



Case Study



## Simulation Technique for Queuing Theory: A Case Study

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### ABSTRACT

This study shows that the analysis and observation of customers in queue and also reveals with the historical backgrounds it gives an overview of different solution methods and tools. The information of this queuing model gives the information that the numbers of their servers are not adequate for the customer's service. This shows that, they need 6 servers instead of the 2 at present in the State Bank of India, India. It suggests a need to increase the number of servers in order to serve the better service to customers and the time of customer in queue is reduce, their satisfaction may be increased.

**Key words:** Customers, Queue, Arrival rate, Service rate.

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### ABSTRACT

This study shows that the analysis and observation of customers in queue and also reveals with the historical backgrounds it gives an overview of different solution methods and tools. The information of this queuing model gives the information that the numbers of their servers are not adequate for the customer's service. This shows that, they need 6 servers instead of the 2 at present in the State Bank of India, India. It suggests a need to increase the number of servers in order to serve the better service to customers and the time of customer in queue is reduce, their satisfaction may be increased.

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### 1. INTRODUCTION

A body of knowledge about waiting lines, often called queuing theory is an important part of operations and a valuable tool for operations managers. Waiting lines are an everyday occurrence, affective people shopping for groceries buying gasoline, making a bank deposit, or waiting on the telephone .In many retail stores and banks, management has tried to reduce the frustration of customers by somehow increasing the speed of the checkout and cashier lines. Although most grocery stores seem to have retained the multiple line/multiple checkout system, many banks, credit unions and fast food providers have gone in recent years to a queuing system where customers wait for the next available cashier. The frustrations of "getting in a slow line" are removed because that one slow transaction does not affect the throughput of the remaining customers.

A.K. Erlang, a Danish telephone engineer, did original work on queuing theory. Erlang started his work in 1905 in an attempt to determine the effects of fluctuating service demand (arrivals)

on the utilization of automatic dialing equipment. It has been only since the end of World War II that work on waiting line models has been extended to other kinds of problems. In today's scenario a wide variety of seemingly diverse problems situations are recognized as being described by the general waiting line model. In any queuing system, we have an input that arrives at some facility for service or processing and the time between the arrivals of individual inputs at the service facility is commonly random in nature. Similarly, the time for service or processing is commonly a random variable. [5]

Banking means the business of receiving money on current or deposit account, paying and collecting cheques drawn by or paid in by customers, the making of advances to customers, and includes such other business as the Authority may prescribe for the purposes of this Act.

The aim of this paper is to decrease customers waiting time by building a homogenous way that analyze the queue status and take decisions about which customer to serve by using the

appropriate scheduling algorithm. The rest of this paper is organized as follows. Section 2 consists of Methodology of queuing system, arrival pattern, service pattern, queue discipline and Customers behavior. Then our proposed queuing system model is shown in section 3. Research methodology and Evaluations are shown in section 4, followed by brief Results and conclusions and suggestions for future work are shown in section 5. Then the references are shown in section 6.

## 2. METHODOLOGY OF QUEUING SYSTEM.

One thing we have to remember is that when we speak of queue, we have to deal with two elements,

i.e. Arrivals and Service facility. Entire queuing system can be completely described by:

- (a) The arrival pattern
- (b) The service pattern,
- (c) The queue discipline and
- (d) Customer behavior.

Components of the queuing system are arrivals, the element waiting in the queue, the unit being served, the service facility and the unit leaving the queue after service. This is shown in Figure.1

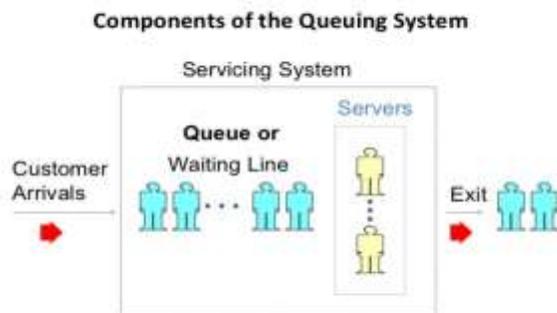


Figure1. Components of Queuing system.

### 2.1. Arrival Pattern

The Arrival Pattern describes the way in which the customers arrive and join the system. In general customer arrival will be in random fashion, which cannot be predicted, because the customer is an independent individual and the service organization has no control over the customer input to the queuing system refers to the pattern of arrival of customers at the service facility. We can see at counters in banks or any

such service facility that the customer arrives randomly individually or in batches. The input process is described by the following characteristics (as shown in the Figure. 2) nature of arrivals, capacity of the system and behavior of the customers.

**2.1.1. Size of arrivals:** The size of arrivals to the service system is greatly depends on the nature of size of the population, which may be infinite or finite. The arrival pattern can be more clearly described in terms of probabilities and consequently the probability distribution for inter- arrival times i.e. the time between two successive arrivals or the distribution of number of customers arriving in unit time must be defined. In our discussion, it is dealt with those queuing system in which the customers arrive in Poisson or Completely random fashion.

**2.1.2. Inter-arrival time:** The period between the arrivals of individual customers may be constant or may be scattered in some distribution fashion. Most queuing models assume that the some inter-arrival time distraction applies for all customers throughout the period of study. It is true that in most situations that service time is a random variable with the same distribution for all arrivals, but cases occur where there are clearly two or more classes of customers such as a machine waiting for repair with a different service time distribution. Service time may be constant or random variable In general the arrivals follow Poisson distribution when the total number of arrivals during any given time interval of the number of arrivals that have already occurred prior to the beginning of time interval.



Figure2.The queuing system.

**2.1.3. Capacity of the service system:** In queuing context the capacity refers to the space available for the arrivals to wait before taken to service. The space available may be limited or unlimited. When the space is limited, length of waiting line crosses a certain limit; no further units or arrivals are permitted to enter the system till some waiting space becomes vacant. This type of system is known as system with finite capacity and it has its effect on the arrival pattern of the system. [5]

## **2.2. Service Pattern**

Service facilities are arranged to serve the arriving customer or a customer in the waiting line is known as service pattern. The time required to serve the customer cannot be estimated until we know the need of the customer. Service facility design and service discipline and the channels of service

**2.2.1. Service facility design:** Arriving customers may be asked to form a single line (Single queue) or multi line (multi queue) depending on the service need. When they stand in single line it is known as Single channel facility when they stand in multi lines it is known as multi channel facility.

(i) Single channel queues: If the organization has provided single facility to serve the customers, only one unit can be served at a time, hence arriving customers form a queue near the facility. The next element is drawn into service only when the service of the previous customer is over. Here also depending on the type of service the system is divided into Single phase and Multi phase service facility. In Single channel Single Phase queue, the customer enters the service zone and the facility will provide the service needed. Once the service is over the customer leaves the system

(ii) Multi Channel queues: When the input rates increases, and the demand for the service increases, the management will provide additional service facilities to reduce the rush of customers or waiting time of customers. In such cases, different queues will be formed in front of different service facilities. If the service is provided to customers at one particular service

center, then it is known as Multi channel Single-phase system

## **2.3. Queue discipline**

When the customers are standing in a queue, they are called to serve depending on the nature of the customer. The order in which they are called is known as Service discipline. There are various ways in which the customer called to serve. They are:

(i) *First in First out (FIFO) or First Come First Served (FCFS)*

We are quite aware that when we are in a queue, we wish that the element which comes should be served first, so that every element has a fair chance of getting service. When the condition of FIFO is violated, there arises the trouble and the management is answerable for the situation.

(ii) *First in Last out (FILO) or Last Come First Served (LCFS)*

In this system, the element arrived last will have a chance of getting service first. In general, this does not happen in a system where human beings are involved. But this is quite common in Inventory system. This is what we call Last come first served. This can also be written as First in Last out (FILO).

(iii) *Service In Random Order (SIRO)*

In this case the items are called for service in a random order. The element might have come first or last does not bother; the servicing facility calls the element in random order without considering the order of arrival. It is also seen to allocate an item whose demand is high and supply is low, also seen in the allocation of shares to the applicants to the company.

(iv) *Service by Priority*

Priority disciplines are those where any arrival is chosen for service ahead of some other customers already in queue. A non- pre-emptive rule of priority is one where an arrival with low priority is given preference for service than a high priority item. This is the rule of priority.

## **2.4. Customer behavior:**

The length of the queue or the waiting time of a customer or the idle time of the service facility mostly depends on the behavior of the customer. Here the behavior refers to the

impatience of a customer during the stay in the line. Customer behavior can be classified as:

(i) **Balking:** This behavior signifies that the customer does not like to join the queue seeing the long length of it. This behavior may effect in losing a customer by the organization. Always a lengthy queue indicates insufficient service facility and customer may not turn out next time.

(ii) **Reneging:** In this case the customer joins the queue and after waiting for certain time loses his patience and leaves the queue. This behavior of the customer may also cause loss of customer to the organization.

(iii) **Collusion:** In this case several customers may collaborate and only one of them may stand in the queue. One customer represents a group of customer. Here the queue length may be small but service time for an individual will be more. This may break the patience of the other customers in the waiting line and situation may lead to any type of worst episode.

(iv) **Jockeying:** If there are number of waiting lines depending on the number of service stations, for example Petrol bunks, Cinema theaters, etc. A customer in one of the queue after seeing the other queue length, which is shorter, with a hope of getting the service, may leave the present queue and join the shorter queue. Because of this character of the customer, the queue lengths may goes on changing from time to time.[5].

### 3. QUEUING SYSTEM MODELS.

The most important information required to solve a waiting line problem is the nature and probability distribution of arrivals and service pattern. The answer to any waiting line problem depending on finding:

(a) Queue length: The probability distribution of queue length or the number of persons in the system at any point of time. Further we can estimate the probability that there is no queue.

(b) Waiting time: This is probability distribution of waiting time of customers in the queue. That is we have to find the time spent by a customer in the queue before the commencement of his service, which is called his waiting time in the

queue. The waiting time depends on various factors, such as:

(i) The number of units already waiting in the system,

(ii) The number of service stations in the system,

(iii) The schedule in which units are selected for service,

(iv) The nature and magnitude of service being given to the element being served.

(c) Service time: It is the time taken for serving a particular arrival.

(d) Average idle time or busy time distribution: The average time for which the system remains idle. We can estimate the probability distribution of busy periods. If we suppose that the server is idle initially and the customer arrives, he will be provided service immediately. On the other hand, during the idle periods no customer is present in the system. A busy period and the idle period following it together constitute a busy cycle. The study of busy period is of great interest in cases where technical features of the server and its capacity for continuous operation must be taken into account.

#### 3.1. Steady, Transient and Explosive States in a Queue System

The distribution of customer's arrival time and service time are the two constituents, which constitutes of study of waiting line. Under a fixed condition of customer arrivals and service facility a queue length is a function of time. We can identify three states of nature in case of arrivals in a queue system. They are named as steady state, transient state, and the explosive state.

(a) Steady State: The system will settle down as steady state when the rate of arrivals of customers is less than the rate of service and both are constant. The system not only becomes steady state but also becomes independent of the initial state of the queue. Then the probability of finding a particular length of the queue at any time will be same. A necessary condition for the steady state to be reached is that elapsed time since the start of the operation becomes sufficiently large i.e. ( $t \rightarrow \infty$ ), but this condition is not sufficient as the existence of

steady state also depend upon the behavior of the system i.e. if the rate of arrival is greater than the rate of service then a steady state cannot be reached. Hence we assume here that the system acquires a steady state as  $t \rightarrow \infty$ , i.e. the number of arrivals during a certain interval becomes independent of time.

i.e.  $\lim_{t \rightarrow \infty} P_n(t) \rightarrow P_n$

Hence in the steady state system, the probability distribution of arrivals, waiting time, and service time does not depend on time.

(b) Transient State: Queuing theory analysis involves the study of a system's behavior over time. A system is said to be in transient state, when its operating characteristics or behavior are dependent on time. So when the probability distribution of arrivals, waiting time and servicing time are dependent on time the system is said to be in transient state.

(c) Explosive State: In a situation, where arrival rate of the system is larger than its service rate, a steady state cannot be reached regardless of the length of the elapsed time. Here queue length will increase with time and theoretically it could build up to infinity. Such case is called the explosive state. In our further discussion, all the problems and situations are dealt with steady state only.

### 3.2. Designation of Queue and Symbols used in Queuing Models

A queue is designated or described as shown below: A model is expressed as **a/b/c : (d / e)** where,

**a:** Arrival pattern of the units, given by the probability distribution of inter - arrival time of units.

**b:** The probability distribution of service time of individual being actually served

**c:** The number of service channels in the system

**d:** Capacity of the system. That is the maximum number of units the system can accommodate at any time.

**e:** The manner or order in which the arriving units are taken into service i.e. FIFO / LIFO / SIRO / Priority.

For the analysis of the State bank of India M/M/1 queuing model, the following variables will be investigated [6]:

$\lambda$ : The mean customers arrival rate

$\mu$  : The mean service rate

$\rho = \lambda/\mu$  : utilization factor

$\rho = \lambda/c\mu$  : utilization factor ,c is number of servers.

(i) Probability of zero customers in the restaurant:  $P_0 = 1 - \rho$  (1)

(ii)  $P_n$ : The probability of having n customers in the restaurant.

$$P_n = P_0 \rho^n = (1 - \rho) \rho^n \quad (2)$$

(iii) L: average number of customers sitting in the queue

$$L = \frac{\rho}{1-\rho} = \frac{\lambda}{\mu-\lambda} \quad (3)$$

(iv)  $L_q$ : average number in the queue.

$$L_q = L - \rho = \frac{\rho^2}{1-\rho} = \frac{\rho\lambda}{\mu-\lambda} \quad (4)$$

(v) W: average time spent in Bank, including the waiting time.

$$W = \frac{L}{\lambda} = \frac{1}{\mu-\lambda} \quad (5)$$

(vi)  $W_q$ : average waiting time in the queue.

$$W_q = \frac{L_q}{\lambda} = \frac{\rho}{\mu-\lambda} \quad (6)$$

### 3.3. Limitations of queuing theory:

The assumptions of classical queuing theory may be too restrictive to be able to model real-world situations exactly. The complexity of production lines with product-specific characteristics cannot be handled with those models. Therefore specialized tools have been developed to simulate, analyze, visualize and optimize time dynamic queuing line behaviour. [2]

Alternative means of analysis have thus been devised in order to provide some insight into problems that do not fall under the scope of queuing theory, although they are often scenario-specific because they generally consist of computer simulations or analysis of experimental data. See network traffic simulation. [3]

All the queuing models that we shall look at have the following characteristics:

- i. Poisson distribution arrivals
- ii. FIFO discipline
- iii. A single-service phase

The different models are summarized in the table below (See after references)

#### 4. RESEARCH METHOD AND EVALUATION:

The research method used in this work is a quantitative research approach. The data gathered were the daily record of queuing system over a week. The method used in this research work were the analysis of queuing systems and techniques and also the development of queuing model for the analysis of queuing method and establish a method that will solve the problem of customers arrival rate. The model will establish the actual time it takes to serve the customer as at when due and estimate the actual working serves necessary in the organization. This model developed was used to predict the actual number of servers and time it takes to solve the problem of queuing or waiting before customers are been served as and at when due in the establishment for a week. The model developed was used to test the queuing system against the number of servers and customers arrival rate of the establishment

Table2: Analysis of Queuing system servers on Monday

Monday	Server-1		Server-2	
	Arrival Rate	Service Rate	Arrival Rate	Service Rate
10.30-11.30	20	14	18	13
11.30-12.30	15	10	16	11
12.30-1.30	18	12	15	10
02.30-04.00	25	20	23	18

Table3: Analysis of Queuing system servers on Tuesday

Tuesday	Server-1		Server-2	
	Arrival Rate	Service Rate	Arrival Rate	Service Rate
10.30-11.30	23	16	21	16
11.30-12.30	15	11	14	11
12.30-1.30	15	12	16	10
02.30-04.00	20	15	22	15

Table4: Analysis of Queuing system servers on Wednesday

Wednesday	Server-1		Server-2	
	Arrival Rate	Service Rate	Arrival Rate	Service Rate
10.30-11.30	15	11	17	12
11.30-12.30	14	10	14	11
12.30-1.30	13	09	14	10
02.30-04.00	15	10	13	10

Table5: Analysis of Queuing system servers on Thursday

Thursday	Server-1		Server-2	
	Arrival Rate	Service Rate	Arrival Rate	Service Rate
10.30-11.30	14	10	13	09
11.30-12.30	10	08	09	08
12.30-1.30	12	10	10	08
02.30-04.00	16	11	17	12

Table6: Analysis of Queuing system servers on Friday

Friday	Server-1		Server-2	
	Arrival Rate	Service Rate	Arrival Rate	Service Rate
10.30-11.30	14	11	17	12
11.30-12.30	18	13	16	12
12.30-1.30	15	11	13	10
02.30-04.00	19	15	18	15

Table7: Analysis of Queuing system servers on Saturday

Saturday	Server-1		Server-2	
	Arrival Rate	Service Rate	Arrival Rate	Service Rate
10.30-11.30	20	17	21	15
11.30-12.30	15	11	17	14

Table8: Analysis of Queuing system servers for Daily.

Day	Total	Server-1		Server-2	
		Arrival Rate	Service Rate	Arrival Rate	Service Rate
Monday	Total arrival or Service rate	78	56	72	52
	Average Arrival or Service Rate	19.5	14	18	13
Tuesday	Total arrival or Service rate	73	54	73	52
	Average Arrival or Service Rate	18.25	13.5	18.25	13

Wednesday	Total arrival or Service rate	57	40	58	43
	Average Arrival or Service Rate	14.25	10	14.5	10.75
Thursday	Total arrival or Service rate	52	39	49	37
	Average Arrival or Service Rate	13	09.75	12.25	09.25
Friday	Total arrival or Service rate	66	50	64	49
	Average Arrival or Service Rate	16.5	12.5	16	12.25
Saturday	Total arrival or Service rate	35	28	38	29
	Average Arrival or Service Rate	08.75	07	09.5	07.25
Total per Week	Total arrival or Service rate	361	267	354	262
	Average Arrival or Service Rate	90.25	66.75	88.5	65.5
	Average system Utilization	1.35205993		1.35114504	

Table 9: Analysis of system utilization of servers for Daily.

Day	Server1	Server2
Monday	1.39285714	1.38461538
Tuesday	1.35185185	1.40384615
Wednesday	1.425	1.34883721
Thursday	1.333333	1.32432432
Friday	1.32	1.30612245
Saturday	1.25	1.31034483
All Days	1.35205993	1.35114504

Customer Arrival rate of Server1 ( $\lambda_1$ ) =15.0416667

Customer Arrival rate of Server1 ( $\lambda_2$ ) =14.75

Average Customer Arrival rate of Server1 ( $\lambda$ ) =14.8958334

Customer Service rate of Server1 ( $\mu_1$ ) =11.125

Customer Service rate of Server1 ( $\mu_2$ ) =10.916667

Average Customer Service rate of Server1 ( $\mu$ ) =11.0208334

The Average Number of customers being served(R)

$$R = \lambda / \mu = 14.8958334 / 11.0208334 = 1.3516068$$

The Average Number of customers being served for Server1 ( $R_1$ )

$$R_1 = \lambda_1 / \mu_1 = 15.0416667 / 11.125 = 1.35205993$$

The Average Number of customers being served for Server2 ( $R_2$ )

$$R_2 = \lambda_2 / \mu_2 = 14.75 / 10.916667 = 1.351145$$

System utilization of each Channel  $\rho = \lambda / c\mu$

$$\rho_1 = \lambda_1 / c\mu_1 = 15.0416667 / 1 (11.125) = 1.35205993$$

$$\rho_2 = \lambda_2 / c\mu_2 = 14.75 / 1 (10.916667) = 1.351145$$

Expected inter arrival time per Hour =  $1/\lambda = (1/14.8958334) \times 60 = 4.0279722$

Service Time per Hour =  $\mu = 11.0208334$

Let  $m=6$  =the number of servers Required

The average number of customers waiting for service ( $Lq$ ) =  $\frac{\rho^m}{m\mu - \lambda} = 0.039300482$

Average waiting time for an arrival not immediately served ( $W_a$ ) =

$$W = \frac{L}{\lambda} = \frac{1}{m\mu - \lambda} = 0.01952013 \text{ per Hour}$$

The average time customers wait in line ( $Wq$ ) =  $Wq = Lq/\lambda = 0.002638354$  per Hour

Probability that an arrival will have to wait for service ( $P_w$ )  $P_w = Wq/Wa = 0.135160678$

The Average Number of Customers in the System (waiting and /or being served)

$$L_s = Lq + R = 0.039300482 + 1.3516068 = 1.39090728$$

The average time spend in the system (waiting in line and service time) ( $W_s$ )

$$W_s = Wq + 1/\mu = L_s/\lambda$$

$$W_s = L_s/\lambda = 1.39090728 / 14.8958334 = 0.09337559$$

System Utilization  $\rho = \lambda/M \mu = 14.8958334 / 6(11.0208334) = 0.2252678$

The system capacity =  $M\mu = 6 \times 11.0208334 = 66.1250004$

## 5. RESULTS AND CONCLUSION

From the analysis, it was observed that number of servers necessary to serve the customers in the case study establishment was Six (6) servers (or channels). This is the appropriate number of servers that can serve the customers as and at when due without waiting for long before customers are been served at the actual time necessary for the service. This increase in servers reduces the waiting time, and the probability that an arrival will have to wait for service is 0.09337559. However, the system utilization was observed to be 0.2252678 for an hour. Furthermore, the system capacity of the six servers was observed to be 66.1250004 for an hour.

The evaluation of queuing system in an establishment is necessary for the betterment of the establishment. As it concerns the case study company, the evaluation or analysis of their queuing system shows that the case study company needs to increase the number of their channels or servers up to Six(6) as show in the result analysis. The increase in the number of servers will reduce the time customers have to wait in line before been served. This will also increase the efficiency of the establishment due to the appreciation in their serve to the customers as and at when due. As our future works, we will develop a simulation model for the Different bank branches. In addition, a simulation model allows us to add more complexity so that the model can mirror the

actual operation of the restaurant more closely.  
 [1]

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Table1: Different Queuing models

Model	Name	No. of channels	No. of Phases	Service time pattern	Population Size	Queue discipline
A	Single-Channel (M/M/1)	Single	Poisson	Exponential	Unlimited	FIFO
B	Multi channel (M/M/S)	Multiple	Poisson	Exponential	Unlimited	FIFO
C	Constant service (M/D/1)	Single	Poisson	Constant	Unlimited	FIFO
D	Limited population	Single	Poisson	Exponential	Limited	FIFO