# Reduction of Waiting Time by Using Simulation & Queuing Analysis

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***Abstract-*** 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.

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## I. INTRODUCTION

Queue is a common word that means a waiting line or the act of joining a line. It is formed when the number of customers arriving is greater than the number of customers being served during a period of time. Long waiting list or waiting time in public health is a notorious problem in most of the countries all over the world. This paper describes the use of queuing systems to decrease the waiting time of patients.

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. Queuing systems are quicker to use however, they do not have the flexibility of simulation technique. 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 can be used to predict some of the important parameters like total waiting time, average waiting time of patients, average queue length. The queuing system predicted the average waiting time of patients, average queue length, closer to the actual values.

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.

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.

### 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.

The Queuing Theory, also called the Waiting Line Theory, owes its development to A. K. Erlang's efforts to analyze telephone traffic congestion with view telephone traffic congestion with a view to satisfying the randomly arising demand for the services of the Copenhagen automatic telephone system, in the year 1909. The theory is used in situations where the customers arrive at some 'service stations' for some service, wait (occasionally not), and then leave the system after getting the service. In such 'arrival and departure' problems, the customers might be people waiting to deposit their electricity bills at a cash counter, machines waiting to be repaired in a factory's repair shop, aero planes waiting to land at an airport, patients in a hospital who need treatment and so on. The service stations in such problems are the cash counters in the electricity office, repairmen in the shop, runways at the airport and doctors attending the patients, respectively.

In general, a queue is formed at a queuing system when either customers (human beings or physical entities) requiring service wait due to number of customers exceeds the number of service facilities, or service facilities do not work efficiently and take more time than prescribed to serve a customer.

The only way that the service demand can be met with ease is to increase the service capacity (and raising the efficiency of the existing capacity if possible) to the exiting level. The capacity might be built to such high level as can always meet the peak demand with no queues. But adding to capacity may be a costly affair and uneconomic after a stage because then it shall remain idle to varying degrees when there are no or few customers. A manger, therefore, has to decide on an appropriate level of service which is neither too low nor too high. Providing too low service would cause excessive waiting which has a cost in terms of customer frustration, loss of goodwill in the long run, direct cost of idle employees (where, for example, the employees have to wait near the store to obtain the supplies of materials, parts or tools needed for their work), or loss associated with poor employee morale resulting from being idle. On the other hand, too high a service level would result in very high set up cost and idle time for the service stations, thus, the goal of queuing modeling is the achievement of an economic balance between the cost of providing service and the cost associated with the wait required for that service.

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.

### Case Study: Overview of Process

Daily, 70-80 patients (new and old) arrived in Chemotherapy section. It seen that, patients are waits in queue for a long time. Large Queue length seen in the Chemotherapy 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

## II. 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 is for the chemo therapy section. The frequencies of patients are calculated and the distributions for this section is plotted on the graph with inter arrival time and frequency as an ordinate as follows.

### A) DISTRIBUTIONS FOR INTER ARRIVAL TIMES

**INTER ARRIVAL TIME PROBABILITY DISTRIBUTION FOR CHEMO THERAPY SECTION :**

The inter arrival time of patients visited to the chemo therapy section for 3 days is recorded and the frequency at fixed values of inter arrival times is calculated 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 fig. 1. Hence it can be concluded that the inter arrival time for chemo therapy section follows the exponential curve.

| Service Time (min.) | Frequency |
|---|---|
| 60 | 6 |
| 90 | 24 |
| 120 | 15 |
| 150 | 9 |
| 180 | 7 |
| 210 | 2 |

It can be observed that highest frequency 22 is at the 5 min. inter arrival time. Then gradually the frequency goes down approximately exponentially towards the lowest value 1 at the inter arrival time of 50 min. hence it can be predicted that the most of the time the patients come frequently with interval of 5 min.

| Inter Arrival Time (min.) | Frequency |
|---|---|
| 5 | 22 |
| 10 | 7 |
| 15 | 6 |
| 20 | 8 |
| 25 | 3 |
| 30 | 3 |
| 35 | 3 |
| 40 | 2 |
| 45 | 1 |
| 50 | 1 |

This kind of frequency may lead for high waiting time. The detailed discussion on waiting time is done in next chapter.

Table 1. Inter arrival time and frequency of patients for Chemotherapy Section

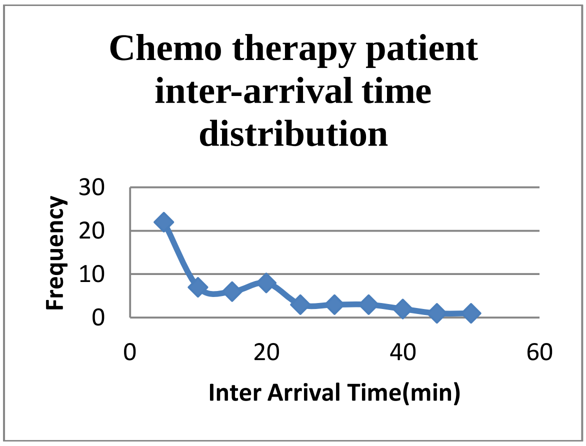


**Fig 1.** The inter arrival time distribution for Chemo Therapy section.

### B) DISTRIBUTIONS FOR SERVICE TIMES

**SERVICE TIME PROBABILITY DISTRIBUTION FOR CHEMO THERAPY SECTION :**

The service time of patients visited to the Chemo therapy 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 normal probability distribution curve as shown in the fig. 2. Hence it can be concluded that the service time for Chemo therapy section follows the Normal distribution.

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Table 2. Service time & frequency of patients for Chemotherapy section

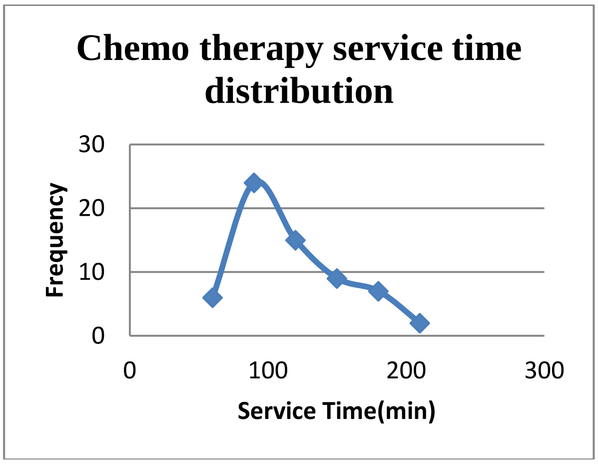


**Fig 2.** The service time distribution for Chemo therapy section.

It can be observed that highest frequency 24 is at the 90 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 90 min.

This kind of frequency may lead for high waiting time. The detailed discussion on waiting time for this chemotherapy section is done in next chapter.

## III. CALCULATIONS OF AVERAGE WAITING TIME FOR CHEMOTHERAPY SECTION USING THE SIMULATION OF PATIENTS

### A) AVERAGE WAITING TIME FOR CHEMO THERAPY SECTION WITH PRESENTLY AVAILABLE BEDS :

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.

| Distribution of Inter-Arrival Time | | | | | Distribution of Service Time | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Inter Arrival Time | Freq. | Prob. | Cum. Prob. | Random No. Interval | Inter Service Time | Freq. | Prob. | Cum. Prob. | Random No. Interval |
| 5 | 22 | 0.35 | 0.35 | 00-34 | 60 | 6 | 0.1 | 0.1 | 00-09 |
| 10 | 7 | 0.11 | 0.46 | 35-45 | 90 | 24 | 0.38 | 0.48 | 10--47 |
| 15 | 13 | 0.2 | 0.66 | 46-65 | 120 | 15 | 0.24 | 0.72 | 48-71 |
| 20 | 8 | 0.12 | 0.78 | 66-77 | 150 | 9 | 0.14 | 0.86 | 72-85 |
| 25 | 3 | 0.05 | 0.83 | 78-82 | 180 | 7 | 0.11 | 0.97 | 86-96 |
| 30 | 3 | 0.05 | 0.88 | 83-87 | 210 | 2 | 0.03 | 1 | 97-99 |
| 35 | 3 | 0.05 | 0.93 | 88-92 | Total | 63 | 1 | | |
| 40 | 2 | 0.03 | 0.96 | 93-95 | | | | | |
| 45 | 1 | 0.02 | 0.98 | 96-97 | | | | | |
| 50 | 1 | 0.02 | 1 | 98-99 | | | | | |
| Total | 63 | 1 | | | | | | | |

**Table 3.** Probability Distribution data for generation of random number (Chemo Therapy)

The simulation is done for 63 patients (3 days) for the Chemo therapy 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 9 beds are available for providing the services. The assignment of patient to each bed is done by checking the availability of beds for next patient. Then the waiting time for each patient is calculated and average waiting time is determined.

The average waiting time for chemo therapy patients is 6.45 min. and the average service time calculated is 112.86.

### B) AVERAGE WAITING TIME FOR CHEMO THERAPY SECTION WITH ONE EXTRA BED.

In order to reduce the average waiting time of patients' one extra bed is made available virtually and the waiting time calculations are done. The results obtained are consolidated in the table 4 as follows. It can be identified that addition of one extra resource or say a bed to chemotherapy section has reduced down the 2.14 min. This indicates that the addition of a bed has reduced down the waiting time to much lower level.

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## IV. RESULTS AND DISCUSSION : RESULTS DISCUSSION FOR CHEMO THERPY SECTION :

The calculations done for the Chemo therapy section with 9 beds (present) and 10 beds (proposed) indicate that the addition of one more bed has reduced the average waiting time from 6.45 min to 2.14 min. from fig. 3 and fig. 4 it can be concluded that the peak waiting time is 45 min when 9 beds are available and its 30 min for 10 beds.

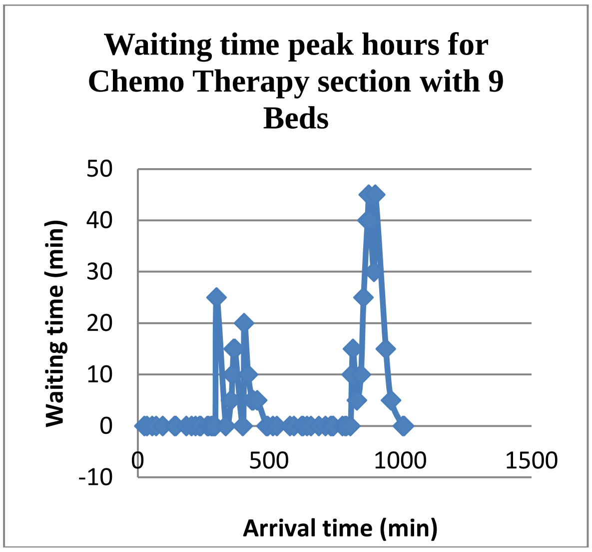


**Fig.3. Waiting time peak hours for Chemo Therapy section with 9 Beds**

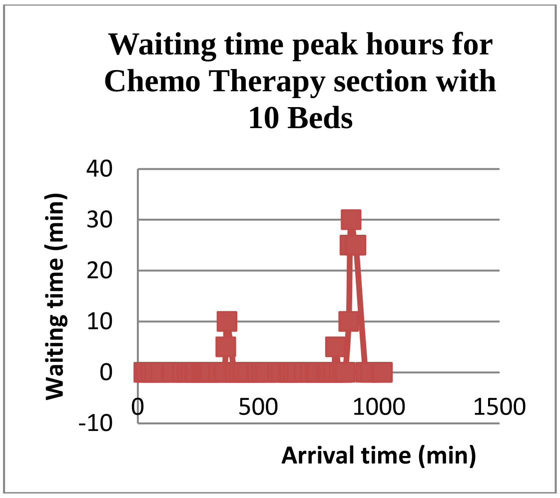


**Fig.4. Waiting time peak hours for Chemo Therapy section with 10 Beds**

## V. CONCLUSION

The objective of this paper is to reduce the average waiting time of patients for chemotherapy 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.. Then the extra resources are added e.g. one bed is added to Chemo therapy section. 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 chemotherapy section as shown in the table 4. and fig 5. by allocating the extra resources as shown in the table 5. and fig. 6.

| | Waiting Time (min) | | | |
|---|---|---|---|---|
| **Sr. No.** | **Sections in Departme nt** | **Before Allocation of Extra resources** | **After Allocation of Extra Resources** | **% Reduced** |
| 1. | Chemo Therapy | 6.45 | 2.14 | 66.82 |

**Table 4.** Comparison of average waiting time for each section before and after the allocation of extra resources.

| | Allocation of extra resources | | | |
|---|---|---|---|---|
| **Sr. No.** | **Sections in Departm ent** | **Before Allocation of Extra resources** | **After Allocation of Extra Resources** | **% Increase in resources** |
| 1 | Chemo Therapy | 9 Beds | 10 Beds | 11.11 |

**Table 5.** Comparison of allocation of resources for each section before and after the allocation of extra resources

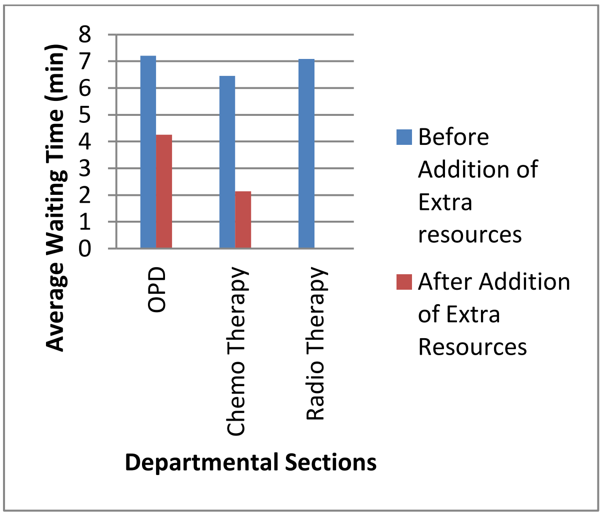


**Fig 5.** Comparison of average waiting time for each section before and after the allocation of extra resources

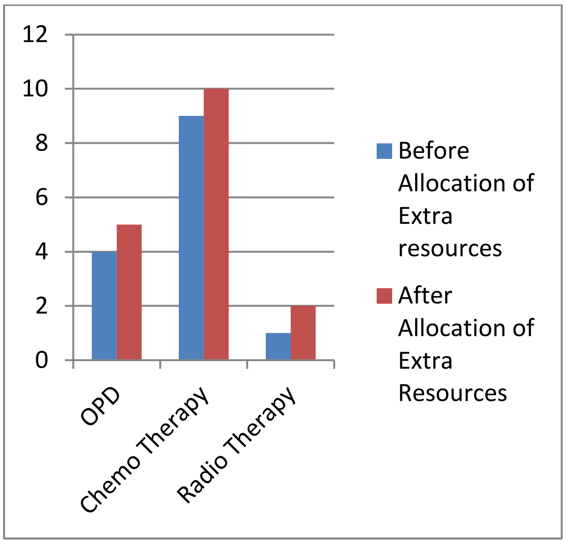


**Fig 6.** Comparison of allocation of resources for each section before and after the allocation of extra resources

Form the above figures and tables following can be concluded.

1. The average waiting time for Chemo therapy section is reduced by the 66.82 % if one more bed in the section i.e. instead of 9 beds there can be 10 beds.

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