

SALE CHECKOUT OPERATION IN BIG BAZAAR USING QUEUING MODEL

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ABSTRACT

This paper deals with analysis of queueing model for Big Bazaar checkout operations. Multiple queues with multiple servers model is employed to examine the checkout operation of service unit (cash counter) for Big Bazaar. We analyze the efficiency of the model in terms of utilization and waiting length of queue. So that we can able to estimate the waiting time and waiting length of queues for validating our analysis. We have been also carried out various performance measures.

Keywords: Queue Models, Multiple servers, Optimal service, Quality of service and Total Cost.

1. INTRODUCTION

Big Bazaar is a corporate group in the retail business more than 1700 stores is operated. These stores have different profits depending on location, range of products and size. Big Bazaar stores are categorized as

- (i) Convenience type stores for daily retail needs,
- (ii) Mid-size supermarkets, located near residential blocks and carrying a wide range of products,
- (iii) Super stores which handle the big crowd. Having large and planned stores where display of the products to attract the attention of the customer to each and every product,
- (iv) Max/ Big Bazaar ensuring availability of quality full range of groceries as well as fashions, home wares, entertainment and home appliances along with electrical /electronics items which does not offers by small stores.

Today customers don't have more time to spend in shopping. Customers require all items/ products at one place. Such demands of customer uplift/grow the business of big departmental stores like Big Bazaar to sell their products more efficiently and effectively. Generally, we have seen three or four checkout counters in one place. We analyze the performance of checking out service time (service rate) during the checking out process and identify the time gap between two or more customers. Researchers have identified such issues and developed new models to achieve quality of service for customers.

Berhan [1] analyzed the performance of multiple server queue. Azmat [2] improved performance of service industries where arrival and service time are random for complex decision environment. Toshiba [3] established the optimization model of queueing system and calculate the optimal model of queueing, optimal number of service stations to improve operational efficiency and optimal service rate and service efficiency by the operating costs. Chowdhury [4] describe several common queueing situations and present mathematical models for analyzing waiting lines for the bank system to measure customer's satisfaction level on the service using multi-channel queueing model with Poisson arrival and Exponential service times. Famul and Bhatwala [5, 7] described a single server that has unlimited queue capacity with both service and arrival rate follow a Poisson distribution. Wang [6] present various queueing model to analyses the performance of service industries. Holman *et al.* [8] established the batch arrival general service queueing model. Zhang [9] analyzed the service sector of queueing system. Zhao [10] gave innovative bank management through queueing theory. Li [11] determined the optimal design of service in supermarket. Kumar *et al.* [12] proposed various performance indices for multi server model.

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This paper is organized as follows. In section 2, described notations and queuing model. Performance measures corresponding customers and service unit is in section 3. Numerical illustrations for comparing the analytical results are provided in section 4. In section 5, Quality of service and optimal service rate is obtained with each service unit (cash counter). Finally in section 6 we draw the conclusion.

2. MODEL DESCRIPTION

1.1 Notations

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

k = Number of parallel servers (Checkout operation units in Bi Bazaar)

λ = Arrival rate per unit of time

μ = Service rate per unit of time

S = Number of Servers (Cash Counter)

$S\mu$ = Serving rate when $S > 1$ in a system

P_n = Steady-state probability of exactly n customers in the system

ρ = The utilization factor ($= \lambda/(S\mu)$) (the expected factor of time the server is busy that is, service capability being utilized on the average arriving customers)

2.2 Queuing System: customers requiring service are generated over time by an input source. This service mechanism is described in three ways:

- Single queue with single server model
- Single queue with multiple server model
- Multiple queue with multiple server model

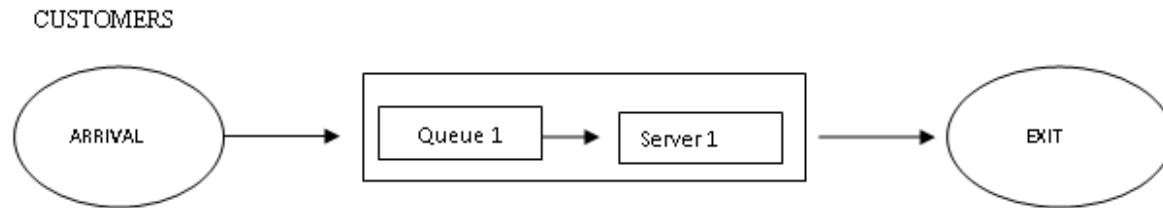


Figure-1: Queuing Model for Single-Queue with Single Server

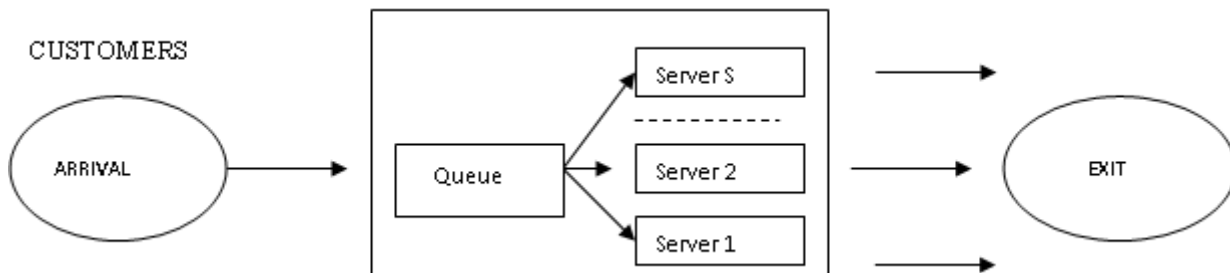


Figure-2: Queuing Model for Single-Queue with Multiple Parallel Servers

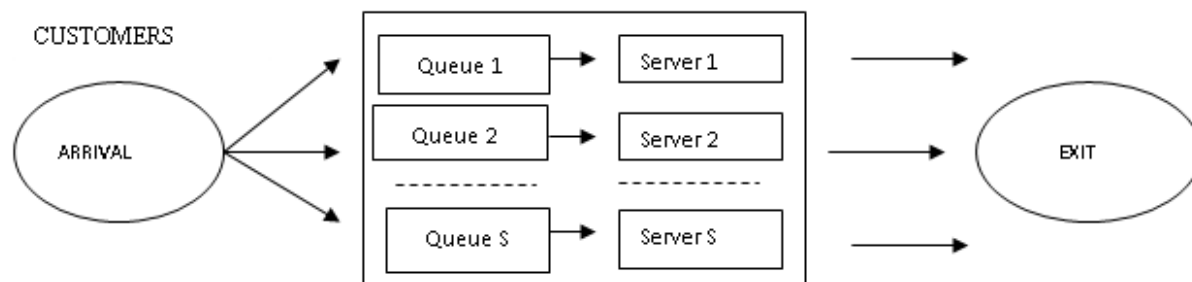


Figure-3: Queuing Model for Multi Queues with Multiple Parallel Servers

The single queue, multi queue and multi queue with multi servers are illustrated in figures 1, 2 & 3. The following three situations are examined in this paper.

We discussed queueing model with multiple servers, which follow a Poisson probability distribution at an average rate λ customer per unit of time and are served on a first served basis by any of the servers. The service times are distributed exponentially with an average of μ customers per unit of time. It is further assumed that only one queue is formed. If there are n customers in the queueing system at point in time, then following two cases may arise:

- i. If $n < S$ (number of customers in the system is less than the number of servers) then there will be no. queue. However, $(S - n)$ number of servers are not busy, The combined service rate will then be: $\mu_n = n\mu$; $n < S$
- ii. If $n \geq S$, (number of customers in the system is more than or equal to the number of servers) then all servers will be busy and the maximum number of customers in the queue will be $(n - S)$.

The combined service rate will be: $\mu_n = S\mu$; $n \geq S$

Thus to derive the result for this model, we have

$$\lambda_n = \lambda \text{ for all } n \geq 0 \quad \text{and} \quad \mu_n = \begin{cases} n\mu; & n < S \\ \mu_n = S\mu; & n \geq S \end{cases}$$

The probability P_n of n customers in the queueing system is given by

$$P_n = \begin{cases} \frac{\rho^n}{n!} P_0; & n \leq s \\ \frac{\rho^n}{s! s^{n-s}} P_0; & n > s \end{cases} \quad \text{and} \quad \rho = \frac{\lambda}{S\mu}$$

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

3. PERFORMANCE MEASURES

Results	Mathematical Formulae
Utilization / Efficiency	$\rho = \frac{\lambda}{S\mu}$
Average number of customers in the queue (L _q)	$L_q = \left[\frac{1}{(s-1)!} \left(\frac{\lambda}{\mu} \right)^s \frac{\lambda\mu}{(s\mu - \lambda)^2} \right] \times P_0$
Average number of customers in the system (L _s)	$L_s = L_q + \frac{\lambda}{\mu}$
Average waiting time in the queue (W _q)	$W_q = \frac{L_q}{\lambda}$
Average time in the system (W _s)	$W_s = W_q + \frac{1}{\mu}$
Expected Total Cost single (TCS) and multi queues (TCM)	$E(TCS) = SC_s + L_s C_w$
	$E(TCM) = S(C_s + L_s C_w)$

3.1 Expected total cost for multi-servers queue model

In this section, we analysis expected total cost service to customers with different service level is the function of two conflicting costs:

1. Cost of offering the service to customers
2. Cost of delay in offering the service to customers

Economic analysis of these costs helps the management to make a trade-off between the increased costs of providing better service and the decreased waiting time costs of customers derived from providing that service.

- **Expected service cost $E(SC) = s C_s$.**
where s is number of service units (cash counters) and C_s is service cost of each server
- **Expected waiting cost in the system $E(WC) = L_s C_w$.**

where L_s is the expected number of customers in the system waiting time with being served and C_w is cost of waiting by customer.

The Expected total cost in the case single queue with multi servers model $E(TC) = E(SC) + E(WC)$, $E(TCS) = sC_s + L_s C_w$ and multi queue with multi servers model $E(TCM) = s(Cs + Ls C_w)$.

4. NUMERICAL ILLUSTRATION

We taking the $\lambda=350$, $\mu=205$ & $S = 2, 3, 4, 5$ & 6 and obtained utilization, steady-state probability, average number of customers in the queue (L_q), average number of customers in the system (L_s), average waiting time in the queue (W_q) and average time in the system (W_s) according to single and multi queues with different service unit (Cash counter). In this we will use multi-server queueing model to find expected total cost and also assuming that service cost is Rs.400 and waiting cost is Rs. 550 in each case.

Various performance measures have been obtained and analyzed by varying different parameters. The results have been analyzed from table 1 to 4.

Case-1: Single queue with five servers

Table-1

Performance Measures	Single Queue system with No. of Service Units				
	2	3	4	5	6
Utilization (ρ)	0.8537	0.5691	0.4268	0.3415	0.2846
Values of Steady-State Prob. (P_0)	0.2399	0.2002	0.187	0.1828	0.1817
L_q	13.9375	0.5089	0.086	0.0174	.0035
L_s	15.6448	2.2162	1.7933	1.7247	1.7108
W_s	0.0398	0.0015	2.46E-04	4.97E-05	9.927E-006
W_q	0.0447	0.0063	0.0051	0.0049	0.0049

Case-II: Two queues with five or more servers

Table-2

Performance Measures	Multi Queue (Two Lines) system with No. of Service Units				
	2	3	4	5	6
Utilization	0.4268	0.2846	0.2134	0.1707	0.1423
Values of Steady-State Prob. (P_0)	0.4507	0.4307	0.4266	0.426	0.4259
L_q	0.2133	0.0248	0.0033	4.00E-04	4.4268E-007
L_s	1.067	0.8785	0.8569	0.8541	0.8537
W_q	0.0012	1.42E-04	1.86E-05	2.28E-06	2.5296E-06
W_s	0.0061	0.005	0.0049	0.0049	0.0049

Case-III: Three queues with five or more servers

Table-3

Performance Measures	Multi Queue system (Three Lines) with No. of Service Units				
	2	3	4	5	6
Utilization	0.2846	0.1897	0.1423	0.1138	0.0949
Values of Steady-State Prob. (P_0)	0.4507	0.5676	0.5662	0.566	0.566
L_q	0.0913	0.005	4.79E-04	4.08E-05	3.09E-06
L_s	0.9449	0.5741	0.5696	0.5691	0.5691
W_q	7.82E-04	4.32E-05	4.10E-06	3.50E-07	2.65E-08
W_s	0.0057	0.0049	0.0049	0.0049	0.0049

Case-IV: Four queues with five or more servers

Table-4

Performance Measures	Multi Queue system (Four Lines)with No. of Service Units				
	2	3	4	5	6
Utilization	0.2134	0.1423	0.1067	0.0854	0.0711
Values of Steady-State Prob. (P0)	0.6587	0.6532	0.6526	0.6526	0.6526
Lq	0.0207	0.0016	1.21E-04	7.86E-06	4.52E-07
Ls	0.4475	0.4285	0.4269	0.4268	0.4268
Wq	2.37E-04	1.87E-05	1.38E-06	8.98E-08	5.16E-09
Ws	0.0051	0.0049	0.0049	0.0049	0.0049

Table-5: Expected total cost (Rs.) for multi-servers with different queues

		Number of Servers				
Number of Queues		S= 2	S= 3	S= 4	S= 5	S= 6
Single Queue		18004	4846	5538	6730	8043
Multi- Queues	Two	1973	2649	3485	4348	5217
	Three	900	2147	2853	4348	4278
	Four	1292	1907	2539	3173	3808

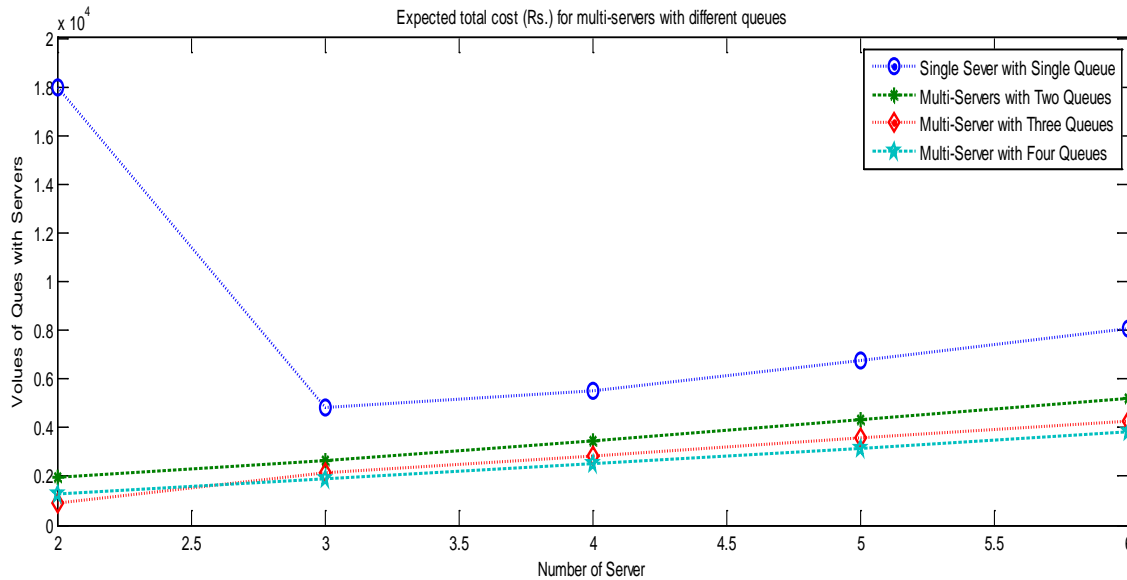


Figure-4: Expected total cost (Rs.) for multi-servers with different queues

5. QUALITY OF SERVICE (QoS)

In order to provide the quality of service, we have the number of service counters with size of customers in queue for the service. Erlang's C formula is used to analyzed quality of service to customers at the rate of $\lambda = 350$, each service counter rate of $\mu = 205$. The QoS corresponding to multiple cash counter is mentioned in table 5, 6 & 7.

$$C(S, \rho) = \frac{(S\rho)^S}{S!(1-\rho)} \times P_0, \quad S = 2, 3, 4, \dots$$

Table -5

No. of Server	Utilization (ρ)	Value of (P ₀)	Quality of Service C(S, ρ)
2	0.4268	0.4507	0.418737
3	0.2846	0.4307	0.06241
4	0.2134	0.4266	0.012
5	0.1707	0.426	0.001941
6	0.1423	0.1817	0.00026687

Table -6

No. of Server	Utilization (ρ)	Value of (P ₀)	Quality of Service C(S, ρ)
2	0.2846	0.4507	0.13073
3	0.1897	0.5676	0.02152
4	0.1423	0.5662	0.00289
5	0.1138	0.566	0.000318
6	0.0949	0.566	2.22E-05

Table -7

No. of Server	Utilization (ρ)	Value of (P ₀)	Quality of Service C(S, ρ)
2	0.2134	0.6587	0.07628
3	0.1423	0.6532	0.00987
4	0.1067	0.6526	0.00101
5	0.0854	0.6526	8.42E-05
6	0.0711	0.6526	5.90E-06

5.1 Optimal Service Rate (OSR)

Optimal service rate is associated with QoS. We analyzed the better optimal service rate in table 8 & 9. Consequently, we get best service outcome when six servers are used with four queues.

$$C(S, \rho) = \sum_{n=s}^{\infty} \rho_n \times P_0 \times 100$$

Table – 8: (Corresponding cases I, II, III & VI)

No. of Servers	S=2	S=3	S=4	S=5	S=6
Case I	448.83%	82.90%	26.35%	7.81%	2.04%
Case II	41.87%	6.24%	1.20%	0.19%	0.03%
Case III	13.07%	2.15%	0.29%	0.03%	0.00%
Case IV	6.69%	0.99%	0.10%	0.01%	0.00%

For customers to arrive at the rate of $\lambda = 350$, each service counter rate of $\mu = 205$, if we need customers need to line near 1% how many service counters should be set up.

Table – 9: (The Probability of Queueing System)

Number of Service Unit (cash counter)	2	3	4	5	6
One Line	448.83%	82.90%	26.35%	7.81%	2.04%
Two Lines	41.87%	6.24%	1.20%	0.19%	0.026687%
Three Lines	13.07%	2.15%	0.28%	0.031%	0.00222013%
Four Line	6.68%	0.98%	0.10%	0.008%	0.00059003%

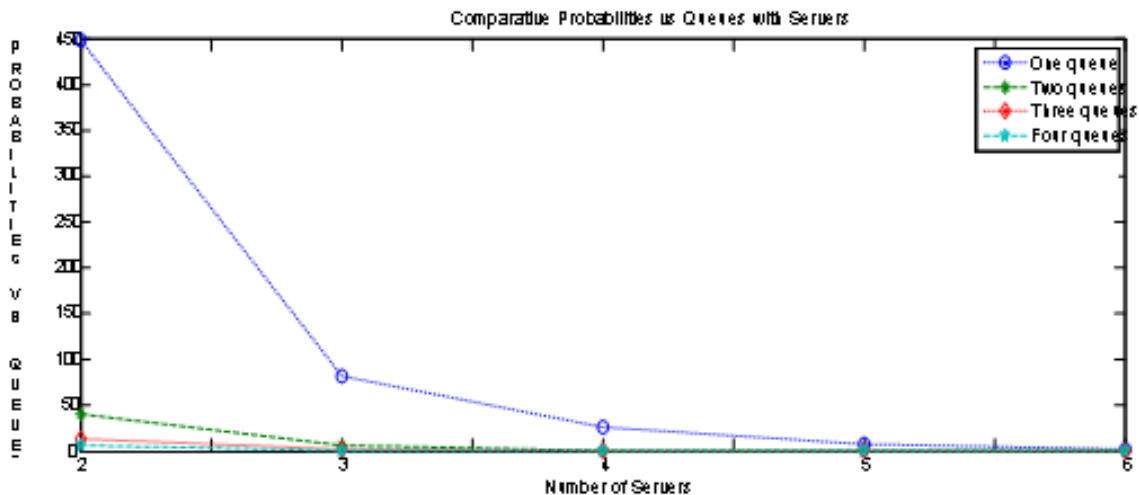


Figure-4: Comparative Probabilities vs Different Queue with Multiple Servers

6. CONCLUSION

In the present investigation, multiple checkout counters were used in order to improve the quality of service and optimal service rate. We also suggest the information of variety of items should be well displayed and accessible without much wastage of their time for searching and retrieval. We validate our model by obtaining the various performances measures, viz queue length and waiting time along with QoS. Our study can be helpful to reducing the queue size and system designer for achieving the best QoS.

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