Patient Flow Management through Waiting line Models in Rural based Multi-Specialty Hospital in Charotar Region, Gujarat

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Abstract. Service systems and Waiting lines are significant parts of the effective health care delivery. This article describes queuing situations and presents a mathematical model to analyze waiting lines pertaining to required assumptions and its relationship to patient satisfaction. The model is illustrated in the rural based multispecialty hospital for the patients with multiple-channel queuing model with Poisson Arrival and Exponential Service Times (M/M/S). This paper explains the analysis of Queuing systems for the empirical data of multi-specialty hospital in Charotar region of Gujarat, India. The research paper aims to bring out the queuing model specifically focusing on utilization and waiting length by estimating the waiting time and length of queue(s).To meet the objectives of the study, this research paper has analyzed the empirical data including the variables, such as time, when patients arrive and join the queue, checkout operating unit (server), time when the patient leave/ depart, service time received from Health Management Information System (HMIS) of the hospital. The model designed in the research is a single queue multiple-server. The model contains seven servers, attached to each server is a queue.

Keywords: Queuing Theory, Waiting Line Theory, Health Care Management, Multispecialty Hospital

1 Introduction

Waiting lines or queuing theory, is considered as one of the most extensively used quantitative and mathematical analysis techniques. Waiting lines are an everyday happening. One experiences queuing in bank, shopping malls, bill payments, reservation counters, government offices, airports, railway stations and many more to mention a but a few. Queues may also formed for machines waiting for repairing, trucks, consignments, containers lined to be loaded and unloaded, or aircrafts lined up to take off. In hospitals queuing theory is used to assess staff schedules, productivity and efficiency of staff members, waiting time of patients, counseling-time of patients. The applicability of queuing theory is to take operational and managerial decisions which may lead to patient centric better health care delivery. Decision makers make decisions to increase the satisfaction level of all the relevant groups: patients, employees, and management. Like other service industries, hospitals also function in the competitive environment. ***Speed of Service*** is an operational strategy which provides competitive advantage to the business.

1.1 Application of Queuing Theory in Health Care Sector

Many service industries have been applying Queuing management. Queuing theory has been used extensively in the health care sector. It applies mathematical models to evaluate and develop the flow of patients. Virginia and Arizona based Department of Motor Vehicles used queuing theory to remove extended lines and it resulted in to improved customer satisfaction. They were also able to recover employee morale and reduce costs of daily operations to the greater extent.

Lourdes Hospital based at Binghamton, New York also used queuing modelto prepare staffing requirements in an OPD and an appointment department. Queuing models optimized the capacity of configuration and staffing levels in both departments. Using waiting line model, the delays by centralized appointments department toanswer the telephone calls were eliminated up to a greater extent by rearranging work shifts of the employees. Seattle, Washington based The Virginia Mason Medical Center applied waiting line theory and reduced the patient waiting time to get appointments to 13 days from 42 days and emergency room triage time to 15 minutes from 45 minutes.

2 Literature Review

Past research reveals that, patient dissatisfaction with lengthy waiting times specifies that, there are issues and concerns in hospital standard practices and it is the frequent source of unease and unhappiness among patients and hospital staffs. The measurement of patient satisfaction relating to waiting time is qualitative and a subjective matter. The relationship between them is inversely proportionate. (i.e. as the waiting time increases, satisfaction level decreases). This association was extended by Maister (1985), and recognized that satisfaction is greatly dependent on patient expectation and perception.

Various scientific studies, articles, and books describe the relationship between patient satisfaction, waiting time, and their behavior. A study examined patient satisfaction related to a pharmaceutical service in a large university hospital. It revealed that, the patients who received prescriptions from university physicians out of them 21% preferred to go to somewhere else to purchase medicine in order to avoid long waiting time. A study carried out in a Veterans Affairs hospital brought out the fact that, because of a pharmacy redesign there was significant decrease in patient waiting time and it resulted in to improved patient satisfaction.

"Waiting line models present the researchers a effective tool to design and evaluate the performance of systems." (Bank, Carson, Nelson &Nicol, 2001).When the customers arrive at a service facility, many of them have to wait before they avail the desired service. Customers have to wait for their turn. Customers enter in a service facility with several queues, each with one server. Customer gets an option to choose a queue of a server according to some method (e.g., shortest path, shortest queue or shortest workload, quick service). (Adan, 2000).A queue is formed when the current the demand exceeds the service capacity and when each server is so busy that arriving customers are not provided the immediate service facility.

2.1 Waiting Line Models

A waiting line model can be categorized by four main elements:

S. No.	Elements	Details
1	Arrival	The arrival is the manner in which a patient arrives in the system to avail the service. The situation in which patient's arrival rate exceeds the hospital's processing rate, will result in to a queue. **Characteristics of Arrival:** • Arrivals may form individually or in batches • Patient's inflow may be in over and over again or may come in a random manner • After arrivals, patients have choice to leave the queue if they find the line is too long.
2	Queue Discipline	It is the imperative to determine the arrangement of a queue and the order in which patients are been served. **Characteristics of Queue Discipline:** • The queue follows First In First Out (FIFO) or First In First Served (FIFS) • There may have more than one queue in order to give certain patients priority. (e.g. privileged patients / emergency patients in reception counter)
3	Service Mechanism	It shows how the patients are been served. **Characteristics of Service Mechanism:** • It includes the number of server facilities and the service time • It may change at each level in a random manner. • The service time may not be same for each job.
4	Cost Structure	It defines the payment made by the patient. It also included the operating costs of the system.

Other than these above mentioned elements, which influence the structure of the queue and performance of the system, include the speed of servers and number of service counters.

3. Research Methodology

The data used in the preparing the Queuing model was collected for the each patients visited the hospital during January -2018. Records were obtained from the Health Management Information System (HMIS) of the hospital. The details for number of patients in a queue, their arrival-time and departure-time, age and gender were extracted from HMIS.Queuing Model with Single-queue and Multiple Parallel Servers is followed in the multi-specialty hospital located in a rural setup of Charotar region of Gujarat, India.

3.1 Multiple-Channel Queuing Model with Poisson Arrivals and Exponential Service Time (M/M/S)

A multiple channel queuing system is with two or more servers are offering the services to serve the arriving patients. The assumption here is that the patients are waiting for the service from one single line and then ensue to further available server. These servers have independent and equal exponential service time distribution with mean $1/\mu$. The assumptions under this system are mentioned as below:

- Arrivals of the patients is from an infinite or a large population
- Patients inflow / arrival follows Poisson distribution
- Patients are treated / served on a First Come First Served (FCFS) basis
- Service time follows negative exponential distribution and is constant

Table 1: Parameters in Queuing Models (Multiple Servers, Single Queues Model)

S. No.	Parameter	Details	Formula
1	n	Total number of patients in the system (in queue + in service)	--
2	S	Total number of servers (Servers/ Laboratory Departments / Units in a hospital)	--
3	λ	Arrival rate (Average number of patients arriving in a queue in a hospital per hour)	--
4	μ	Serving rate (Average number of patients getting service per hour)	--
5	ρ	System intensity or utilization factor	$\frac{\lambda}{S\mu}$

6	P_0	Probability of servers are ideal in the system (Zero patients in the system)	$\frac{1}{\sum_{n=0}^{S-1}\frac{\rho^n}{n!}+\frac{\rho^S}{S!\left(1-\frac{\rho}{S}\right)}}$
7	P_n	Probability of n number of patients in the system	$\frac{\rho^n}{n!}\,f0$, if n < S $\frac{\rho^n}{S!S^{n-s}}\,f0$, if n ≥ S
8	Ls	Average number of patients in the system (Patients getting service + Patients waiting in a queue for their turn)	$\left[\frac{\rho^S}{\lambda S!\,S\left(1-\frac{\rho}{S}\right)^2}P0+\frac{1}{\lambda}\right]\lambda$
9	Lq	Average number of patients in a queue (Patients waiting in a queue to avail their service)	Ls – ρ
10	Ws	Average time spent by a patient in a system (Average time taken during waiting in a queue + availing service)	Ls / λ
11	Wq	Average time a patient spends in the queue waiting for service	Ws – 1/μ

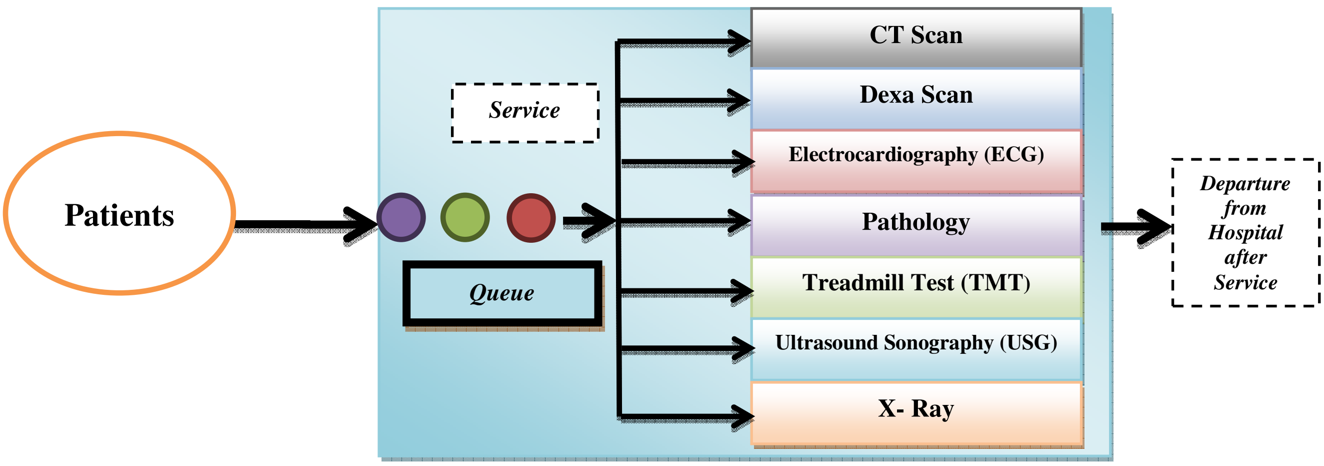

Figure 1: Single-queue and Multiple Parallel Servers Queuing Model

4. Empirical Results

Size of the sample: N = 335 patients (data generated through HMIS of the hospital) who visited the hospital to carry out various medical tests during January month. (One week data was taken into consideration to prepare the queuing model). The details of the number of patients visited during hospital working hours are as below:

Table 2: Details of Frequency Distribution

Department / Server	09 AM -10 AM	10 AM -11 AM	11 AM -12 PM	12 Noon-13 PM	13PM-14 PM	14PM –15 PM	15 PM –16 PM	16 PM -17 PM	Total Patients
CT Scan	1	0	0	0	0	2	0	0	3
Dexa Scan	0	1	0	0	1	1	0	0	3
ECG	8	20	17	3	12	11	5	2	78
Pathology	9	21	20	5	15	20	14	3	107
TMT	0	0	0	0	1	0	0	0	1
USG	2	18	14	0	11	8	5	2	60
X Ray	2	25	22	0	17	10	5	2	83
Total Patients	**22**	**85**	**73**	**8**	**57**	**52**	**29**	**9**	**335**

As shown in the above graph, Pathology department had the highest footfall of patients (approximately 32% of patients) while Treadmill Test (TMT) had the least patients (only 0.29% of patients in a week time). The peak hours of the hospital laboratory were 10: 00 AM to 11:00 AM during which approximately 25% of patients arrive to avail the services. Among those patients who visited during 10:00 AM – 11:00 AM, approximately 30 % of patients visited for X-Ray. While, during 12:00 Noon to 13:00 PM least number of patients visited the hospital (only 2% of the total patients). It is inferred from the frequency tabulation, Pathology, X Ray, ECG and USG were the busiest servers during whole week.

Using grouped data mean for the above table, the average number of patients per hour is 12. Hence the arrival rate of the system λ = 12 patients/hour. Average service time taken to one patient is 31.92 minutes. Hence calculating average service rate μ = 1.87 patients/ hour. Total number of servers in the system is seven.

Table 3: Calculations of Waiting Line Model

S. No.	Particular	Notation	Value
1	Utilization rate or Traffic Intensity	P	91.7%
2	Probability of Zero Patients in the system	P_0	0.07 %
3	Average Patients in System	Ls	14.82 Patients
4	Average Patients in Queue	Lq	8.41 Patients
5	Average time a patient spends in the waiting line or being served in a system	Ws	74.12 Minutes
6	Average time a Patient spends in the queue waiting for service	W_q	42.03 Minutes

The table above shows that the average time for a patient has to wait in a queue using the Single queue Parallel server design was 42.03 minutes and the average time a patient has to wait in the system was calculated as 74.12 minutes. This includes registration process, reaching to relevant department/ server, availing service and waiting for collection of diagnosed reports from the laboratory. For Multiple Server, the average time a patient waits in the queue is about 57% of the waiting time in a system. Referring to the above calculations, the research has the evidence suggesting reducing the time duration to generate reports of the tests. Utilization rate of the server is 91.7%, which shows the fraction of time the servers are busy. The calculations suggest that, the servers are busy for 7.33 hours out of 8 hours a day. The probability of system is ideal is only 0.07% which shows high patient inflow, more rush. Exceeding the demand than the service capacity of the server leads to formation of queues in the hospital. The two figures below show the probability distributions (time based and discrete distribution).

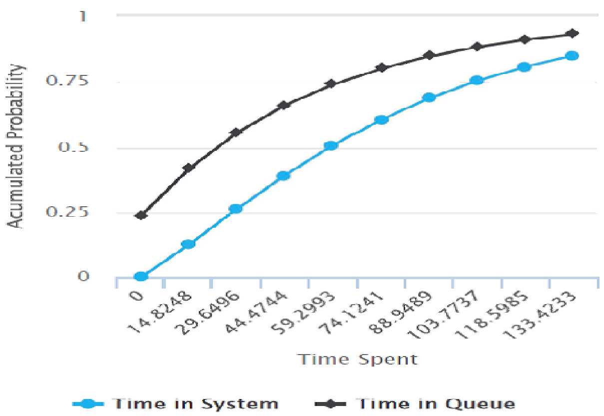

Figure 2: Time Based Probability

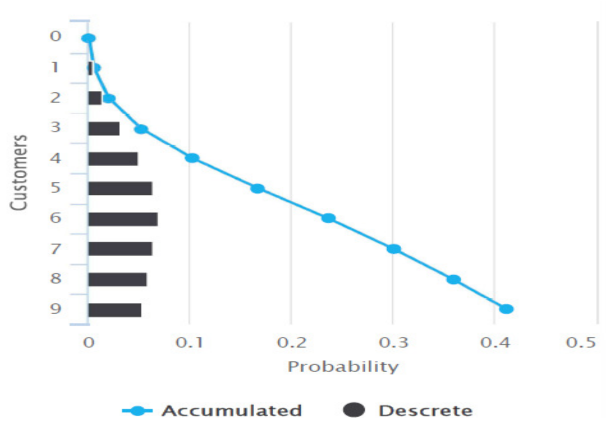

Figure 3: Discrete Probability

5. Conclusion

With the increasing number of patients coming to the multi-specialty hospital for diagnosis, there is a trained medical staff serving at each service unit. Each department / server has adequate number of medical staff which is helpful during the peak hours of weekdays. Other than these peak hours, there is a possibility of short Queues in a model and hence no need to open all servers/ facilities for each hour (especially for CTScan, Dexa Scan and TMT). Adding more than required number of servers may not be the proper solution to increase the efficiency of the service by each service unit.

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