical point by numerically.

Here let $\rho = \lambda/\mu$

Steady – state probability of all idle servers in the system

$$P_0 = 1 - \lambda/\mu$$

Steady – state probability of exactly n customers in the system

$$P_n = \left(\frac{\lambda}{\mu}\right)^n P_0,$$

Average number of customers in the system $[N(s)] = \frac{\rho}{1-\rho}$

Expected number of customers waiting for service in the queue $[N(q)] = \frac{\rho^2}{1-\rho}$

Average waiting time of a customer in the system

$$[T(s)] = \frac{1}{\mu-\lambda} \text{ (or) } \frac{N(s)}{\lambda}$$

Average waiting time a customer spends waiting in line excluding the service time $[T(q)] = \frac{\lambda}{\mu(\mu-\lambda)} \text{ (or) } \frac{N(q)}{\lambda}$

For single queue and parallel multiple servers' model (fig.2) assuming the system is in steady-state condition

Here let $\gamma = \lambda/\mu$ and $\rho = \lambda/s\mu$

Steady – state probability of all idle servers in the system

$$P_0 = \left[\sum_{n=0}^{s-1}\frac{\gamma^n}{n!} + \frac{\gamma^s}{s!(1-\rho)}\right]$$

Steady – state probability of exactly n customers in the system

$$P_n = \frac{\gamma^n}{s!\, s^{n-s}} P_0,\ n>s$$

Average number of customers in the queue (waiting line)

$$[N(q)] = \frac{\gamma^c \rho}{s!(1-\rho)^2} P_0$$

Average waiting time a customer spends waiting in line excluding the service time

$$[T(q)] = \frac{N(q)}{\lambda}$$

There are no predefined formulas for networks of queues, i.e. multiple queues (fig.3). Acomplexity of the model is the main reason for that. Therefore, we use notations and formulas for single queue with parallel servers.

Analysis of service in Bank

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

Expected length of each Queue

Besides service time, it is important to know the number of customers waiting in a queue to be served. It is possible that any customer would change his queue and choose another if find a shorter queue in another parallel server. In general, variability of inter arrival and service time causes lines to fluctuate in length. Then question arises, what could be the estimated length of the queue in any server? Some papers describe the general criterion for counting the number of customers in a queue. These counts are a combination of input processes that are: arrival point process, Poisson counting process (which counts only those units that arrive during the inter arrival time and these units are conditionally independent on Poisson interval), and counting group of units being served within the Poisson interval. We can find the expected length of queue by using empirical data. In survey, the number of customers waiting in a queue was observed (Appendix A).

Queuing Analysis

On Wednesday (weekday), customers arrive at an average of 98 customers per hour, and an average of 55 customers can be served per hour.

Results for Weekday applying Queuing model 1 (fig.1)

The parameters and corresponding characteristics in Queuing Model M/M/1 for two response sections in bank, assuming system is in steady-state conditions are

λ Arrival rate = 98 customers per hour for two response sections i.e. 49 customers
μ Serving rate = 55 customers per server per hour
ρ = 0.8909 i.e. Overall system utilization ρ = 89.09 %
The probability that all servers are idle (*Po*) = 0.1091
Average number of customers in the queue *N (q)* = 7.27497
Average time customer spends in the queue *T (q)* = 0.1485 hours

Consequences for Weekday applying Queuing model 2 (fig.2)

The parameters and corresponding characteristics in Queuing Model M/M/2, assuming system is in steady-state condition are

s number of servers = 2
λ Arrival rate = 98 customers per hour
μ Serving rate = 55 customers per server per hour
c μ = 110 (service rate for 2 servers)
γ = 1.7818, Overall system utilization ρ = 89.09 %
The probability that all servers are idle *(Po)* = 0.5769
Average number of customers in the queue *N (q)* = 6.8560
Average time customer spends in the queue *T (q)* = 0.0700 hours. The performance of the service on weekday is sufficiently good.

Results for Weekday applying Queuing model 3 (fig.3)

A section of bank has 3 waiting lines in a form of parallel counters (see fig.3), Customers are served on a first-come, first-served (FIFO) basis. The data has been collected for three servers. It was assumed that the customers' crowd is more, on average, on weekday. Although the unit has 3 parallel counters out of which 2 were observed (each of them has an individual servers to deal with the customers in a queue), it is possible that some of the units are idle.

Mean inter arrival time = 0.6333 min
Mean Serving time = 1.1000 min
Server utilization = ρ = 99.00 %

Server 1

Number customers served = 93 customers
Average number of customers in the queue *N (q)* = 28.1820 customers Average time customer spends in the queue
T (q) = 21.3131 min

Server 2

Number customers served = 77 customers
Average number of customers in the queue *N (q)* = 39.3991 customers
Average time customer spends in the queue *T (q)* = 28.8511 min

Overall for two servers

Average number of customers in the queue *N (q)* = 67.5812 customers Average time customer spends in the queue *T (q)* = 25.0821 min

Analysis of Queuing model 3

A formulation has clearly shown the performance of the service of two servers including their corresponding queues. The servers are found to be very busy (99%). The average number of customers waiting in a queue in overall two servers on weekday is *N (q)* = 67.5812 whereas the waiting time in a queue in overall two servers is approximately *T (q)* = 25.0821 min which is normal time in a very busy server. Such a longer queue can be reduced in size by a decrease in service time or server utilization. Although inter arrival time and mean service time is same for both servers but there is a small difference in the value of *N (q)* and *T (q)*. This is possible when system has multiple queues and queues have jockey behavior. In other words, customers tend to switch to a shorter queue to reduce the waiting time.

Comparison of the results for Queuing model 2 and model 3

The actual structure of our survey example in Bank has a queuing model with single Queue and multi servers in model 2 and multiple queues with multiple parallel servers model 3. For instance, the utilization factor for both servers varies in each analysis, i.e. for model 2 its 89% whereas for model 3 its 99%. A formulation process shows the performance of each server with their corresponding queues. For instance, in server 2 each customer has to wait for 15.67 minutes in case of 40 customers in a queue and in server 1 each customer has to wait for 21.87 minutes in case of 31 customers waiting in a queue for being served.

DISCUSSION

This paper reviews the three types of queuing models for single and multiple servers. The average queue length can be estimated simply from raw data by using the collected number of customers waiting in a queue each minute. We can compare this average with that of queuing model. Three different models are used to estimate a queue length: a single-queue and single- server model, single-queue and multi-server model, multiple queue and multi-server model. In case of more than one queue (multiple queue), customers in any queue switch to shorter queue (jockey behavior of queue). The practical analysis of queuing system in Bank sectors is that they may be very efficient in terms of resources utilization. Queues form and customers wait are a direct consequence of the variability of the arrival and service processes. Increasing more than sufficient number of servers may not be the solution to increase the efficiency of the service by each service unit. When servers are analyzed with one queue for two parallel servers, the results are estimated as per server whereas when each server is analyzed with its individual queue, the results computed are for each server individually.

Conclusion

Queueing systems are useful throughout society. The capability of these systems can have an important result on the quality of human life and productivity of the process. In this paper the applications of queueing theory extend for Bank behavior in service sectors. This analysis provides fundamental information for successfully designing queueing systems. This queueing models are helpful in preparation of optimal decision on structures and service organizations from client and manager viewpoint and in study of methods, which allow calculating of basic characteristics of the service process. They can be used to improve flow of customers, for the evaluation of utilization and response times. By this practical analysis of this research, we suggest that the Bank Managers can increase the number of servers in model 3. In this way, this research can contribute to the betterment of a bank in terms of its functioning.

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Appendix A

Spreadsheets - Monday

S.No	Arrival Time	Inter arrival Time	No. of People in a Queue	Departure Time	Service Time
1	09:50:00	0:00:00	2	09:51:00	0:01:00
2	09:51:00	0:01:00	3	09:53:30	0:02:30
3	09:53:00	0:02:00	3	09:55:00	0:02:00
4	09:54:00	0:01:00	4	09:55:00	0:01:00
5	09:55:00	0:01:00	3	09:56:00	0:01:00

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6	09:55:00	0:00:00	2	09:56:00	0:01:00
7	09:56:00	0:01:00	1	09:56:45	0:00:45
8	09:56:00	0:00:00	1	09:57:00	0:01:00
9	09:57:00	0:01:00	0	09:59:10	0:02:10
10	09:58:00	0:01:00	2	09:59:00	0:01:00
11	09:59:10	0:01:10	1	09:59:40	0:00:30
12	10:00:00	0:00:50	0	10:01:00	0:01:00
13	10:01:00	0:01:00	0	10:03:00	0:02:00
14	10:03:00	0:02:00	1	10:03:30	0:00:30
15	10:03:00	0:00:00	3	10:03:40	0:00:40
16	10:03:30	0:00:30	2	10:04:00	0:00:30
17	10:04:00	0:00:30	1	10:05:00	0:01:00
18	10:04:00	0:00:00	0	10:05:00	0:01:00
19	10:05:00	0:01:00	0	10:06:00	0:01:00
20	10:07:00	0:02:00	2	10:07:00	0:01:00
21	10:07:00	0:00:00	0	10:09:00	0:02:00
22	10:09:00	0:02:00	1	10:10:00	0:01:00
23	10:10:00	0:01:00	2	10:11:00	0:01:00
24	10:10:00	0:00:00	Enquiry		
25	10:11:00	0:01:00	1	10:12:00	0:01:00
26	10:12:00	0:01:00	2	10:12:50	0:00:50
27	10:12:50	0:00:50	2	10:14:00	0:01:10
28	10:14:00	0:01:10	3	10:14:30	0:00:30
29	10:14:30	0:00:30	3	10:15:00	0:00:30
30	10:15:00	0:00:30	4	10:18:00	0:03:00
31	10:15:00	0:00:00	5	10:16:00	0:01:00
32	10:15:00	0:00:00	2	10:16:00	0:01:00
33	10:16:00	0:01:00	0	10:17:00	0:01:00
34	10:17:00	0:01:00	2	10:17:30	0:00:30
35	10:18:00	0:01:00	0	10:18:30	0:00:30
36	10:18:00	0:00:00	1	10:19:00	0:01:00
37	10:19:00	0:01:00	2	10:20:00	0:01:00
38	10:19:00	0:00:00	0	10:19:30	0:00:30
39	10:20:00	0:01:00	2	10:21:00	0:01:00
40	10:20:00	0:00:00	2	10:21:00	0:01:00
41	10:21:00	0:01:00	2	10:21:40	0:00:40
42	10:21:00	0:00:00	0	10:21:30	0:00:30
43	10:21:00	0:00:00	0	10:23:00	0:02:00
44	10:21:40	0:00:40	1	10:23:00	0:01:20
45	10:23:00	0:01:20	1	10:23:30	0:00:30

Mean arrival time = 0:00:44 seconds or 0.73333 minutes per customer

Arrival Rate = 81.818 customers per hour

Mean serving time = 1.0667 minutes per customer Service Rate = 56.250 customers per hour Duration of data collection = 0:33:00 min

Spreadsheets – Friday

S.No	Arrival Time	Inter arrival Time	No. of People in a Queue	Departure Time	Service
1	10: 25:00	0:00:00	1	10: 26:00	0:01:00
2	10: 26:00	0:01:00	1	10: 27:00	0:01:00
3	10: 27:00	0:01:00	3	10: 27:30	0:00:30
4	10: 27:00	0:00:00	2	10: 28:00	0:01:00
5	10: 28:00	0:01:00	2	10: 28:30	0:00:30
6	10: 28:30	0:00:30	3	10: 29:00	0:00:30
7	10: 29:00	0:00:30	4	10: 31:00	0:02:00
8	10: 29:00	0:00:00	2	10: 30:00	0:01:00
9	10: 30:00	0:01:00	4	10: 31:00	0:01:00
10	10: 30:00	0:00:00	1	10: 31:00	0:01:00
11	10: 31:00	0:01:00	2	10: 32:00	0:01:00
12	10: 31:00	0:00:00	3	10: 32:00	0:01:00
13	10: 32:00	0:01:00	3	10: 32:30	0:00:30
14	10: 32:00	0:00:00	5	10: 33:00	0:01:00
15	10: 33:00	0:01:00	5	10: 33:30	0:00:30
16	10: 33:00	0:00:00	5	10: 36:00	0:03:00
17	10: 34:00	0:01:00	4	10: 34:30	0:00:30
18	10: 34:00	0:00:00	3	10: 35:00	0:01:00
19	10: 35:00	0:01:00	2	10: 35:30	0:00:30
20	10: 36:00	0:01:00	1	10: 37:00	0:01:00
21	10: 36:00	0:00:00	6	10: 37:00	0:01:00
22	10: 37:00	0:01:00	0	10: 37:30	0:00:30
23	10: 37:00	0:00:00	0	10:40:00	0:03:00
24	10: 37:00	0:00:00	4	10: 38:00	0:01:00
25	10: 38:00	0:01:00	1	10: 38:30	0:00:30

………………Continue

26	10: 38:30	0:00:30	1	10: 40:00	0:01:30
27	10: 40:00	0:01:30	0	10: 40:30	0:00:30
28	10: 40:00	0:00:00	0	10: 42:00	0:02:00
29	10: 40:00	0:00:00	0	10: 43:00	0:03:00
30	10: 41:00	0:01:00	1	10: 43:00	0:02:00
31	10: 43:00	0:02:00	2	10: 44:00	0:01:00
32	10: 43:00	0:00:00	1	10: 44:00	0:01:00
33	10: 44:00	0:01:00	1	10: 45:00	0:01:00
34	10: 45:00	0:01:00	2	10: 46:00	0:01:00
35	10: 46:00	0:01:00	1	10: 47:00	0:01:00
36	10: 47:00	0:01:00	2	10: 48:00	0:01:00
37	10: 48:00	0:01:00	2	10: 48:40	0:00:40
38	10: 48:00	0:00:00	1	10: 49:00	0:01:00
39	10: 49:00	0:01:00	1	10: 49:35	0:00:35
40	10: 49:00	0:00:00	2	10: 50:00	0:01:00
41	10: 50:00	0:01:00	0	10: 51:00	0:01:00

Mean arrival time = 0:00:37 seconds or 0.61667 minutes per customer

Arrival Rate = 97.297 customers per hour

Mean serving time = 1.1000 minutes per customer Service Rate = 54.545 customers per hour Duration of data collection = 0:25 min

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