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SYSTEM PERFORMANCE MEASURES OF M/M QUEUEING MODELS WITH BALKING BY USING SIMULATION

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ABSTRACT. In this paper, we aim to evolve a flowchart for the simulation originate in advent affair and leave-taking affair originates in on queueing model for a variety of two servers. It is thus demonstrated how queue models can be nearly new to regulate the queue and how to equip the assistance to the passengers through the servers and also analyze the variation of different servers. This analysis study is the analysis of single queue-single server and single queue - multi server system for finite and infinite queue models mistreatment the simulation of passenger's statistics assembled from Atal Indore City Transport Assistance Limited (AICTSL) office Indore (M.P.) India for the specific bus route. This analysis determines the result for judgment makers to equip better assistance to the passenger and reduce waiting time or analyze the passengers being balked. Also we nearly new MATLAB and WinQSB simulation software to plotting the graph between numerous simulation consequences and analytical consequences and also compute numerous system characteristics of queueing models M/M queue model for judgment making.

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1. Introduction

Advent and leave-taking affair is the most important part of our daily life for getting and providing assistance. The time interval between arriving and the start of the assistance is called waiting time and it generates the queue. Queueing problems are most commonly seen in many situations such as post office, bank, public transport, traffic jam, hospital, educational institutes, computer networking, and telecommunication Jhala et al. 2017, [2].

Most of the Ahmad et al. 2017, [4] reported queueing models assume that the advents and leave-takings follow as birth and death process is also called a Poisson process. Raid, 2010 [3], proposed so many authors work on this assumption in many fields. Here we are using the Poisson method. Although queueing theory, today's scenario many researchers widely use simulation tool, technique, and their software in many streams like object-oriented problems, queueing theory, telecommunication, computer networking. Joshi et al., a proposal of passenger behaviour is Balking, Reneging, Jockeying. The meaning of balking in queueing theory the passenger not joins the queue if it is too long. F. A. Height [5], reported queueing system with Balking was researched by many authors. Firstly the M/M/1 balking introduce by Okonkwo et al., 2011 [1]. Queueing models are running by different simulation algorithms evolved by many authors. Simulation has a user interface as well as a mathematical approach; with this feature, consequences can be analyzed easily.

The valid and reliable evolved simulation algorithm with each step requires fewer statistics with a quick number of simulation runs which is time-consuming. The authors resulted from that simulation process can be tested by a number of the system. Sometimes it is useful to repeat runs so that model parts have different random number while the rest use the same random numbers on each run et al. Jerry, John S. WinQSB is simulation software nearly new for measuring system performance and compare the opportunities or help for making business judgments, which also help to reduce waiting time of passengers.

2. Structure for Two Servers of Advent Affair and Leave-taking Affair

In this paper, we are taking the real-world bus route statistics for measuring waiting time, the queue length of the passengers for concluding how the most effective assistance can be equipped to the passengers. Before analyzing these points we need to understand how the passengers enter into the system and get assistance and leave the system. For this, we are preparing an advent and leave-taking affair for two servers to the passengers. In this paper, we are handling a specific bus route multi-server statistics. The advent affair and leave-taking affair for two server models are represented in Figures 1 and 2. In which we see the passenger enters into the system it will be in advent affair and the passenger is waiting for their turn when both the servers are busy when the assistance turn arrives at the passenger, the passenger goes into the leave-taking affair. In the leave-taking affair, we see how the passengers are getting assistance one by one from the servers. We studied advent affair and leave-taking affair for one server et al Jhala 2017, [2], Raid 2010, [3]. With the help of this, we prepare a flow chart for two servers. The benefit of this flow chart for two servers will help to reduce the waiting time, queue length, and better utilization of the system.

3. METHODS

The statistics for this study was assembled for Indian public transport vehicle at the specific route from Atal Indore City Transport Assistance Limited (AICTSL), Indore (M.P.). We assembled 5 months of statistics of passengers. By using the statistics we apply numerical calculations using queueing theory M/M queue models and simulation techniques for better consequences. The following are:

(1) Λ passengers per unit of an hour of Poisson advents distributions (exponential inter advent time).
(2) μ Passengers per unit of hour of Poisson assistance distribution (exponential assistance time).
(3) The queue discipline is a first come first serve basis for all the servers.
(4) Queue capacity may be finite and infinite for a single server as well as multiple servers.
(5) The average advent rate is greater than the average assistance rate.
(6) Here servers are the number of buses.
(7) P_s passengers per unit of the hour being balked
(8) In the capacity of the infinite situation, we cannot measure the average balked queue.

(9) We are using $M/M/1$ with a balked normalized formula with the value consider $k = 1$.

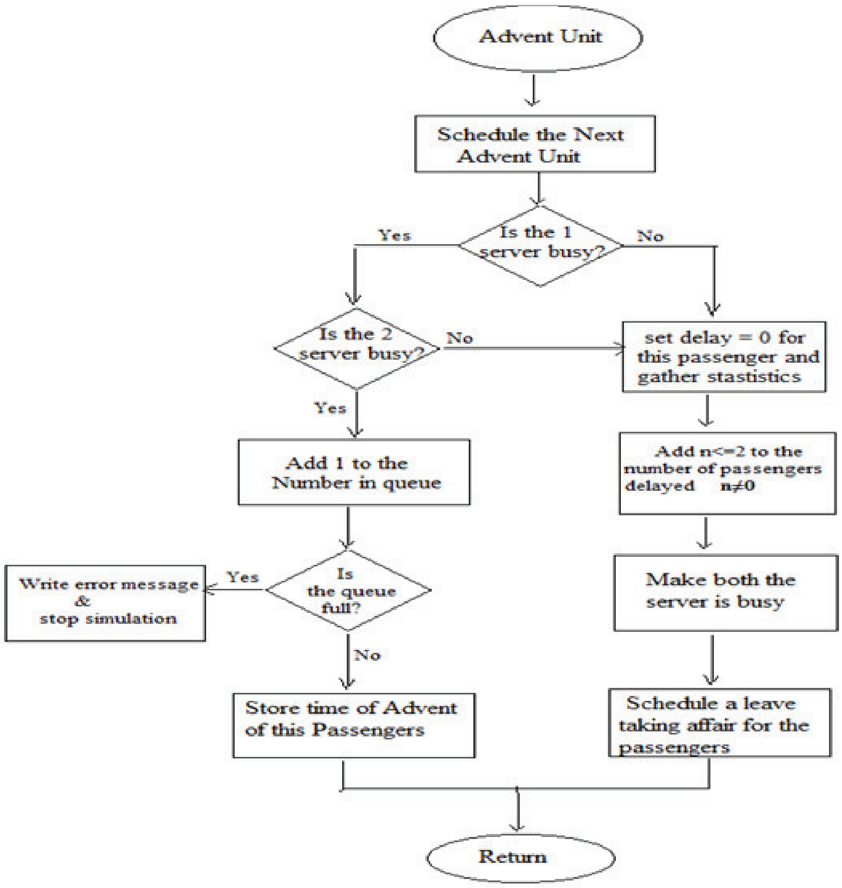

FIGURE 1. Flowchart for the advent affair for 2 servers

Notation:

Λ – The advent rate of passengers per unit

μ - The assistancerate per unit time

S - The number of servers

P_0 - The probability that there are several passengers in the system

L_q - Average number of passengers in the queue

L_s - The system's total number of passengers

W_q - Total passenger time spent in the queue

W_s - Average time in the system a passenger spends

P_s - Average number of passengers being balked per hour

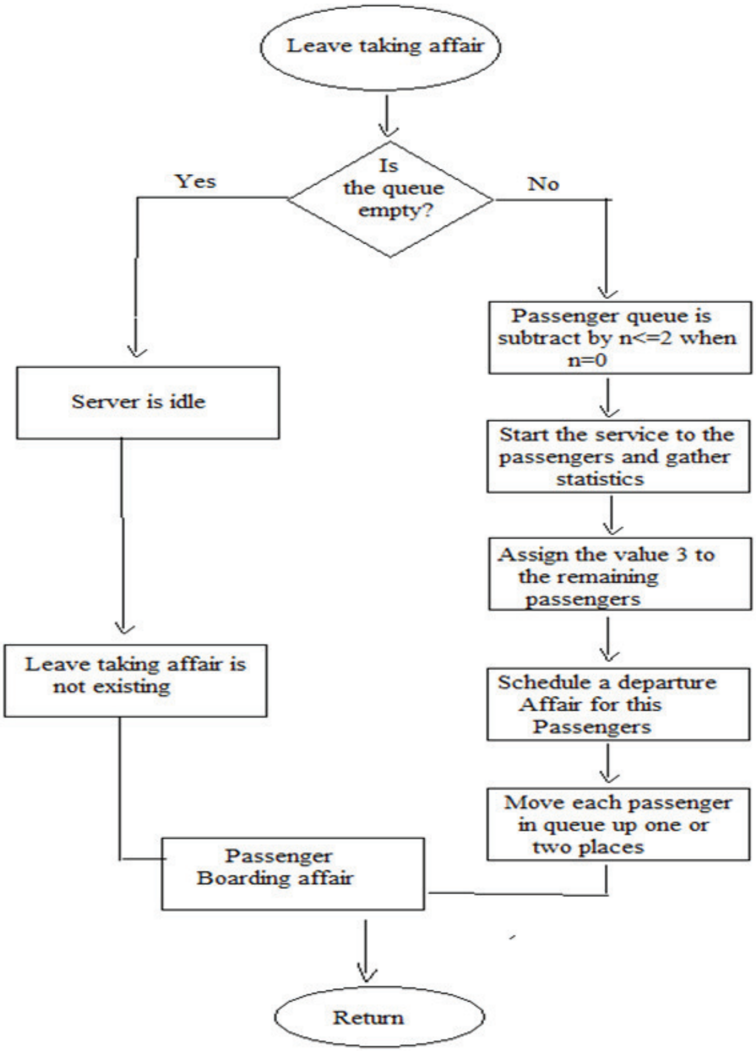

FIGURE 2. Flowchart for the leave-takingaffair for 2 servers.

A measure of the virtual load of the server should be prepared for is equipped by potential advents. Since passengers will balk, some of the future advents may be fostered by the system. The balking passengers are potential passengers, who attend and ultimately get assistance for advents. The time throughout that all servers stay busy are known as a busy amount for the reason. The average number missing and the average number of potential advents during a busy period during a unit assistance time are expressed by N and D respectively. Since

$\sum_{n=c}^{\infty} P_n$ is the likelihood that all servers are busy, the likelihood of losing passengers is $\sum_{n=c}^{\infty} P_n$ due to balking. In addition, during a busy time the average rate of advents is λ_p, and therefore the average loss due to balking during a busy period is $\lambda_{pq} \sum_{n=s}^{\infty} P_n$. Therefore

$$N = \frac{1}{s\mu}\left[\alpha + \lambda_{pq} \sum_{n=s}^{\infty} P_n\right], \tag{3.1}$$

where$(1/c\mu)$ is the average duration during a busy time of unit assistance. On the opposite hand, the typical group action (denoted by A) throughout a busy time during unit help is given by

$$A = \frac{1}{s\mu}\left[\sum_{n=0}^{s} \lambda P_n + \sum_{n=s+1}^{\infty} \lambda p P_n\right]. \tag{3.2}$$

When the queue is not filled by the passenger, (3.1) and (3.2) become

$$N = \frac{\lambda pq}{s\mu - \lambda p} \frac{1}{s!}\left(\frac{\lambda}{\mu}\right)^s P_0$$

and

$$A = \frac{\lambda P_0}{s\mu}\left[\sum_{n=0}^{\infty} \frac{1}{n!}\left(\frac{\lambda}{\mu}\right)^n + \frac{p^2}{s!}\left(\frac{\lambda}{\mu}\right)^{s+1} \frac{\mu}{s\mu - \lambda p}\right]. \tag{3.3}$$

Since $D = A + N$, the loss ratio l is given as

$$l = \frac{N}{D}.$$

Now if the number of servers was just one then the entire number of passengers served throughout a busy time would are $\frac{1}{1-\lambda/\mu} = \frac{\mu}{\mu-\lambda}$, which is well understood. Within the current situation, after we have s - servers, considering $s\mu$ as the typical rate throughout a busy amount, the average potential variety K served during a busy period is given by the average potential number K served during a busy period,

$$K = \frac{1}{1 - \lambda/s\mu} = \frac{s\mu}{s\mu - \lambda}. \tag{3.4}$$

Therefore if we tend to work out the typical loss by L throughout a busy time, then we will have

$$L = lK. \tag{3.5}$$

Let I and T be the lengths of associate in nursing idle and busy time respectively; let T^* be the length of the amount starting with a passenger's advent to the instant once the device first becomes empty. The scheme is clearly either in I or is in T^*. Also, $T^* \geq T$. We tend to have an interest within the proportion of the time the system remains occupied, that given by

$$\frac{E(T)}{E(I)+E(T^*)}.E(I) = \frac{1}{\lambda}. \tag{3.6}$$

It is known that $P_0 = \frac{E(I)}{E(I)+E(T^*)^2}$, and $E(T) = \frac{1}{s\mu-\lambda'}$, Thus we've got

$$\frac{E(T)}{E(I)+E(T^*)} = \frac{\lambda P_0}{s\mu - \lambda}.$$

Using (3.6) we tend to get the common loss of passengers throughout a hard and fast length of time t as $\frac{\lambda P_0 t}{(s\mu-\lambda)}L$, Which by the use of (3.4) and (3.5) becomes

$$\frac{s\lambda\mu t P_0}{(s\mu-\lambda)^2}l.$$

The expression for P_0 and l is given by equation (3.3), respectively. The other name of simulation in general terms is numerical computation, not a single model can distinguish this. The analytical consequences are listed for queueing models demonstrated in Table 2. Here we use multi-server statistics but the calculation is also applied on single server systems as well as multi-server systems. The balking is only measured for finite queue because the balking means after specific queue length passengers will not join the queue, if we can only compute for the finite length for the infinite situation it is not possible. The number of servers helps to reduce the waiting time of the passengers, these factors are numerically analysed by queueing model and analytical consequences are found in Table 2, system performance measure by pie charts through MATLAB and simulation and performance measured through the WinQSB software. The analytical consequences and simulation consequences are almost the same but the single server for an infinite queue are very different because analytical consequences give negative values which indicate the system is not sustainable that's why the simulation result is so far from the analytical consequences because of unsustainable statistics and the maximum passengers in the queue is very highly demonstrated by the simulation calculation. However we increase the servers, the maximum number of passengers in the queue is decreased. This shows the system efficiency for assisting the passengers which also decreases waiting time and queue length. Based on these analytical and simulation calculations consequences are represented by pie charts by using MATLAB and WinQSB.

TABLE 1. Queueing Models

	Model-I [(M/M/I): (∞/FCFS)]	**Model-II: [(M/M/I): (N/FCFS)]**	**Model-III: [(M/M/s): (∞/FCFS)]**	**Model-IV: [(M/M/s): (N/FCFS)]**
ρ	$\frac{\lambda}{\mu}$	$\frac{\lambda}{\mu}$	$\frac{\lambda}{s\mu}$	$\frac{\lambda}{s\mu}$
p_0	$1-\frac{\lambda}{\mu}$	$\frac{1-\rho}{1-\rho^{N+1}}$	$\left[\sum_{n=0}^{s-1}\frac{(s\rho)^n}{n!}+\frac{1}{s!}\frac{(s\rho)^s}{1-\rho}\right]^{-1}$	$\left[\sum_{n=0}^{s-1}\frac{(s\rho)^n}{n!}+\frac{1}{s!}\left(\frac{\lambda}{\mu}\right)^s(N-s+1)\right]^{-1}$
p_n	$\rho^n(1-\rho)$	$\rho^n\left(\frac{1-\rho}{1-\rho^{N+1}}\right)$	$\begin{cases}\frac{\rho^n}{n!}P_0; & 1\leq n<s\\ \frac{\rho^n}{s!s^{n-s}}P_0; & n\geq s;\rho=\lambda/\mu\end{cases}$	$\begin{cases}\frac{1}{n!}\left(\frac{\lambda}{\mu}\right)^n P_0; & n\geq s\\ \frac{1}{s!s^{n-s}}\left(\frac{\lambda}{\mu}\right)^n P_0; & s<n\geq N\\ 0; & n>N\end{cases}$
L_s	$\frac{\rho}{1-\rho}$	$\sum_{n=1}^{N} n\left[\frac{1-\rho}{1-\rho^{N+1}}\right]\rho^n$	$L_q+\frac{\lambda}{\mu}$	$L_q+\frac{\lambda}{\mu}(1-P_N)$
L_q	$\frac{\rho^2}{1-\rho}$	$L_s-\frac{\lambda}{\mu}$	$\left[\frac{1}{(s-1)!}(\frac{\lambda}{\mu})^s\frac{\lambda\mu}{(s\mu-\lambda)^2}\right]P_0$	$\frac{(s\rho)^s\rho}{s!(1-\rho)^2}\left[1-\rho^{N-s+1}-(1-\rho)(N-s+1)\rho^{N-s}\right]P_0$
W_q	$\frac{\rho}{\mu(1-\rho)}$	$W_s-\frac{1}{\mu}$	$\frac{L_q}{\lambda}$	$W_s-\frac{1}{\mu}$
W_s	$\frac{1}{\mu-\lambda}$	$\frac{L_s}{\lambda(1-P_N)}$	$W_q+\frac{1}{\mu}$	$\frac{Ls}{\lambda(1-P_N)}$
P_s	-	$\frac{\rho^k}{k!}e^{-\rho}$	-	$\frac{(\lambda/\mu)^s}{s!\sum_{n=0}^{s}\frac{(\lambda/\mu)^n}{n!}}$

The mean advent rate of passengers = 17, the mean assistance rate of passengers = 16, the number of servers = 5, the number of seats = 44.

TABLE 2. Calculation of numerous performance measures

Model	P_0	L_s	L_q	W_s	W_q	P_s
$(M/M/1)$:$(\infty/FCFS)$	-0.0625	-17	-18.0625	-1	0.066406	-
$(M/M/s)$:$(\infty/FCFS)$,s=2	0.312911	1.489537	0.427037	0.08762	0.025120	-
$s=3$	0.344691	1.12101	0.058510	0.065942	0.03442	-
$s=4$	0.346363	1.071559	0.009059	0.063033	0.000533	-
$s=5$	0.345876	1.063838	0.001338	0.062579	0.000079	-
$(M/M/1)$:$(N/FCFS)$	0.004369	31.142882	30.038038	1.934765	1.872265	0.367190
$(M/M/s)$:$(N/FCFS)$,s=2	0.037974	1.935529	0.051824	0.113855	0.051355	0.214870
$s=3$	0.090718	2.493809	0.009945	0.146695	2.431309	0.070718
$s=4$	0.19980	2.301937	0.003838	0.135408	2.239437	0.018438
$s=5$	0.300181	1.580214	0.001161	0.092954	0.030454	0.003903

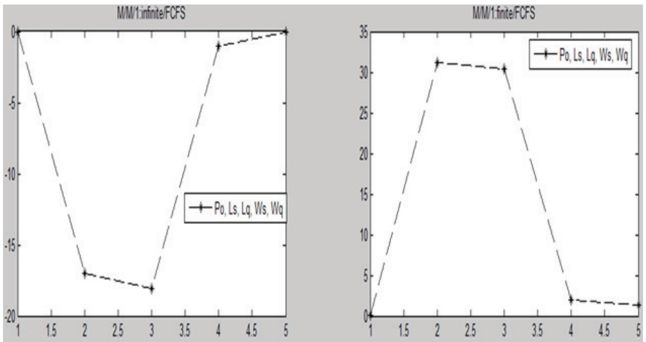

FIGURE 3. Graphical representation of all M/M/1 models

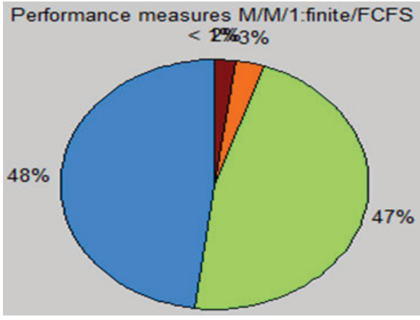

FIGURE 4. Performance measures for M/M/1 model through a pie chart

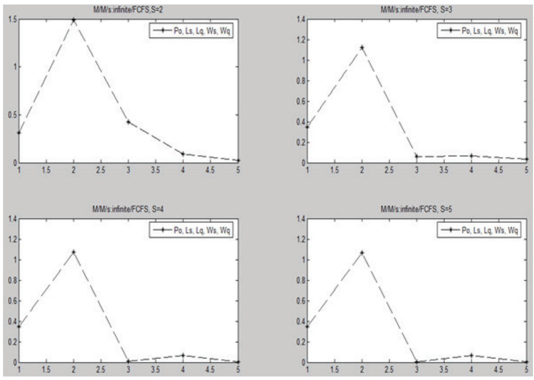

FIGURE 5. Graphical representation of (M/M/s): (∞/FCFS) models for all servers

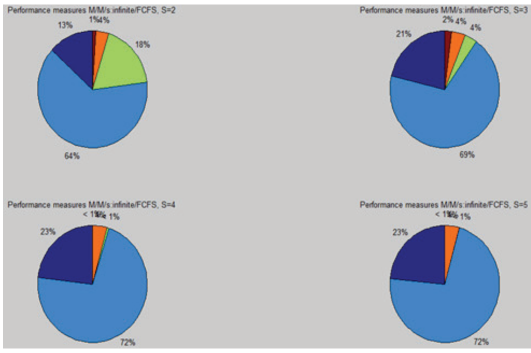

FIGURE 6. Performance measures for (M/M/s): (∞/FCFS) model through the pie chart

4. CONCLUSION

The formation of the advent affair and assistance affair of passengers through the flow chart gives a better understanding of system utilization. From the numerical consequences, we able to see the feasibility towards their parameter of the system like model one single server - the infinite model has all the values with the negative sign which shows the instability of a system and parameters are not feasible. Apart from these all three models single server - finite model, multi-server - infinite model, multi-server – the finite model has all of the values with the positive sign which represents the stability of the system parameters are feasible for all these models. Through the MATLAB and WinQSB software's performance measures are demonstrated by pie charts. Through the output, the consequences of both analytic and simulation are almost the same. The drawback of graphical representation is that it only represents the feasible consequences; the single server - the finite queue is infeasible towards their parameters so it can't be demonstrated through graphical representation.

The study suggests to the AICTSL office that as the number of the server gets increased, the waiting time and queue length as well as balked will get reduced thereby.

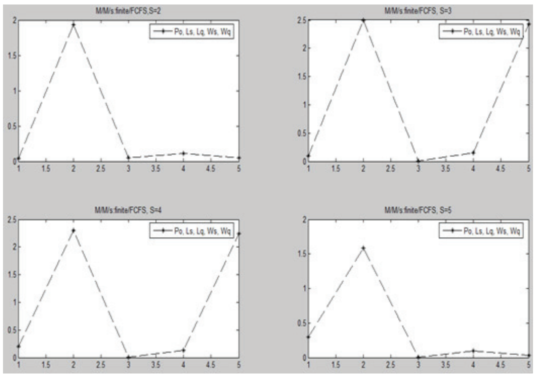

FIGURE 7. Graphical representation of (M/M/s): (N/FCFS) models for all servers

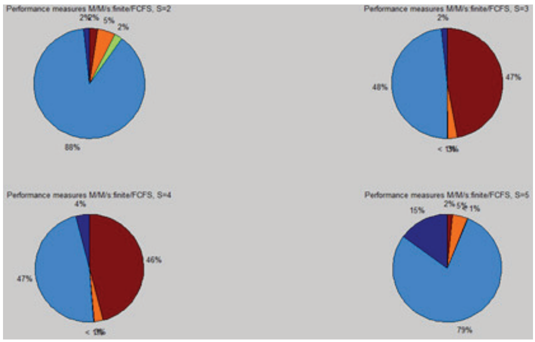

FIGURE 8. Performance measures for (M/M/s): (N/FCFS)

08-21-2018	Performance Measure	Result
1	System: M/M/1	From Simulation
2	Customer arrival rate (lambda) per hour =	17.0000
3	Service rate per server (mu) per hour =	16.0000
4	Overall system effective arrival rate per hour =	16.9514
5	Overall system effective service rate per hour =	15.9655
6	Overall system utilization =	99.9962 %
7	Average number of customers in the system (L) =	563.5248
8	Average number of customers in the queue (Lq) =	562.5217
9	Average number of customers in the queue for a busy system (Lb) =	562.5433
10	Average time customer spends in the system (W) =	33.6066 hours
11	Average time customer spends in the queue (Wq) =	33.5440 hours
12	Average time customer spends in the queue for a busy system (Wb) =	33.5452 hours
13	The probability that all servers are idle (Po) =	0.0038 %
14	The probability an arriving customer waits (Pw) or system is busy (Pb) =	99.9962 %
15	Average number of customers being balked per hour =	0
16	Total cost of busy server per hour =	$0
17	Total cost of idle server per hour =	$0
18	Total cost of customer waiting per hour =	$0
19	Total cost of customer being served per hour =	$0
20	Total cost of customer being balked per hour =	$0
21	Total queue space cost per hour =	$0
22	Total system cost per hour =	$0
23	Simulation time in hour =	1000.0000
24	Starting data collection time in hour =	0
25	Number of observations collected =	15966
26	Maximum number of customers in the queue =	988
27	Total simulation CPU time in second =	4.0090

FIGURE 9. Simulation Performance measures using WinQSB for (M/M/1): (∞/FCFS)

09-02-2018	Performance Measure	Result
1	System: M/M/2	From Simulation
2	Customer arrival rate (lambda) per hour =	17.0000
3	Service rate per server (mu) per hour =	16.0000
4	Overall system effective arrival rate per hour =	16.9177
5	Overall system effective service rate per hour =	16.9167
6	Overall system utilization =	52.8808 %
7	Average number of customers in the system (L) =	1.4814
8	Average number of customers in the queue (Lq) =	0.4237
9	Average number of customers in the queue for a busy system (Lb) =	1.1569
10	Average time customer spends in the system (W) =	0.0876 hours
11	Average time customer spends in the queue (Wq) =	0.0250 hours
12	Average time customer spends in the queue for a busy system (Wb) =	0.0684 hours
13	The probability that all servers are idle (Po) =	30.8671 %
14	The probability an arriving customer waits (Pw) or system is busy (Pb) =	36.6287 %
15	Average number of customers being balked per hour =	0
16	Total cost of busy server per hour =	$0
17	Total cost of idle server per hour =	$0
18	Total cost of customer waiting per hour =	$0
19	Total cost of customer being served per hour =	$0
20	Total cost of customer being balked per hour =	$0
21	Total queue space cost per hour =	$0
22	Total system cost per hour =	$0
23	Simulation time in hour =	1000.0000
24	Starting data collection time in hour =	0
25	Number of observations collected =	16917
26	Maximum number of customers in the queue =	12
27	Total simulation CPU time in second =	1.9340

FIGURE 10. Simulation Performance measures using WinQSB for(M/M/2): (∞/FCFS)

09-02-2018	Performance Measure	Result
1	System: M/M/3	From Simulation
2	Customer arrival rate (lambda) per hour =	17.0000
3	Service rate per server (mu) per hour =	16.0000
4	Overall system effective arrival rate per hour =	16.9413
5	Overall system effective service rate per hour =	16.9403
6	Overall system utilization =	35.3582 %
7	Average number of customers in the system (L) =	1.1219
8	Average number of customers in the queue (Lq) =	0.0611
9	Average number of customers in the queue for a busy system (Lb) =	0.5859
10	Average time customer spends in the system (W) =	0.0662 hours
11	Average time customer spends in the queue (Wq) =	0.0036 hours
12	Average time customer spends in the queue for a busy system (Wb) =	0.0346 hours
13	The probability that all servers are idle (Po) =	34.0359 %
14	The probability an arriving customer waits (Pw) or system is busy (Pb) =	10.4367 %
15	Average number of customers being balked per hour =	0
16	Total cost of busy server per hour =	$0
17	Total cost of idle server per hour =	$0
18	Total cost of customer waiting per hour =	$0
19	Total cost of customer being served per hour =	$0
20	Total cost of customer being balked per hour =	$0
21	Total queue space cost per hour =	$0
22	Total system cost per hour =	$0
23	Simulation time in hour =	1000.0000
24	Starting data collection time in hour =	0
25	Number of observations collected =	16944
26	Maximum number of customers in the queue =	10
27	Total simulation CPU time in second =	1.9200

FIGURE 11. Simulation Performance measures using WinQSB for (M/M/3): (∞/FCFS)

09-02-2018	Performance Measure	Result
1	System: M/M/4	From Simulation
2	Customer arrival rate (lambda) per hour =	17.0000
3	Service rate per server (mu) per hour =	16.0000
4	Overall system effective arrival rate per hour =	16.9877
5	Overall system effective service rate per hour =	16.9877
6	Overall system utilization =	26.6817 %
7	Average number of customers in the system (L) =	1.0781
8	Average number of customers in the queue (Lq) =	0.0109
9	Average number of customers in the queue for a busy system (Lb) =	0.3983
10	Average time customer spends in the system (W) =	0.0635 hours
11	Average time customer spends in the queue (Wq) =	0.0006 hours
12	Average time customer spends in the queue for a busy system (Wb) =	0.0234 hours
13	The probability that all servers are idle (Po) =	34.3663 %
14	The probability an arriving customer waits (Pw) or system is busy (Pb) =	2.7274 %
15	Average number of customers being balked per hour =	0
16	Total cost of busy server per hour =	$0
17	Total cost of idle server per hour =	$0
18	Total cost of customer waiting per hour =	$0
19	Total cost of customer being served per hour =	$0
20	Total cost of customer being balked per hour =	$0
21	Total queue space cost per hour =	$0
22	Total system cost per hour =	$0
23	Simulation time in hour =	1000.0000
24	Starting data collection time in hour =	0
25	Number of observations collected =	16990
26	Maximum number of customers in the queue =	5
27	Total simulation CPU time in second =	1.9210

FIGURE 12. Simulation Performance measures using WinQSB for(M/M/4): (∞/FCFS)

08-21-2018	Performance Measure	Result
1	System: M/M/5	From Formula
2	Customer arrival rate (lambda) per hour =	17.0000
3	Service rate per server (mu) per hour =	16.0000
4	Overall system effective arrival rate per hour =	17.0000
5	Overall system effective service rate per hour =	17.0000
6	Overall system utilization =	21.2500 %
7	Average number of customers in the system (L) =	1.0638
8	Average number of customers in the queue (Lq) =	0.0013
9	Average number of customers in the queue for a busy system (Lb) =	0.2698
10	Average time customer spends in the system (W) =	0.0626 hours
11	Average time customer spends in the queue (Wq) =	0.0001 hours
12	Average time customer spends in the queue for a busy system (Wb) =	0.0159 hours
13	The probability that all servers are idle (Po) =	34.5507 %
14	The probability an arriving customer waits (Pw) or system is busy (Pb) =	0.4951 %
15	Average number of customers being balked per hour =	0
16	Total cost of busy server per hour =	$0
17	Total cost of idle server per hour =	$0
18	Total cost of customer waiting per hour =	$0
19	Total cost of customer being served per hour =	$0
20	Total cost of customer being balked per hour =	$0
21	Total queue space cost per hour =	$0
22	Total system cost per hour =	$0

FIGURE 13. Simulation Performance measures using WinQSB for (M/M/5): (∞/FCFS)

08-21-2018	Performance Measure	Result
1	System: M/M/1	From Simulation
2	Customer arrival rate (lambda) per hour =	17.0000
3	Service rate per server (mu) per hour =	16.0000
4	Overall system effective arrival rate per hour =	8.2254
5	Overall system effective service rate per hour =	8.2244
6	Overall system utilization =	52.0087 %
7	Average number of customers in the system (L) =	0.5201
8	Average number of customers in the queue (Lq) =	0
9	Average number of customers in the queue for a busy system (Lb) =	0
10	Average time customer spends in the system (W) =	0.0632 hours
11	Average time customer spends in the queue (Wq) =	0 hour
12	Average time customer spends in the queue for a busy system (Wb) =	0 hour
13	The probability that all servers are idle (Po) =	47.9913 %
14	The probability an arriving customer waits (Pw) or system is busy (Pb) =	52.0087 %
15	Average number of customers being balked per hour =	8.7434
16	Total cost of busy server per hour =	$0
17	Total cost of idle server per hour =	$0
18	Total cost of customer waiting per hour =	$0
19	Total cost of customer being served per hour =	$0
20	Total cost of customer being balked per hour =	$0
21	Total queue space cost per hour =	$0
22	Total system cost per hour =	$0
23	Simulation time in hour =	1000.0000
24	Starting data collection time in hour =	0
25	Number of observations collected =	8225
26	Maximum number of customers in the queue =	0
27	Total simulation CPU time in second =	2.9640

FIGURE 14. Simulation Performance measures using WinQSB for(M/M/1): (N/FCFS)

09-02-2018	Performance Measure	Result
1	System: M/M/2	From Simulation
2	Customer arrival rate (lambda) per hour =	17.0000
3	Service rate per server (mu) per hour =	16.0000
4	Overall system effective arrival rate per hour =	13.2650
5	Overall system effective service rate per hour =	13.2640
6	Overall system utilization =	41.5991 %
7	Average number of customers in the system (L) =	0.8320
8	Average number of customers in the queue (Lq) =	0
9	Average number of customers in the queue for a busy system (Lb) =	0
10	Average time customer spends in the system (W) =	0.0627 hours
11	Average time customer spends in the queue (Wq) =	0 hour
12	Average time customer spends in the queue for a busy system (Wb) =	0 hour
13	The probability that all servers are idle (Po) =	38.0220 %
14	The probability an arriving customer waits (Pw) or system is busy (Pb) =	21.2203 %
15	Average number of customers being balked per hour =	3.6460
16	Total cost of busy server per hour =	$0
17	Total cost of idle server per hour =	$0
18	Total cost of customer waiting per hour =	$0
19	Total cost of customer being served per hour =	$0
20	Total cost of customer being balked per hour =	$0
21	Total queue space cost per hour =	$0
22	Total system cost per hour =	$0
23	Simulation time in hour =	1000.0000
24	Starting data collection time in hour =	0
25	Number of observations collected =	13264
26	Maximum number of customers in the queue =	0
27	Total simulation CPU time in second =	1.7160

FIGURE 15. Simulation Performance measures using WinQSB for (M/M/2): (N/FCFS)

09-02-2018	Performance Measure	Result
1	System: M/M/3	From Simulation
2	Customer arrival rate (lambda) per hour =	17.0000
3	Service rate per server (mu) per hour =	16.0000
4	Overall system effective arrival rate per hour =	15.7017
5	Overall system effective service rate per hour =	15.7007
6	Overall system utilization =	32.7153 %
7	Average number of customers in the system (L) =	0.9815
8	Average number of customers in the queue (Lq) =	0
9	Average number of customers in the queue for a busy system (Lb) =	0
10	Average time customer spends in the system (W) =	0.0625 hours
11	Average time customer spends in the queue (Wq) =	0 hour
12	Average time customer spends in the queue for a busy system (Wb) =	0 hour
13	The probability that all servers are idle (Po) =	35.6018 %
14	The probability an arriving customer waits (Pw) or system is busy (Pb) =	6.9866 %
15	Average number of customers being balked per hour =	1.2350
16	Total cost of busy server per hour =	$0
17	Total cost of idle server per hour =	$0
18	Total cost of customer waiting per hour =	$0
19	Total cost of customer being served per hour =	$0
20	Total cost of customer being balked per hour =	$0
21	Total queue space cost per hour =	$0
22	Total system cost per hour =	$0
23	Simulation time in hour =	1000.0000
24	Starting data collection time in hour =	0
25	Number of observations collected =	15701
26	Maximum number of customers in the queue =	0
27	Total simulation CPU time in second =	1.8270

FIGURE 16. Simulation Performance measures using WinQSB for(M/M/3): (N/FCFS)

09-02-2018	Performance Measure	Result
1	System: M/M/4	From Simulation
2	Customer arrival rate (lambda) per hour =	17.0000
3	Service rate per server (mu) per hour =	16.0000
4	Overall system effective arrival rate per hour =	16.7274
5	Overall system effective service rate per hour =	16.7254
6	Overall system utilization =	26.3603 %
7	Average number of customers in the system (L) =	1.0544
8	Average number of customers in the queue (Lq) =	0
9	Average number of customers in the queue for a busy system (Lb) =	0
10	Average time customer spends in the system (W) =	0.0630 hours
11	Average time customer spends in the queue (Wq) =	0 hour
12	Average time customer spends in the queue for a busy system (Wb) =	0 hour
13	The probability that all servers are idle (Po) =	33.9804 %
14	The probability an arriving customer waits (Pw) or system is busy (Pb) =	1.9605 %
15	Average number of customers being balked per hour =	0.3260
16	Total cost of busy server per hour =	$0
17	Total cost of idle server per hour =	$0
18	Total cost of customer waiting per hour =	$0
19	Total cost of customer being served per hour =	$0
20	Total cost of customer being balked per hour =	$0
21	Total queue space cost per hour =	$0
22	Total system cost per hour =	$0
23	Simulation time in hour =	1000.0000
24	Starting data collection time in hour =	0
25	Number of observations collected =	16726
26	Maximum number of customers in the queue =	0
27	Total simulation CPU time in second =	1.8840

FIGURE 17. Simulation Performance measures using WinQSB for (M/M/4): (N/FCFS)

08-21-2018	Performance Measure	Result
1	System: M/M/5	From Simulation
2	Customer arrival rate (lambda) per hour =	17.0000
3	Service rate per server (mu) per hour =	16.0000
4	Overall system effective arrival rate per hour =	16.9004
5	Overall system effective service rate per hour =	16.8994
6	Overall system utilization =	21.2204 %
7	Average number of customers in the system (L) =	1.0610
8	Average number of customers in the queue (Lq) =	0
9	Average number of customers in the queue for a busy system (Lb) =	0
10	Average time customer spends in the system (W) =	0.0628 hours
11	Average time customer spends in the queue (Wq) =	0 hour
12	Average time customer spends in the queue for a busy system (Wb) =	0 hour
13	The probability that all servers are idle (Po) =	34.4834 %
14	The probability an arriving customer waits (Pw) or system is busy (Pb) =	0.4241 %
15	Average number of customers being balked per hour =	0.0860
16	Total cost of busy server per hour =	$0
17	Total cost of idle server per hour =	$0
18	Total cost of customer waiting per hour =	$0
19	Total cost of customer being served per hour =	$0
20	Total cost of customer being balked per hour =	$0
21	Total queue space cost per hour =	$0
22	Total system cost per hour =	$0
23	Simulation time in hour =	1000.0000
24	Starting data collection time in hour =	0
25	Number of observations collected =	16901
26	Maximum number of customers in the queue =	0
27	Total simulation CPU time in second =	3.9160

FIGURE 18. Simulation Performance measures using WinQSB for(M/M/5): (N/FCFS)

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