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Queuing Theory to Reduce Waiting Time in Automatic TellerMachine (ATM)

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Abstract: In order to receive the requested service, which may be processed or supplied one at a time, consumers or people frequently queue up. Bank ATMS wouldn't lose clients as a result of lengthy queue waits. When we apply M/M/S model (i.e., MULTI SERVER QUEUING MODEL) we can reduce the waiting time in queue line. To implement this method the bank should places two ATM in each branch. This essay demonstrates how this issue was resolved using the queuing theory. Getting the data from a city's bank ATM. Next we determine the frequency of arrival, level of service, rate of utilization, and duration of waiting queue as well as the typical clientele.

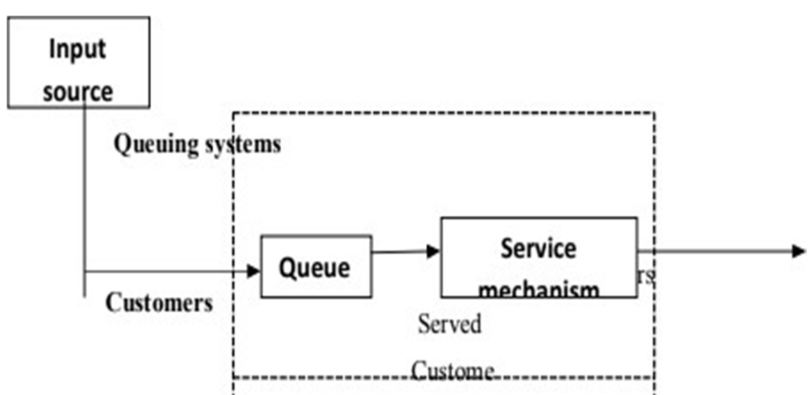
Keywords: Queuing System, Characteristics Of Queuing System, Arrival Pattern, Mean Arrival Rate (Λ), Service Pattern, Mean Service Rate (μ), Number Of Servers, Queuing Discipline, Multi Server Queuing Model, (M/M/C): (∞ /Fcfs), Formulas For Multi Server Queuing Model, Results And Discussion

I. INTRODUCTION

The mathematical study of waiting lines, or queues, is known as queuing theory. The study of queues deals with measuring the phenomenon of waiting lines using representative measures of performances, such as average queue length , average waiting time in queue and average facility utilization. A queuing model is constructed so that queue lengths and waiting time can be predicted. 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 a service. This methodology is applicable in the field of Business, Industries, Government, Transportation, Restaurants, and Library etc. Queues arise when the short term demand for service exceeds the capacity. The Mathematical analysis of queues and waiting times in stochastic systems is called Modeling theory or Queuing theory.

II. MATERIALS AND METHODS

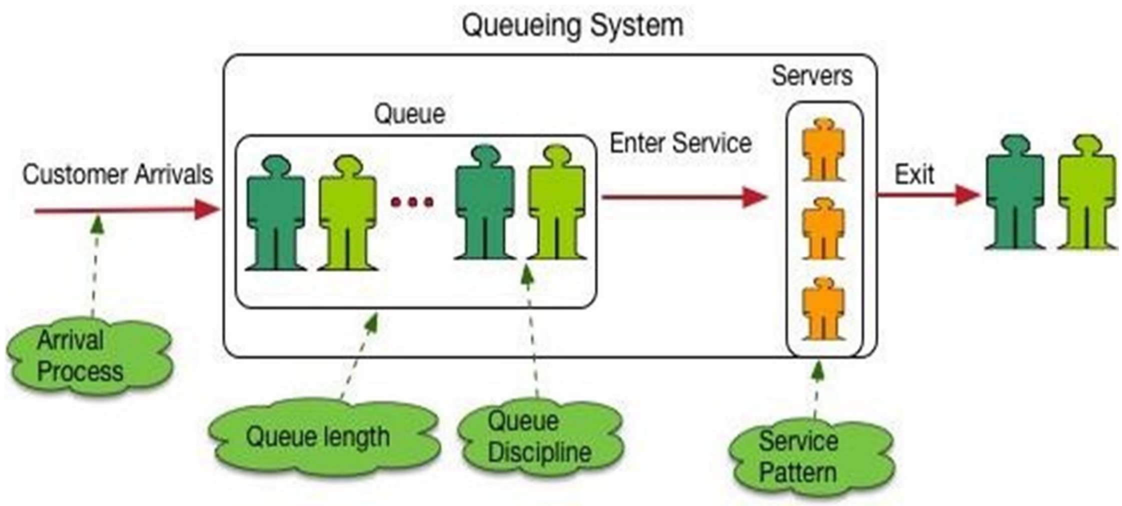
A. Structures and Classifiaction of Queuing Theory



B. Queuing System

The mechanism of queuing process is very simple. Customers arrive at a service counter and are attended to by one or more of the servers. As soon as customer is served it departs from the system. Thus a queuing system can be described as consisting of customers arriving for service, waiting for services it is not immediate and leaving the system after being served.

The general framework of a queuing system is shown in below:



1) Characteristics Of Queuing System

In designing a good queuing system, it is necessary to have a good information about the model. Thecharacteristic listed below would provide sufficient information,

Arrival pattern Server pattern Number of serversQueuing discipline

2) Arrival Pattern

This is the manner in which arrivals occur, indicted by the inter-arrival time between any two consecutive arrivals.For our stochastic modelling framework, the inter-arrival time may vary and may be described by a specific probability distribution that best describes the arrival pattern observed.

3) Mean Arrival Rate (λ)

The mean arrival rate in a waiting line situation is defined as the expected number of arrivals occurring in a lengthunity.

We define λ to be the arrival rate, which will have units of arrivals per hour

4) Service Pattern

This is the manner in which the service is rendered and is specified by the time taken to complete a service. Similar to the arrival pattern, distribution of the service time must be specified under stochastic modelling considerations.

5) Mean Service Rate (µ)

The mean service rate is defined as the expected number of services completed in a time interval of length unity

We define µ to be the service rate is the expected number of customers that can be served by one of the serversper unit time

6) Number of Servers

The number of servers that are being utilize should be specified and in the manner. They work as a parallel serversor a series server has to be specified

7) Queuing Discipline

The most common queue disciplines are:

First in first out(FIFO)First in last out (FILO)

Served in random order(SIRO)Priority scheduling

Processor sharing

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C. Multi Server Queuing Model(M/M/C): (∞ /FCFS)

Multi server queue has two or more services facility in parallel providing identical service. All the customers in the waiting line can be served by more than one station. The arrival time and the services time follows Poisson and exponential distribution. First, the queuing formulas for a multiple-server queuing system will be presented. 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.

III. FORMULAS FOR MULTI SERVER QUEUING MODEL

1) The probability that all the servers are idle is

$$P_0 = [\sum_{n=0}^{c-1} \frac{(\lambda/u)^n}{n!} + \frac{1}{c!}\left(\frac{\lambda}{\mu}\right)^c \left(\frac{cu}{cu-\lambda}\right)]^{-1}.$$

2) The probability of n customers in the queuing system is

$$P_n = \frac{1}{c!c^{n-c}}\left(\frac{\lambda}{\mu}\right)^n P_0, \text{ for } n > c; \; P_n = \frac{1}{n}\left(\frac{\lambda}{\mu}\right)^n P_0, \text{ for } n \le c$$

3) The average number of customers in the queuing system is

$$L = \frac{\lambda\mu(\lambda/\mu)^c}{(c-1)!(c\mu-\lambda)^2} P_0 + \frac{\lambda}{\mu}$$

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

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

5) The average number of customers in the queue is

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

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

$$W_q = W - \frac{1}{\mu} = \frac{L_q}{\lambda}$$

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

$$P_w = \frac{1}{c!}\left(\frac{\lambda}{\mu}\right)^c \frac{c\mu}{c\mu-\lambda} P_0$$

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IV. RESULTS AND DISCUSSION

The summary of data collected for a period of five working Days (Monday - Friday) from8am-6pm is presented in Table 1

Table 1

Days	Inter-Arrival Time (MIN)	Service Time for ATM 1 (MIN)	Service Time for ATM 2 (MIN)	Total No of Customers
Monday	594	444	358	307
Tuesday	601	409	414	356
Wednesday	595	403	370	300
Thursday	596	407	381	289
Friday	599	454	451	365
Total	2985	2117	1974	1617

From Table 1, we obtain the following:

1) Average Inter-Arrival time for each Day = total inter – arrival time for each day/total number of customers foreach day
Hence, Average inter-arrival time for Monday is 594/307 = 1.935 minutesAverage inter-arrival time for Tuesday is 601/356 = 1.688 minutes Average inter-arrival time for Wednesday is 595/300 = 1.983 minutes Average inter-arrival time for Thursday is 596/289 = 1.062 minutes Average inter-arrival time for Friday is 599/365 = 1.641 minutes

2) The Average service time for each server is = total service time for each day/total number of customers for eachday
Hence, (a) the average service time for ATM 1 is = total service time for each day/total number of customers foreach day
Therefore, the average service time for Monday is 444/307 = 1.446 minutes Average service time for Tuesday is 409/356 = 1.149minutes
Average service time for Wednesday is 403/300 = 1.343 minutes Average service time for Thursday is 407/289 = 1.408 minutes Average service time for Friday is 454/65 = 1.244 minutes
(b) The average service time for ATM 2 is = total service time for each day/total number of customers for eachday
Hence, the average service time for Monday is 358/307 = 1.166 minutes
Average service time for Tuesday is 414/356 = 1.63 minutes Average service time for Wednesday is 370/300 = 1.233 minutes Average service time for Thursday is 381/289 = 1.318 minutes Average service time for Friday is 451/365 = 1.236 minutes

Table 2: Shows the Total, Average Inter-arrival Time and Service Time with TotalNumber of Customers for thefive Working Days considered

Days		Inter-Arrival Time(MIN)	Service TimeATM 1 (MIN)	Service TimeATM 2 (MIN)	Total Number ofCustomers
Mon	Total	594	444	358	307
	Average	1.935	1.446	1.166	
Tue	Total	601	409	414	356
	Average	1.688	1.149	1.163	
Wed	Total	595	403	370	300
	Average	1.983	1.343	1.233	
Thur	Total	596	407	381	289
	Average	2.062	1.408	1.318	
Fri	Total	599	454	451	365
	Average	1.641	1.244	1.236	

The Total 2 is presentation of the average inter-arrival time of the customer in the system and the averageservice time for the two ATMs for the five Working Days considered.

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From the Table 2 we obtain,
The Total average service time for ATM 1 is = sum of average service for non Friday / 5 = 6.590/5 = 1.318minutes
The Total average service time for ATM 1 is = sum of average service for non Friday / 5 = 6.116/5 = 1.223minutes
Hence, The Average service Time for the system is =ATM 1 avg. service time + ATM 2 avg. servicetime / 2 =1.223 / 1.318 = 1.27 minutes
Hence, The Average service Time for the system is = sum of avg. inner arrival time (mon – fri)/ 5 =9.309/5 = 1.86 minutes
Hence, the Average inter-arrival time is 1.86minutesThe average service time is 1.27minutes
Then, the service rate and arrival rate is calculated as;
Service rate 1 / average service time = 1/1.27 = 0.787 Customers per minute = 47.4 Customers per hour Arrival rate 1 / average arrival time =1/1.86 = 0.538 Customers per minute = 32.4 Customers per hour
Using equation (7) we obtain $\rho = \frac{\lambda}{s\mu}$ =0.54/ 2 x 0.79 = 0.3418 or 34.18 %
To calculate probability of no customer in the system, we use equation (1)

$$P_0 = \left[\sum_{n=0}^{1} \frac{1}{0!}\left(\frac{0.54}{0.79}\right)^0 + \frac{1}{1!}\left(\frac{0.54}{0.79}\right)^1 + \frac{1}{2!}\left(\frac{0.54}{0.79}\right)^2 \times \left(\frac{1}{1-0.3418}\right)\right]^{-1}$$

$$P_0 = \left[\sum_{n=0}^{1} 1 + 0.6835 + 0.2336 \times 1.5193\right]^{-1}$$

$$P_0 = [1.6835 + 0.3549]^{-1} = \frac{1}{2.0387} = 0.4905$$

To obtain the expected number of customers waiting in the queue, we use equation (3)

$$L_q = \left[\frac{1}{(2-1)!}\left(\frac{0.54}{0.79}\right)^2 \times \frac{0.54 \times 0.79}{(1.58-0.54)^2}\right] \times 0.4905$$

L_q 0.0904 Customers

To calculate expected number of customers in the system, we use equation (4)

L_s= 0.094+0.54/0.79 = 0.7740 customers

Using equation (5) we obtain expected waiting time in the queue as W_q = 0.094/0.54= 0.1680 minutes

Using equation (6) we obtain expected waiting time in the system as W_S = 0.1680+1/0.79 = 1.434 Minutes

Using equation (1) we obtain probability of n customers in the queuing system as

$$P_n = \begin{cases} \frac{\rho^n}{n!} P_o; & n \le s \\ \frac{\rho^n}{s!\,s^{n-s}} P_o; & n > s \end{cases}$$

where, $\rho = \frac{\lambda}{s\mu}$

Probability when n s i.e. n 2, n 0,1, 2

$$P_0 = \frac{\rho^n}{n!} P_0 = \frac{(0.3418)^0}{0!}(0.4905) = 0.4905$$

$$P_1 = \frac{\rho^n}{n!} P_0 = \frac{(0.3418)^1}{1!}(0.4905) = 0.1677$$

$$P_2 = \frac{\rho^n}{n!} P_0 = \frac{(0.3418)^2}{2!}(0.4905) = 0.0287$$

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The probability when n > 2 i.e. $n = 3, 4, 5, \ldots$

$$P_3 = \frac{\rho^n}{s!s^{n-s}} P_0 = \frac{(0.3418)^3}{2!2^{3-2}} \times 0.4905 = 0.004897$$

$$P_4 = \frac{\rho^n}{s!s^{n-s}} P_0 = \frac{(0.3418)^4}{2!2^{4-2}} \times 0.4905 = 0.0008368$$

$$\vdots$$

$$P_{12} = \frac{\rho^n}{s!s^{n-s}} P_0 = \frac{(0.3418)^{12}}{2!2^{12-2}} (0.4905) = 0.0000000006089$$

The values from P_0 to P_{12} is presented in Table 3

N	Probability	Cumulative
0	0.4905	0.4905
1	0.1677	0.6582
2	0.02870	0.6869
3	0.004897	0.691797
4	0.0008368	0.6926338
5	0.0001430	0.6927768
6	0.00002444	0.69280124
7	0.000004177	0.692805417
8	0.0000007138	0.6928061308
9	0.0000001220	0.6928062528
10	0.00000002085	0.6928062736
11	0.000000003563	0.6928062772
12	0.0000000006089	0.6928062778

From the Table 3, it can be observed that as n increases the probability decreases. This means that probability ofhaving no customer in system is unlikely while the probability of having many customers in the system is also unlikely.

The probability that on arrival a customer has to wait for service is calculated using equation (8) thus

$$P_s = \frac{1}{2!}\left(\frac{0.54}{0.79}\right)^2 \left(\frac{2 \times 0.79}{2 \times 0.79 - 0.54}\right) \times 0.4905$$

$$P_s = \frac{1}{2}(0.467)(1.519) \times 0.4905$$

P_S □ 0.174

A. *Busy Time of the System*

To calculate the busy time of the machines we multiply the banking hours of the ATM machine used bythe utilization factor i.e.

Busy Time=Banking hours of ATMs□ $\frac{□}{s□}$

Busy Time =10x0.3418= 3.418hours

B. Idle Time of the System

To calculate the idle time of the machine we subtract Busy time from Banking hours of the ATM i.e.Idle Time = Banking hours of ATM – Busy time (10)

Idle Time =10-3.418 = 6.582 hours

Table 4: The table below shows the values of the parameters & some queueformulae used

Queue parameters &formulae	Value
Arrival rate □	0.54
Service rate □	0.79
Utilization factor □	0.3418
Expected number of customers in system L_S	0.7740
Average Length of queue L_q	0.0904
Expected waiting time in the system W_S	1.4340
Expected waiting time in queue W_q	0.1680
Prob of zero customers in the system P_0	0.4905
Prob that a customer must wait for service on arrival P_S	0.1740

The number of customers recorded during the five working days considered is 1617persons with arrival rate of 0.54 customers per minute equivalent to 32.4customer per hour while the service rate is 0.79 customer per minutes also equivalent to 47.4 customers per hour. This shows that the service rate of the system is greater than the arrival rate, which implies that customers don't have to queue up for so long to be served. Probability that theATMs are idle is 0.4905, which implies a probability of 49.05% idle time and 50.95% busy time of the ATMs and the traffic intensity is 0.3418 (34.18%). A customer spent a total time of 1.434 minutes in the system.

V. CONCLUSION

The performance level of the Axis Bank ATM's stand located in Saravanampatti has been effectively investigated using the M/M/S Queuing model. It was observed that the busy time of the machine is 3.418 Hours while the idle time is 6.582 hours in the 10 hours of banking time. The utilization factor is 0.3418 or 34.18%, thisimplies good service delivery by the machines therefore no urgent need for an additional ATM at the location.

VI. ACKNOWLEDGEMENT

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