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Management

# OPTIMIZING RESOURCES AT OPD REGISTRATION BY QUEUING THEORY

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**ABSTRACT** The arrival pattern of patients in the Outpatient Department is variable and the staffing to manage the varying arrival rate is fixed, leading to long waiting time for patients during peak arrival rate time and waiting of registration staff during the lean time. Queuing theory is an Operation Research technique that aids in making decisions involving the establishment of service facilities to meet irregular demands. Cost challenges arise when more facilities are available than needed, or when too few facilities are available resulting in long waiting lines.A study was carried out at the central registration for OPD patients in a tertiary care teaching hospital to optimize the resources using queuing theory.

**KEYWORDS :** Queuing Theory, OPD, Waiting time, Hospital operations, Optimizing resources

## INTRODUCTION

Hospital services operations particularly, the Outpatient Department (OPD), play a crucial role in providing quality healthcare for multi-specialty hospitals. Prolonged waiting time is a major challenge for healthcare services all over the world. Complaints regarding long waiting times are caused majorly due to observable queues which result in patient dissatisfaction. Queuing theory is a potent mathematical approach to the analysis of waiting lines performance parameters in healthcare delivery systems.

## LITERATURE REVIEW

The Queuing theory or waiting line theory owes its development to AK Erlang, who in 1903, took up the problem of congestion of telephone traffic. Waiting lines or queues are omnipresent in establishments of all types including hospitals. Waiting line problems arise either because there is too much demand for the facilities, leading to excess waiting time or an inadequate number of service facilities or there is too little demand, in which case there is too much idle facility time or too many facilities.

The important parameters for applying queuing theory are the Arrival rate (λ), Service rate(μ)and Traffic Intensity [Utilization factor] Rho(ρ)– which is the ratio between the mean arrival rate and the mean service rate (λ/μ). At ρvalue of 0.5, the queue starts forming and at ρ one, queue length and waiting time tend to become infinity. At ρ value of more than 0.75, there is a disproportionate increase in the queue length and waiting time. The other factors affecting the queue are the queue discipline, arrangement of servers and arrival pattern. Because of the above governing factors, a waiting line is formed.

Long queues are an indication of a lack of coordination, poor management, and insufficient resources, which affects the quality of services in hospital operations and reduce patients' satisfaction. It is necessary to focus on optimizing waiting time in hospital operations for the benefit and wellbeing of patients. Given the role of waiting time in improving service quality for the higher satisfaction of patients, it is necessary to review it as one of the most common problems in hospital service operations –"—'—".

There are number of publications involving the application of queuing theory to service operations in hospital settings.The analysis of waiting time in healthcare systems can be approached mathematically using queuing theory , . A queuing system aims to minimize the time that customers i.e., patients in healthcare, have to wait and maximize the utilization of the servers or resources i.e., doctors, nurses and hospital beds in healthcare. Unfortunately, this vital tool is underutilized in most hospital operations across India.

## METHODOLOGY

### Data Collection

The present study was conducted at OPD central registration of a Tertiary care Hosp in Dec 2019. The queuing theory model was used for the study. Focused group discussions were held with the staff involved in registration, relevant documents were studied and direct observations of the flow of patients, arrival pattern, queue formation, and service pattern was carried out to gather data.

### Data Analysis

The arrival rate and service rates were evaluated using the queuing model in the Microsoft office excel template

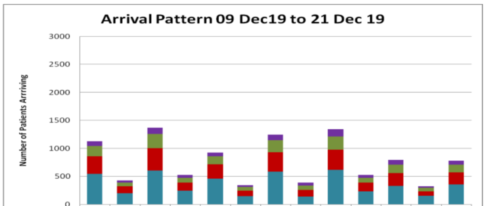
## OBSERVATIONS

A. Queue Discipline: First in First Out (FIFO)
B. Arrangement of Severs: Multi-Channel (04 queues), Single Phase (only registration)
C. Kendall Notation:Markovian Arrival/ Markovian service distribution/ 04 servers M/M/S = (M/M/4).
D. Mean Arrival Rate (λ) :
Mean Arrival Rate of patients/hour =

Total number of patients registered in Dec 19
Number of working days x working hours per day
= 19740/26* 4 = 189.8 per hour
E. Service Rate: The observed average service time per patient for each counter was 56 seconds.

Service rate per hour per counter =
Total Seconds in 1 hour/ service rate per patient
=3600/ 56 = 64.28/ hour

Total Service rate for all four counters =
64.28 * 4 = 257.12/ hour
F. Utilization factor (ρ) :(ρ) = (λ/μ) =
189.8/ 257.12 = 0.738
G. Arrival pattern: Variable pattern as shown in Fig 1




| | Mon | Tue | Wed | Thu | Fri | Sat | Mon | Tue | Wed | Thu | Fri | Sat | Mean Arrival Rate |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total | 1129 | 431 | 1373 | 527 | 930 | 349 | 1250 | 395 | 1347 | 527 | 795 | 324 | 195 |
| 1030-1130 | 80 | 41 | 112 | 53 | 66 | 34 | 102 | 54 | 130 | 53 | 84 | 24 | 69 |
| 0930-1030 | 189 | 63 | 253 | 84 | 145 | 65 | 212 | 81 | 234 | 84 | 151 | 63 | 135 |
| 0830-0930 | 311 | 124 | 403 | 143 | 256 | 97 | 347 | 113 | 363 | 153 | 225 | 83 | 218 |
| 0730-0830 | 549 | 203 | 605 | 247 | 463 | 153 | 589 | 147 | 620 | 237 | 335 | 154 | 359 |

**Figure 1:Arrival pattern of Patients at Central Registration.**

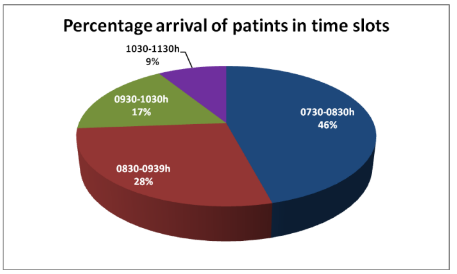



**Figure 2: Percentage arrival of patients in the hourly time slots**

## ANALYSIS

The existing system is capable of registering 257patients per hour vs the mean arrival rate of 190 patients per hour. The arrival rate observed was variable in each hour of registration with peak loads in the first two hours of registration and relatively less number of arrivals in the latter 2 hrs of registration. The workloads on Mondays, Wednesdays, and Fridays were higher than the other working days. The main identified problem time slots were evaluated using the M/M/S queuing model spreadsheet. The findings of the critical time slots are shown in tables 2 to 5.

**Table 1: Definition of Terms**

| | Definition of Terms |
|---|---|
| λ | Arrival rate |
| μ | Service rate |
| s | Number of servers (registration counters) |
| Lq | Average number of patients in the queue |
| Ls | Average number of patients in the system |
| Wq | Average wait in the queue |
| Ws | Average wait in the system |
| P(0) | Probability of zero customers in the system |
| P(delay) | Probability that an arriving customer has to wait |

**Table 2: Monday 0730 to 0930h**

| Mondays 0730 to 0930h λ = 449 μ = 64.28 | | | | | | | |
|---|---|---|---|---|---|---|---|
| s | Lq | Ls | Wq | Ws | P(0) | P(delay) | Utilization |
| 1 | Infinity | Infinity | infinity | infinity | 0.0000 | 1.0000 | 1.0000 |
| 2 | Infinity | Infinity | infinity | infinity | 0.0000 | 1.0000 | 1.0000 |
| 3 | Infinity | Infinity | infinity | infinity | 0.0000 | 1.0000 | 1.0000 |
| 4 | Infinity | Infinity | infinity | infinity | 0.0000 | 1.0000 | 1.0000 |
| 5 | Infinity | Infinity | infinity | infinity | 0.0000 | 1.0000 | 1.0000 |
| 6 | Infinity | Infinity | infinity | infinity | 0.0000 | 1.0000 | 1.0000 |
| 7 | 464.7 | 471.69 | 1.0350 | 1.0505 | 0.0000 | 0.9936 | 0.998 |
| 8 | 4.3393 | 11.324 | 0.0097 | 0.0252 | 0.0006 | 0.6305 | 0.873 |
| 9 | 1.3227 | 8.3077 | 0.0029 | 0.0185 | 0.0008 | 0.3815 | 0.776 |
| 10 | 0.5085 | 7.4935 | 0.0011 | 0.0167 | 0.0009 | 0.2195 | 0.698 |
| 11 | 0.2082 | 7.1933 | 0.0005 | 0.0160 | 0.0009 | 0.1197 | 0.635 |

**Table 3: Wednesdays 0730 to 0930h**

| Wednesday 0730 to 0930h λ = 497.75 μ = 64.28 | | | | | | | |
|---|---|---|---|---|---|---|---|
| s | Lq | Ls | Wq | Ws | P(0) | P(delay) | Utilization |
| 1 | infinity | infinity | infinity | infinity | 0.0000 | 1.0000 | 1.0000 |
| 2 | infinity | infinity | infinity | infinity | 0.0000 | 1.0000 | 1.0000 |
| 3 | infinity | infinity | infinity | infinity | 0.0000 | 1.0000 | 1.0000 |
| 4 | infinity | infinity | infinity | infinity | 0.0000 | 1.0000 | 1.0000 |
| 5 | infinity | infinity | infinity | infinity | 0.0000 | 1.0000 | 1.0000 |
| 6 | infinity | infinity | infinity | infinity | 0.0000 | 1.0000 | 1.0000 |
| 7 | infinity | infinity | infinity | infinity | 0.0000 | 1.0000 | 1.0000 |
| 8 | 27.123 | 34.867 | 0.0545 | 0.0700 | 0.0001 | 0.8986 | 0.9679 |
| 9 | 3.5550 | 11.299 | 0.0071 | 0.0227 | 0.0003 | 0.5769 | 0.8604 |
| 10 | 1.2158 | 8.9593 | 0.0024 | 0.0180 | 0.0004 | 0.3543 | 0.7743 |
| 11 | 0.4936 | 8.2371 | 0.0010 | 0.0165 | 0.0004 | 0.2076 | 0.7040 |

**Table 3 : Fridays 0730 to 0830h**

| Friday 0730 to 0830h λ = 399 μ = 64.28 | | | | | | | |
|---|---|---|---|---|---|---|---|
| s | Lq | Ls | Wq | Ws | P(0) | P(delay) | Utilization |
| 1 | infinity | infinity | infinity | infinity | 0.0000 | 1.0000 | 1.0000 |
| 2 | infinity | infinity | infinity | infinity | 0.0000 | 1.0000 | 1.0000 |
| 3 | infinity | infinity | infinity | infinity | 0.0000 | 1.0000 | 1.0000 |
| 4 | infinity | infinity | infinity | infinity | 0.0000 | 1.0000 | 1.0000 |
| 5 | infinity | infinity | infinity | infinity | 0.0000 | 1.0000 | 1.0000 |
| 6 | infinity | infinity | infinity | infinity | 0.0000 | 1.0000 | 1.0000 |
| 7 | 5.3729 | 11.580 | 0.0135 | 0.0290 | 0.0011 | 0.6862 | 0.8867 |
| 8 | 1.4104 | 7.6176 | 0.0035 | 0.0191 | 0.0017 | 0.4073 | 0.7759 |
| 9 | 0.5085 | 6.7157 | 0.0013 | 0.0168 | 0.0019 | 0.2288 | 0.6897 |
| 10 | 0.1984 | 6.4056 | 0.0005 | 0.0161 | 0.0020 | 0.1212 | 0.6207 |
| 11 | 0.0784 | 6.2856 | 0.0002 | 0.0158 | 0.0020 | 0.0605 | 0.5643 |

**Table 5: Saturdays 0730 to 0830h**

| Saturday 0730 to 0830h λ = 153.5 μ = 64.28 | | | | | | | |
|---|---|---|---|---|---|---|---|
| s | Lq | Ls | Wq | Ws | P(0) | P(delay) | Utilization |
| 1 | infinity | infinity | infinity | infinity | 0.0000 | 1.0000 | 1.0000 |
| 2 | infinity | infinity | infinity | infinity | 0.0000 | 1.0000 | 1.0000 |
| 3 | 2.4999 | 4.8879 | 0.0163 | 0.0318 | 0.0576 | 0.6407 | 0.7960 |
| 4 | 0.4196 | 2.8075 | 0.0027 | 0.0183 | 0.0842 | 0.2832 | 0.5970 |
| 5 | 0.1020 | 2.4900 | 0.0007 | 0.0162 | 0.0901 | 0.1116 | 0.4776 |
| 6 | 0.0259 | 2.4138 | 0.0002 | 0.0157 | 0.0914 | 0.0391 | 0.3980 |
| 7 | 0.0063 | 2.3943 | 0.0000 | 0.0156 | 0.0917 | 0.0122 | 0.3411 |
| 8 | 0.0015 | 2.3895 | 0.0000 | 0.0156 | 0.0918 | 0.0034 | 0.2985 |
| 9 | 0.0003 | 2.3883 | 0.0000 | 0.0156 | 0.0918 | 0.0009 | 0.2653 |
| 10 | 0.0001 | 2.3881 | 0.0000 | 0.0156 | 0.0918 | 0.0002 | 0.2388 |

46% of patients arrive at the registration counter in the first hour, 28% in the second hour and 26% in the remaining two hours of registration (Figure 2).

The mean arrival rate of patients in the first hour (358.5) in the two weeks under study was higher than the service rate of 310 patients per day and caused long queues. The problem was more acute on Mondays, Wednesdays and Fridays.

The mean arrival in the second hour was also more than the service rate for the second hour on Mondays and Wednesdays causing long queues throughout the registration hours.

The total arrival of patients was high on Mondays and Wednesdays with service rate much lower than the arrival rate in the first 2 hours.On Tuesdays, Thursdays and Saturdays the system (registration counters) is idle for long durations during the registration period as the service rate is higher than the arrival rate.As per the queuing model, the number of servers needed on Monday and Wednesday 0730 hrs to 0930 hrs should be 08 servers instead of the present 04 to have a minimal queuing length of 04 to 27 people. On Friday 0730h to 0830h having 07 registration counters can reduce queue length to 5 people. On Tuesdays, Thursdays, and Saturdays 03 counters should be adequate to prevent queuing of patients even in the peak first hour of registration.

## RECOMMENDATIONS AND CONCLUSION

The Outpatient Department (OPD) plays a crucial role in providing quality healthcare for multi-specialty hospitals.Complaints regarding long waiting times are majorly due to observable queues, which result in patient dissatisfaction. Long queues are an indication of a lack of coordination, poor management, and insufficient resources, which affects the quality of services in hospital operations and reduce patients' satisfaction.

In the study, there was an observable pattern in the variation of rate of arrival of patients on day wise as well as time-wise. The arrivals on Mondays, Wednesdays, and Fridays were high and the arrival on Tuesdays, Thursdays, and Saturdays was relatively low.46% of all the patients arrive in the first hour of registration, 28 % in the second hour and only 26 % in the remaining 02 hours.

The number of servers (counter for registration) in this varying arrival rate is fixed as 04 counters causing long queues during high arrival rate and the system remaining idle during low arrival rates.

It is recommended to use the queuing model to optimize the number of counters needed to prevent both long queues as well as having an idle system. More Registration Counters should be functioning with an adequate number of Data entry operators especially during the peak arrival rates of first 02 hours on Mondays, Wednesdays, and Fridays and the number of counters can be reduced during the slow arrival rate in the later 02 hours and on Tuesdays, Thursdays, and Saturdays.

Other methods to reduce queuing can also be adopted like having an appointment system for review patients not requiring them to go to the central registration counter.Decentralized registration can also be considered where the patients especially the review patients having valid patient booklet can register directly at the OPD rather than coming to the central registration. However, the data of the patients registered in decentralized OPD should be readily available to the administration for better management. Ideally, this can work if there is a Hospital Information System with a LAN network between the Central registration, OPDs and the Administration for real-time feedback. With better availability, affordability and accessibility of the internet as well as increasing awareness and usage of information technology, by the general population online registration can also be considered.

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