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Research Paper

SIMULATION OF QUEUING ANALYSIS IN HOSPITAL

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from this paper, it helps to the scheduling system of the department. Queuing theory can be used to predict some of the important parameters like total waiting time, average waiting time of patients, average queue length. The simulation of queuing system can be applied to many real-world applications. If it were possible to improve the queues, there would be more profits made and more time to carry out business than ever before, which would be very useful in this fast paced world. This paper describes the use of queuing systems to decrease the waiting time of patients (Edward, 2007).

Keywords: Queuing theory, Simulation, Probability distribution, Scheduling

INTRODUCTION

Long waiting list or waiting time in public health is a notorious problem in most of the countries all over the world. Patient flow is a complex phenomenon because of the random nature of the arrival and service of the patients. This requires a systematic approach in planning. Queuing theory and simulation are analytical techniques that are increasingly being accepted as valuable tools. It describes the inter arrival time and service time of the patients coming to the hospital with a suitable distribution. The primary inputs to these models are arrival and service patterns. These patterns are generally described by suitable random distribution. It is found that the inter arrival time of patients follows the Exponential distribution, and the service time follows Normal distribution. Queuing theory is a stochastic approach dealing with random input and servicing processes. As there is a phenomenological analogy between a queuing system and the systems in humans, the aim of the present study was to apply queuing theory with Monte Carlo simulation (Wijewickrama, 2006).

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Simulation is a mimic of reality that exists or is contemplated. Simulation is most effectively used as a stage in queuing analysis. The simulation is run for patients coming to department, the pertinent parameters like waiting time, service time, waiting time-service time ratio (Fatima and Abdalla, 2008).

Queuing Theory

Queuing Theory is mainly seen as a branch of applied probability theory. Its applications are in different fields, e.g., communication networks, computer systems, machine plants and so forth.

Queuing Theory tries to answer questions like, e.g., the mean waiting time in the queue, the mean system response time (waiting time in the queue plus service times), mean utilization of the service facility, distribution of the number of customers in the queue, distribution of the number of customers in the system and so forth. These questions are mainly investigated in a stochastic scenario, where, e.g., the inter-arrival times of the customers or the service times are assumed to be random (Susan *et al.*, 1990).

Case Study: Overview of Process

Daily, 70-80 patients (new and old) arrived in OPD section. It seen that, patients are waits in queue for a long time. Large Queue length seen in the OPD section. When the demand for a service exceeds the capacity of that service, waiting is unsurprising and inevitable. So this the large problems in the healthcare sector. Queuing systems theories have been used to study waiting time and predict the efficiency of services to be provided. In this department, problem is to be identified. Queuing theory and simulation technique is used and optimum resources used to reduced the average waiting time (Igor *et al.*, 2011).

OBJECTIVE AND METHODOLOGIES

The objective of this paper is to apply waiting line model to the different sections in the health service center in order to calculate the average waiting time for the patients of each section and suggest the alternatives to reduce the average waiting time of each section.

The health service center is identified and a particular department is selected for study. The different sections in the department and their processes are thoroughly studied.

The methodology followed to achieve the objective is as follows:

- The identification of health service center and a particular department.
- Process study of each section in department. In this department, there are 4 sections; Registration Counter, OPD section. First, Patient is register at registration counter, then goes to the OPD section for check-up and test.
- Data collection of inter arrival times and service times for patients. Data of inter arrival times of patients and service time for each server or doctor for each patients for each section collected.
- Identification of inter arrival time probability distributions and service time probability distributions from the data collected.

  From the data of inter arrival times, plot a graph between inter arrival times and frequencies of patients, the graph occurs as Exponential distribution type curve. And,

from the data of service time, plot a graph between service times of each server and frequencies of patients, the graph occurs as Normal distribution type curve.

- Validation of actual probability distributions with the standard probability distributions.

  It is found that the inter arrival time of patients follows approximately Exponential distribution, and the service time follows approximately Normal distribution from the graphs.

- Calculations for reducing the average waiting time by using extra resources and technology alternatives.
- Suggestions to the health center to reduce the average waiting time of each section in the identified department.

VALIDATION OF INTER ARRIVAL TIME AND SERVICE TIME PROBABILITY DISTRIBUTIONS

The data collected from the different sections of the hospital comprised of patients inter arrival times and service times. The data collected for the OPD section.

The frequencies of patients are calculated and the distributions for each section is plotted on the graph with inter arrival time as abscissa and frequency as an ordinate as follows.

Distribution of Inter Arrival Times

Inter Arrival Time Probability Distribution for OPD Section

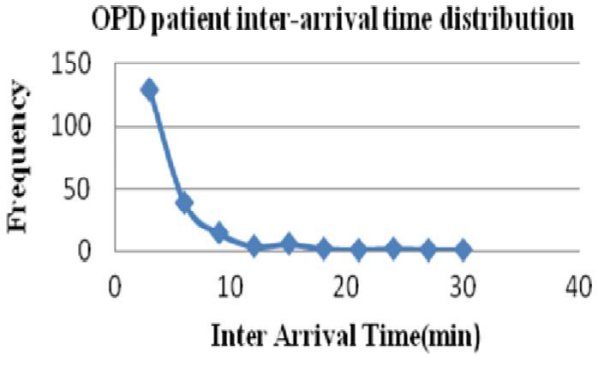
The inter arrival time of patients visited to the OPD section for 3 days is recorded and the frequency at fixed values of inter arrival times is calculated from the data collected as shown in the Table 1.

The graph is plotted between the inter arrival times and frequency of patients visited. The curve obtained resembles to the standard exponential probability distribution curve as shown in the Figure 1. Hence it can be concluded that the inter arrival time for OPD section follows the exponential curve. It can be observed that highest frequency 129 is at the 3 min. inter arrival time. Then gradually the frequency goes down exponentially towards the lowest value 1 at the inter arrival time of

Table 1: Inter Arrival Time and Frequency of Patients for OPD

Inter Arrival Time (min.)	Frequency
3	129
6	39
9	15
12	4
15	6
18	2
21	1
24	2
27	1
30	1

Figure 1: The Inter Arrival Time Distribution for OPD Section



30 min. hence it can be predicted that the most of the time the patients come frequently with interval of 3 min. This kind of frequency may lead for high waiting time.

Distributions of Service Times

Service Time Probability Distribution for OPD Section

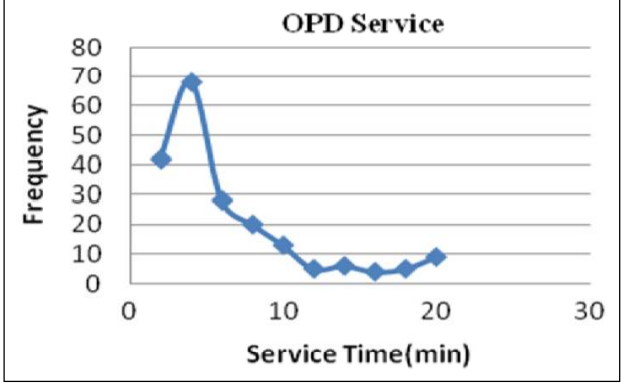
The service time of patients visited to the OPD section for 3 days is recorded and the frequency at fixed values of service times is calculated data collected as shown in the Table 2.

The graph is plotted between the service times and frequency of patients visited. The curve obtained resembles to the standard exponential probability distribution curve but generally the service time follows the normal or Poisson distribution hence the data collected resulted into abnormal distribution as shown in the Figure 2. The 4 points at left side of curve make the curve approximately normal distribution. Hence it can be concluded that the service time for OPD section follows the Normal distribution.

Table 2: Service Time and Frequency of Patients for OPD

Service Time (min.)	Frequency
2	42
4	68
6	28
8	20
10	13
12	5
14	6
16	4
18	5
20	9

Figure 2: The Service Time Distribution for OPD Section



It can be observed that highest frequency 68 is at the 4 min. service time. In the curve gradually the frequency goes up and then down. Hence it can be predicted that the most of the time the patients come frequently with service time of 4 min. This kind of frequency may lead for high waiting time as there are only 4 doctors to serve the patients.

In all above mentioned sections the inter arrival time and service time distributions have been discussed in details. After identifying the probability distributions the patient's arrival and service time behavior can be predicted and the whole system can be simulated to find out the average waiting time by simulating the much more number of patients. In next chapter the average waiting time has been calculated for each section of the hospital department.

CALCULATIONS OF AVERAGE WAITING TIME FOR EACH SECTION USING THE SIMULATION OF PATIENTS

Average Waiting Time for OPD Section with Presently Available Doctors

The first frequencies are calculated for each inter arrival time and probabilities are

calculated by dividing the each frequency by total frequency. The cumulative frequency is calculated as shown in the Table 3.

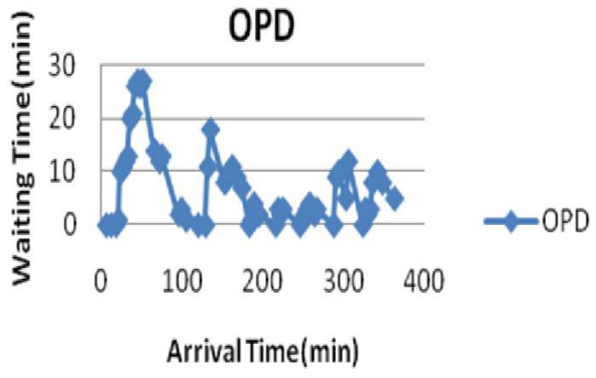
The simulation is done for 59 patients for the OPD section. Random numbers are generated and the interval is identified for the generated random number and accordingly the inter arrival time of the patient is decided same is done for the service time. Presently the four doctors are available for providing the services. The assignment of patient to each doctor is done by checking the availability of doctors for next patient. Then the waiting time for each patient is calculated and average waiting time is determined. The calculations and output is as shown in the Table 3.

Table 3: Probability Distribution Data for Generation of Random Number

Inter-Arrival Time (min)					Service Time (min)				
Inter-Arrival Time No.	Freq.	Prob.	Cum. Prob.	Random	Service Time No.	Freq.	Prob.	Cum. Prob.	Random
3	40	0.67	0.67	00-66	2	11	0.19	0.19	00-18
6	13	0.22	0.89	67-88	4	25	0.42	0.61	19-60
9	2	0.03	0.92	89-91	6	6	0.1	0.71	61-70
12	1	0.02	0.94	92-93	8	8	0.14	0.85	71-84
15	1	0.02	0.96	94-95	10	3	0.05	0.9	85-89
18	1	0.02	0.98	96-97	12	3	0.05	0.95	90-94
21	1	0.02	1	98-99	14	3	0.05	1	95-99
Total	**59**	**1**		**Total**	**59**	**1**			

Hence the average waiting time for the patients is 7.20 min per patient when 4 doctors are available to provide services. Figure 3 shows that the peak waiting hour's are in the morning session 9 a.m. to 12 noon.

Figure 3: Waiting Time Peak Hours for OPD Section



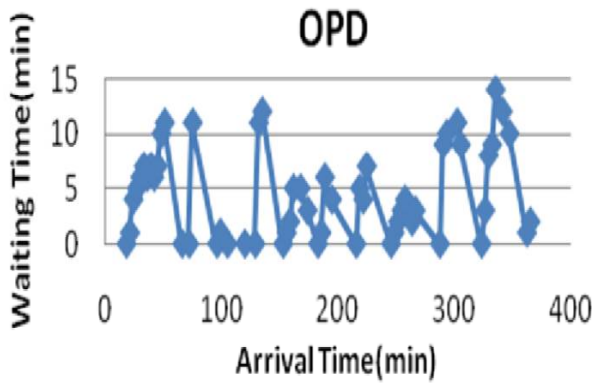
So in next section, one extra doctor is made available to provide the services and results are obtained to see the effect on average waiting time.

AVERAGE WAITING TIME FOR OPD SECTION WITH ONE EXTRA DOCTOR

In order to reduce the average waiting time of OPD patients' one extra doctor is made available and the waiting time calculations are done. The results obtained are consolidated. It can be identified that addition of one extra resource or say a Doctor to OPD section has reduced down the 4.25 min. This indicates that the addition of doctor has reduced down the waiting time to much lower level.

Figure 4 shows the peak waiting hours after allocation of 1 more doctor to the OPD section. The average waiting time has been reduced down to 4.25 min the highest waiting time at the peak is 14 min.

Figure 4: Waiting Time Peak Hours for OPD Section for 1 Extra Doctor/Server



RESULTS AND DISCUSSION

Results Discussions for the OPD Section

The calculations done for the OPD section with 4 doctors and 5 doctors indicate that the addition of one more doctor has reduced the average waiting time from 7.20 min to 4.25 min from Figures 5 and 6, it can be concluded that the peak waiting time is 27 min when 4 doctors are available and its 14 min for 5 doctors. Generally the waiting time is more in morning session, i.e., from 9 a.m. to 12 noon. In Figure 5, it's about 0 to 150 min when the waiting time is very high. If same interval is looked into Figure 6, the waiting time peaks have been much more reduced.

Figure 5: Waiting Time Peak Hours for OPD with 4 Doctors

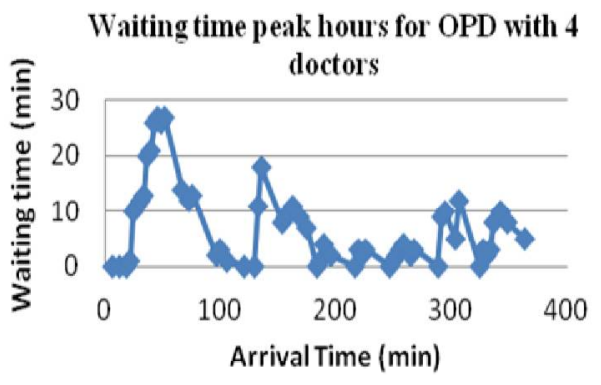
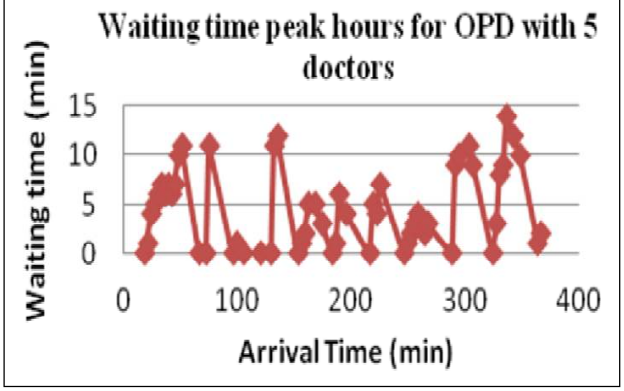


Figure 6: Waiting Time Peak Hours for OPD with 5 Doctors



CONCLUSION

The objective of this paper is to reduce the average waiting time of patients for each section in the radiation therapy and oncology department. The probability distributions for patient's arrival time and service time for each section have been calculated from the data collected and the average waiting time for the present resources quantity and availability has been calculated for each section by simulating the number of patients. Then the extra resources are added, e.g., one doctor is added to OPD. After adding the resources again the average waiting time has been calculated for sections with extra resources. The objective is achieved by reducing the average waiting times of each department as shown in the Table 4.

Table 4: Comparison of Average Waiting Time for Each Section Before and After the Allocation of Extra Resources

S. No.	Waiting Time (min)			
	Sections in Department	Before Allocation of Extra Resources	After Allocation of Extra Resources	% Reduced
1.	OPD	7.2	4.25	40.97

Table 5: Comparison of Allocation of Resources for Each Section Before and After the Allocation of Extra Resources

S. No.	Allocation of Extra Resources			
	Sections in Department	Before Allocation of Extra Resources	After Allocation of Extra Resources	% Increase in Resources
1.	OPD	4 Doctors	5 Doctors	25

Form the above table one point can be concluded.

1. The average waiting time for the OPD section is reduced by 40.97% if one more doctor allocated for providing the services i.e., instead of 4 doctors there can be 5 doctors. The extra doctor allocated here must be present in section at least in the peak hours (9 a.m. to 12 noon) in order to get the above mentioned reduction in the average waiting time.

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