ISSN: 2321-7782 (Online)
e-ISJN: A4372-3114
Impact Factor: 7.327

Volume 6, Issue 2, February 2018
International Journal of Advance Research in
Computer Science and Management Studies
Research Article / Survey Paper / Case Study
Available online at: www.ijarcsms.com

Queueing Model in Shopping Malls

Pipul Kumar Jha[1]
Operations Management
Symbiosis Institute of Management Studies
Pune – India

M K Gandhi[2]
Operations Management
Symbiosis Institute of Management Studies
Pune – India

Abstract: With the increasing influence of e-tailing and with the fast-moving world, waiting in the queue is considered as the ultimate wastage of time and the customer is no more tolerant to wait for billing in queues. This paper deals with an objective to provide understanding towards the similar problem through application of the concepts of probabilistic queueing models on waiting lines in malls in order to find out the impact of queueing model on the value gained by the customer and also to see the impact of location of malls and time of visit on the waiting time in the queue.

This paper shows a real-life implementation of queueing model to understand how it can help to look at the hidden costs of business. For this study we have taken 3 malls with their respective Average waiting time in queue coming out to be 0.11 hours in case of Central – Noida-Garden Galleria, 0.10 hours in case of Central-New Delhi-World Mark and 0.09 hours in case of Central Mall Rohini and the Average tolerance levels of the customer for waiting time at three malls came out to be 0.11 hours for Central – Noida-Garden Galleria, 0.12 hours for Central-New Delhi-World Mark, 0.1167 hours for Central Mall Rohini.

This helped us to quantify the probability of the three malls to lose a customer standing in the queue for whom the tolerance level is lower than the average waiting time in the queue.

Keywords: Queueing model; Poisson distribution; waiting time; service time; Hypothesis testing; utilization factor.

I. Introduction

Waiting lines are a part of everyday life in any country. Queues can be observed at different shopping centers, grocery stores, petrol bunks, government offices, banks, ATMs, manufacturing plants etc. and the more we have to wait for the service the less is our satisfaction (since we lose the value gained) from the whole process.

With upcoming technological advancements like IOT and AI in the field of e-tailing, the companies like Amazon and Alibaba are gaining more edge upon the offline retailers. One benefit which bricks and mortar stores have over the online retailers is that they provide the physical touch to the customer before buying anything but with technological advancements in future the customer would appreciate the benefits of online shopping and thus the offline retailers need to understand that how the waiting time is influencing its customers and what are the independent factors which affect the offline store queue length and waiting time.

II. Literature Review

Unlike a manufactured product, where quality can readily be assessed, service quality is an elusive and abstract concept that is difficult to define and measure (Markanday, 2011). According to Taylor (1994), waiting for service is "the time from which a customer is ready to receive the service until the time the service commences". Waiting time is often regarded as a waste of time (Leclerc, Schmitt, and dube 1995) and has been described by researchers as boring, frustrating, and irritating (Hui and Tse 1996;

Katz et al. 1991). Queuing theory came into existence in the early 1900s with a work of A. K. Erlang of the Copenhagen Telephone Company, who derived several important formulas for telephone traffic engineering. He was the first who treated congestion problems caused by telephone calls where the company requested him to work on the holding times in a telephone switch. He identified that the number of telephone conversations and telephone holding time fit into Poisson distribution and exponentially distributed. This was the beginning of the study of queuing theory.

These problems also arise in more technical environments in manufacturing where they play an important role for business process re-engineering purposes in administrative tasks. "Queuing models provide the analyst with a powerful tool for designing and evaluating the performance of queuing systems." (Bank, Carson, Nelson & Nicol, 2001)

Queuing theory is still widely used in solving network problems namely "The Monitoring of The Network Traffic Based on Queuing Theory" (Palash Sahoo, May 2011). Opara-Nadi (2005) insisted that customers want fast checkout systems and retailers are always searching for ways to improve store checkout systems. To begin the study used a pilot project with 10 shoppers. The study compared the cashier checkout and the electronic self-checkout systems. Results of these analyses showed that consumers preferred the cashier checkout system to the electronic self-checkout system, although shoppers also want to learn how to use the new self-checkout technology. The efficiency of waiting systems is one of the factors that influence student's or client's perceptions of service quality. The waiting time problem is inevitable in cases of random requests thus, providing the capacity for a sufficient service is needed, but it is involving high costs. "This is the premise from which the queuing theory starts in designing service systems." (Alecu, F, 2004).

Kandemir-Cavas and Cavas, (2007) carried out a study stressing queues form when the demand for a service exceeds its supply, for many patients or clients, "waiting in queues for a service is annoying" (Obamiro, 2003) or is a "negative experience" (Scotland, 1991). From the perspective of a business, waiting lines are damaging the business and have become an important issue for marketing. Even though many companies have tried to manage the consumer waiting time through various strategies (e.g., increase of frontline employees, installing tv near waiting area, news updates etc. are used as fillers) (Kumar, Kalwani, and Dada 1997), still consumer waiting is an unresolved issue. Consequently, more efforts are required to be made to understand the waiting process and reduce the negative impacts of this on consumer's evaluation of the business process (Kostecki 1996).

III. Problem Statement

From this paper what I have tried to show is whether the waiting time in queue is dependent upon two major factors like location and time of shopping and also how it affects the values gained by the customer.

IV. Objective

- To find out the dependency of waiting time at billing counter on location and time of malls
- To study the impact of queue on values gained by the customer and how it could impact the sales

V. Scope

- This research is confined to the queueing models in shopping malls with a single server and FCFS system.

VI. Methodology

- Sources of Data: Primary research, Convenient sampling
- 3 malls*7 days*5 times a day = 90 samples
- Customer samples from 30 customers to study customers' tolerance for waiting time

VII. Limitations of the Study

- The average service rate is calculated from the reciprocal of service time and thus not necessarily be constant for the whole day and thus there will be changes in the service rate from time to time.
- Since the primary data is calculated from prime locations of NCR and there is not much difference in the type of mall (all three are Central malls) the total sales are almost similar.
- The survey data was collected in evening at different time frames when the malls were already crowded
- The customer data can be biased due to customer experience and their mood.
- The arrival rate and service time are assumed to be Poisson and exponentially distributed respectively and the actual case can differ from this assumption.

The data is collected through convenient sampling which can result into biases and thus this data undermines the ability of our research for generalization of the population.

VIII. Queuing Theory and Model Formulation

Queueing Theory is basically a formal study of waiting time in queue and is a well-known discipline of operations management. It uses mathematical modeling to represent the various types of queueing systems. Each model has its own formulas which help to evaluate the performance of a queueing in a given system.

Terminology and Notations:

The following terminologies and notations are used in the model formulation and calculations:

Ls = Number of customers in the system

Lq = Number of customers in the queue

Ws = Waiting time of customer in the system

Wq = Waiting time of customer in the queue

Pn = Probability of exactly n customers in the system

λ = The mean arrival rate (expected number of customers per unit time) of new customers in the system

μ = The mean service rate (expected number of customers being served per unit time) when there are n customers in the system

$\rho = \lambda/\mu$ i.e., utilization factor

The model which is used in this paper is M/M/1: FIFO/∞/ ∞ (Kendall's notation) which means:

- The arrival rate and service time are following memoryless property or Markovian property.
- The arrival rate λ is in Poisson distribution
- Service times are exponentially distributed with mean service rate μ and mean service time of $1/\mu$
- System consists of a single server
- Service discipline is FIFO (first in first out)
- The first ∞ represents the queue length can be of infinite length
- The second ∞ represents the population size from where the customers are coming to the mall.

However, in real life, the population is not infinite but since it is too large we can make this assumption and similarly, we make the same assumption for queue length capacity.

Poisson and exponential probability distributions are directly related to each other. If the number of arrivals follows a Poisson distribution, it turns out that the time between successive arrivals follows an exponential distribution.

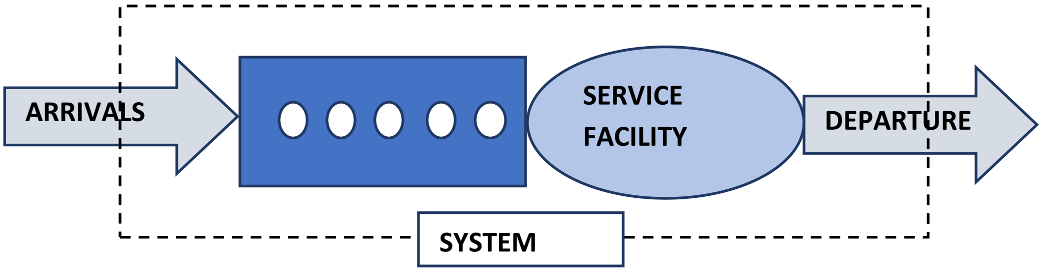

Fig.1 Typical single server queueing model

Here we have some formulae for the probabilistic queueing model (M/M/1: FIFO/∞/ ∞):

- Probability that the system is busy, ρ = λ/μ
- Probability that the system is idle, P0 = 1-ρ
- Probability that there are exactly 'n' customers in the system, P(n) = ρn(1-ρ)
- Probability that there are more than 'n' customers in the system, P(>n) = ρn+1
- Expected number of customers in the system, Ls = ρ/(1-ρ) or λ/(μ-λ)
- Expected number of customers in the queue, Lq = ρ2/(1-ρ) or λ2/μ(μ-λ)
- Expected length of non-empty queues i.e. at least one customer, Lq'=1/(1-ρ) or μ/(μ- λ)
- Expected waiting time for a customer in the system, Ws=1/(μ- λ)
- Expected waiting time for a customer in the queue, Wq = ρ/(μ-λ) or λ/μ(μ-λ)
- Probability that a customer spends more than 't' units of time in the system, Ws = e-t/Ws
- Probability that a customer spends more than 't' units of time in the queue, Wq = ρ.e-t/Ws

IX. Empirical Data

TABLE I Central Mall – Noida, Garden Galleria

Mall 1 (M/M/1 Queue):			
Single server, Poisson arrival, Exponential service time, FCFS, Infinite population, Unlimited queue length			
Inputs			
	Time	Hour	
	Rate of Arrival (λ)	18.83	Customers per hour
	Rate of Service (μ)	25.42	Customers per hour
Outputs			
	Mean time between arrivals	0.053	Hour
	Mean time per service	0.039333333	Hour
	Traffic intensity	0.740590476	
Summary measures			
	Utilization rate of the server	74.10%	
	Average number of customers in Queue (Lq)	2.114318107	Customers
	Average number of customers in System (Ls)	2.854908584	Customers
	Average time spent waiting in Queue (Wq)	0.112293071	Hour
	Average time spent in System (Ws)	0.151626404	Hour

	Probability of having no customers in the System (P0)	25.90%	(probability of an empty system)
Distribution of number of customers in system			
	n (customers)	Probability (n in system)	
	4 customers	0.078037	
Distribution of time in queue			
	t (time in queue)	Probability (waiting time > t)	
	0.11 hour	0.358519	

TABLE II Central – New Delhi, World Mark

Mall 2 (M/M/1 Queue):			
Single server, Poisson arrival, Exponential service time, FCFS, Infinite population, Unlimited queue length			
Inputs			
	Time	Hour	
	Rate of Arrival (λ)	18.51	Customers per hour
	Rate of Service (μ)	25.36	Customers per hour
Outputs			
	Mean time between arrivals	0.054	Hour
	Mean time per service	0.039428571	Hour
	Traffic intensity	0.729991837	
Summary measures			
	Utilization rate of the server	73.0%	
	Average number of customers in Queue (Lq)	1.973599891	Customers
	Average number of customers in System (Ls)	2.703591728	Customers
	Average time spent waiting in Queue (Wq)	0.10659876	Hour
	Average time spent in System (Ws)	0.146027331	Hour
	Probability of having no customers in the System (P0)	27.0%	(probability of an empty system)
Distribution of number of customers in system			
	n (customers)	Probability (n in system)	
	4 customers	0.076674	
Distribution of time in queue			
	t (time in queue)	Probability (waiting time > t)	
	0.11 hour	0.320945	

TABLE III Central Mall – Rohini, Sector-10

Mall 2 (M/M/1 Queue):			
Single server, Poisson arrival, Exponential service time, FCFS, Infinite population, Unlimited queue length			
Inputs			
	Time	Hour	
	Rate of Arrival (λ)	17.94	Customers per hour
	Rate of Service (μ)	25.45	Customers per hour
Outputs			
	Mean time between arrivals	0.056	Hour

	Mean time per service	0.039285714	Hour
	Traffic intensity	0.704897959	
Summary measures			
	Utilization rate of the server	70.5%	
	Average number of customers in Queue (Lq)	1.683760409	Customers
	Average number of customers in System (Ls)	2.388658368	Customers
	Average time spent waiting in Queue (Wq)	0.09384015	Hour
	Average time spent in System (Ws)	0.133125864	Hour
	Probability of having no customers in the System (P0)	29.5%	(probability of an empty system)
Distribution of number of customers in system			
	n (customers)	Probability (n in system)	
	4 customers	0.072858	
Distribution of time in queue			
	t (time in queue)	Probability (waiting time > t)	
	0.11 hour	0.292711	

X. Hypothesis for Testing

H_0 (Null Hypothesis): Waiting time in queue independent of the location of the mall.

H_1 (Alternate Hypothesis): Waiting time in queue depends upon the location of the mall.

H_0' (Null Hypothesis): Waiting time in queue independent of time of visit

H_1' (Alternate Hypothesis): Waiting time in queue depends upon time of visit

H_0'' (Null Hypothesis): There is no interaction between the two independent variables (Location of mall and time of visit)

H_1'' (Alternate Hypothesis): There is significant interaction between the two independent variables (Location of mall and time of visit)

For the above hypothesis testing, we will use univariate Two Way ANOVA Testing by using SPSS in which Independent variables: Location of malls (Nominal), Time Frames (Nominal) Dependent variables: Waiting time in Queue

XI. Assumptions for Two Way ANOVA Test

Assumption 1: The dependent variable (Waiting Time) is continuous.

Assumption 2: The two independent variables (Locations and Time) consist of two or more categorical, independent groups.

Assumption 3: There is no relationship between the observations (waiting time) in each group (locations & time) or between the groups themselves.

Assumption 4: There are no significant outliers.

Assumption 5: The dependent variable (waiting time) approximately normally distributed for each combination of the groups of the two independent variables.

Assumption 6: There is the homogeneity of variances for each combination of the groups of the two independent variables.

XII. Findings and Conclusions

In this paper, we have tried to measure the values lost by the customer due to large waiting times and we also tried to find out the behaviour of how the server is working. Further below are the findings and the conclusions drawn from this research.

A. *Finding 1:*

The customer loses the value gained (from buying the product) if he/she has to wait in queue and this loss of value can be calculated by the customer readiness to pay for avoiding the queue

B. *Conclusion 1:*

Major steps are required to make changes in the system to enhance customer values lost due to waiting in queue some of these are suggested in this paper

C. *Finding 2:*

- The findings from ANOVA Test shows that we cannot reject any of the three-null hypothesis H0, H0', H0''.
- There is no significant change in waiting time with change in location of malls or change in timings of visit to the malls
- Further, we can say that the two independent variables, location of mall and time of visit are not related to one another (no interaction between the two independent variables)

D. *Conclusion 2:*

Acceptance of null hypothesis in this ANOVA test suggests that if the queue length increases/decreases so do the service rate and thus the waiting time in the queue does not experience many changes with an increase or decrease in queue length of the system.

XIII. Recommendations

Following are the recommendations from this research:

- First, try to improve the queueing model through system improvement this can be done by cost-benefit analysis of the queueing system.
- Try to improve the customer tolerance towards waiting time by facilitating the customer to pass time in the waiting area.
- The employees who are serving the queue should be trained to utilize their empty time during low rush hour to prepare for high rush hours.
- Further, there can be special offers after studying the system efficiency and cost-benefit analysis for low rush hours to deviate the traffic and decrease the queueing in rush hours.
- Try to innovate and utilize new technology and patents to reduce the waiting time for customer and increase his/her experience of shopping; Amazon Go to Seattle is a product of such innovation.

Acknowledgement

We would like to take this opportunity to express our profound gratitude and deep regards to Dr. Rajiv Divekar and Dr. Hirak Dasgupta for their exemplary guidance, constant encouragement, and monitoring till the completion of this research.

References

1. János Sztrik (January 2010). Queueing Theory and its Applications, A Personal View. Proceedings of the 8th International Conference on Applied Informatics Eger, Hungary
2. Toshiba Sheikh, Sanjay Kumar Singh, Anil Kumar Kashyap, (June 2017). Application of Queueing Theory for The Improvement of Bank Service. International Journal of Advanced Computational Engineering and Networking.
3. RRP Jackson (January 1989). Some Applications of Queueing Theory in Operational Research. IMA Journal of management Mathematics Volume 2
4. Najeeb Al Matar (February 2017). Theories and application related to queueing systems. International Journal of Advances in electronics and computer science
5. Prasanta Kumar Brahma (June 2013). Queueing Theory and customer satisfaction: a review of terminology, Trends, and application to hospital practice. Asia Pacific Journal of Marketing and Management Review
6. F. R. B. Cruz and T. van Woensel (March 2014) Finite Queueing Modeling and Optimization: A Selected Review. Journal of Applied Mathematics Volume 2014
7. Mathias Dharmawirya, Erwin Adi (2011). Case Study for Restaurant Queuing Model. International Conference on Management and Artificial Intelligence
8. Dr. Engr. Chuka Emmanuel Chinwuko, Ezeliora Chukwuemeka Daniel, Okoye Patrick Ugochukwu, Obiafudo Obiora J. (2014). Analysis of a queuing system in an organization (a case study of First Bank PLC, Nigeria). American Journal of Engineering Research (AJER)
9. Azmat Nafees (June 2007). Queuing Theory and Its Application: Analysis of The Sales Checkout Operation in ICA Supermarket. Department of Economics and Society, University of Dalarna
10. Ger Koole & Avishai Mandelbaum (October 2001). Queueing Models of Call Centers an Introduction. Industrial Engineering and Management, Technion, Haifa.

AUTHOR(S) PROFILE

Pipul Kumar Jha, received the B.E. degree in Mechanical engineering from Rajiv Gandhi Technical University in 2015 and is currently pursuing MBA in Operations Management from Symbiosis Institute of Management Studies, Pune. I have done my summer internship from a research and analytics-based company, The Smart Cube, Noida where my contribution was in secondary research and thus this research was my first introduction to the field of primary research.