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AN EMPIRICAL STUDY OF QUEUING ANALYSIS OF PUBLIC AND PRIVATE HOSPITALS OF SOUTHERN RAJASTHAN

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Abstract

A hospital service is one of the most highly congested fields of hospitality services and faces a great deal of pressure, compared with any other hospitality services. Delays in the hospital system may result in difficulties of scheduling services at any units and decrease in patient satisfaction. So waiting times in health services is a wide spread problem which affects the quality of services as well. With the help of queuing analysis/waiting line model of every hospital it can be examined for every scenario that how much time a patient spent in queue and system and what is average time of waiting in queue and system in various time frames captured through the questionnaire. This analysis supports management to identify that in which time slot more effective management is required to reduce the service delays.

In this research paper for the purpose of data collection 2 public and 2 private hospitals of southern Rajasthan has been used.

Key Words: *- Health Care System, Waiting Line Model, Queuing Analysis, Decision-Making.*

1.1 Queuing Analysis Of Study Area Hospitals

The basic purposes of examining the admission process in any hospital were the purpose of documenting the existing process and its congestion or bottlenecks points, to determine the waiting time distribution, and developing the recommendations for modifying the outline and staffing of the system to reduce the waiting time for patients. The queuing model adopted assumes that daily admission rates (average arrivals) follow a Poisson distribution (coefficient of variation=1) in consonance with some studies which follows a Poisson distribution (**McManus et al, 2004: Green, 2002; Arnoud, et al, 2007**).

Although the study area hospitals confirmed that they experience overcrowding most of the times and in such situation patients get treated get discharged to create the space for new patient arrival. The arrival data were considered over period of 24 hours based on the medical personnel shift as it is in developed countries. Although, the arrivals at night shift were very low but they were included in the study. Among the reasons that contribute to low patronage at night is our peculiar situations of less human activities at night because of our working hours, insecurity and lack of adequate social amenities such as electricity and ambulance, etc.

1.2 Research Design

This study emphasize on applicability of waiting line model / queuing theory in hospital sector means research focuses on a set of issues of a single type of organization unit in this research it is health care industry (Hospitals) locate in five different districts of study area in southern Rajasthan.

1.2.1 Sampling Procedure

The present study is confined to study the applicability of waiting line model in health care sector with special reference to the hospitals of two districts of southern Rajasthan, India. These **two districts are Udaipur, Banswara**. As respondent two major elements of health care system that is doctors and patients were selected because one side is service provider and one side demands for service.

1.2.2 Sampling Procedure for Hospitals

A list of participating hospitals is given in Table 1.1. This list is district wise hospitals name of both private and public / government sector.

Table 1.1: Participating Hospitals in Research

S. No.	District	Type	Name of Hospital
1	**Udaipur**	Private	G.B.H. American Hospital, BhattJi Ki Bari, Udaipur
		Public	Maharana Bhopal General Hospital, Nr. Chetak Circle
2	**Banswara**	Private	Laddha Hospital, Sindhi Colony, Banswara City
		Public	General Hospital, Banswara

1.3 Objectives Of The Study

1. To assess the applicability of Waiting Line Model in proper Management of hospitals.
2. To present the waiting line model's mathematical computation for reception counter of study area's public and private hospitals with reference to indoor and outdoor patients.
3. To interrogate selected functionaries including the administrator/manager of respondent hospitals about the applicability of waiting Line model.

1.4 Sources Of Data Collection

The data were recorded from the sing in log, reception register, tracking sheets, transition from sign in to admitting arrangement processing (i.e. waiting in the waiting area), arrival to the reception counter or registration desk, hospital information system, and departure from the system to a specialty unit or out of the system.

Modified M/M/s queuing model was used to achieve the objectives of this study. A classic M/M/s, or Erlang delay model, assumes a single queue with unlimited waiting room that feeds into identical servers. Patients arrive according to a Poisson process with a constant rate and the service duration has an exponential distribution (**Hall 1990**). In healthcare, the Poisson process has been identified as an optimal representation of unscheduled arrivals to various systems (**Kim et al 1999, Green et al 2005**). Since in our case the majority of out-patient non-emergent visits were not scheduled we used the Poisson distribution for arrival process in the models. After an extensive statistical analysis of the collected data, it was determined that the service rate had a Poisson distribution as well. M/M/s model assumes that the arrival rate does not change over the day, to model our system (that had a fluctuating arrival rate) we used the M/M/s model as a part of a SIPP (stationary independent period-by-period) approach to determine how to vary staff to meet changing demand. The SIPP approach starts with dividing the day into staffing periods, then a series of M/M/s models are constructed. After that, each of these periods is separately analyzed and solved for optimal number of servers to meet the target service requirements (**Green 2005).**

There are several possible ways of improving patient flow, and thereby reducing waiting time for the patients. These **include (1) Increasing the number of servers; (2) Managing the arrival rate; and (3) Optimizing the service rate.** The number of servers can be increased by hiring more admitting clerks. This is the most obvious by not necessarily the best decision. The most effective approach to improvement should involve optimization of all three variables mentioned above. The arrival rate should be decreased during busy times and increased during "slow" periods. Scheduling arrivals would modify the arrival rate to the necessary degree.

As stated earlier, Poisson arrivals and exponential distribution were used to describe the hospital admissions and service times (length of stay) respectively. The steady state analysis of admission unit of the study area hospitals using the M/M/∞ to model is presented tables below from 1.2 to 1.12. This implies that over time the fluctuations in arrival rate are overlooked or neglected to assume a steady state. **This model helps to determine the efficiency and effectiveness of the selected units.**

1.5 Queuing Output Analysis

Table 1.2: G.B.H. American Hospital, Udaipur Admission Department Analysis

Current Model	7.00-8.00 A.M.	11.00- 12.00 P.M.	5.00 -7.00 P.M.

INPUTS:			
Number of servers	2	3	3
Mean Service time (min. / server)	28	20	13
Arrival Rate (Units / Hour)	14	12	9

Application of queuing theory in admission unit of G.B.H. American hospital, Udaipur

Scenario 1 - (M/M/2): (FCFS/infinity/infinity)

Lambda = 14.00000; Mu = 28.00000; Lambda eff = 14.00000;

Rho = 0.50000 Rho/c = 0.25000; Ls = 1.00000;

Lq = 0.50000; Ws = 0.07142; Wq = 0.03571.

Table 1.3: Results of (M/M/2): (FCFS/infinity/infinity)

N	Probability, Pn	Cumulative, Pn
0	0.12500	0.12500
1	0.27844	0.40344
2	0.17845	0.58189
3	0.15444	0.73633
4	0.08746	0.82379
5	0.06333	0.88712
6	0.04673	0.93385
7	0.03429	0.96184
8	0.01192	0.98006
9	0.00937	0.98943
10	0.00889	0.99832
11	0.00116	0.99948

Scenario 2-(M/M/3): (FCFS/infinity/infinity)

Lambda = 12.00000; Mu = 20.00000; Lambda eff = 12.00000;

Rho = 0.60000 Rho/c = 0.20000; Ls = 1.50000;

Lq = 0.90000; Ws = 0.12500; Wq = 0.07500.

Table 1.4: Results of (M/M/3): (FCFS/infinity/infinity)

N	Probability, Pn	Cumulative, Pn
0	0.14400	0.14400
1	0.26688	0.41088
2	0.18751	0.59839
3	0.18899	0.78738
4	0.09882	0.88620
5	0.04933	0.93553
6	0.03673	0.97226
7	0.01929	0.99155
8	0.00092	0.99247
9	0.00067	0.99314
10	0.00049	0.99363

Scenario 3-(M/M/3): (FCFS/infinity/infinity)

Lambda = 9.00000; Mu = 13.00000; Lambda eff = 9.00000; Rho = 0.69230 Rho/c = 0.23076; Ls = 2.24991;

Lq = 1.55761; Ws = 0.24999; Wq = 0.17306.

Table 1.5: Results of (M/M/3): (FCFS/infinity/infinity)

N	Probability, Pn	Cumulative, Pn
0	0.14747	0.14747
1	0.29591	0.44338
2	0.22847	0.67185
3	0.19387	0.86572
4	0.07225	0.93797
5	0.03328	0.97125
6	0.01984	0.99109
7	0.00612	0.99721
8	0.00211	0.99932
9	0.00047	0.99979
10	0.00018	0.99997

Table 1.6: Comparative Analysis of Application of Queuing theory in Admission unit of G.B.H. American Hospital, Udaipur

S*	C	Lambda	Mu	L'daeff	P_0	Ls	Lq	Ws	Wq
1	2	14.0000	28.0000	14.0000	0.12500	1.00000	0.50000	0.07142	0.03571
2	3	12.0000	20.0000	12.0000	0.14400	1.50000	0.90000	0.12500	0.07500
3	3	9.0000	13.0000	9.0000	0.14747	2.24991	1.55761	0.24999	0.17306

S*= Scenario

In scenario one, where the arrival rate (Lambda effective) =14 patients; number of servers were 2 and service rate (Mu) is 28 patients. The system performance parameters are as follows:

Lq = 0.50000. This implies there are 0.50000 patients in the queue waiting to be served by doctors.

Ls = 1.00000. This measures the average number of patients in the system. That is, there are 1.00000 patients in the system.

Wq = 0.03571, meaning that patients spent 0.03571 hour on the queue waiting to be attended to by the doctor.

Ws = 0.07142 this means that patients spent 0.07142 hour in the system. The time spent before joining the queue, waiting in the queue to be served and time spent after being served before departure.

In scenario two, where the arrival rate (Lambda effective) =12 patients; number of servers were 3 and service rate (Mu) is 20 patients. The system performance parameters are as follows:

Lq = 0.90000. This implies there are 0.90000 patients in the queue waiting to be served by doctors.

Ls = 1.50000. This measures the average number of patients in the system. That is, there are 1.50000 patients in the system.

Wq = 0.07500, meaning that patients spent 0.07500 hour on the queue waiting to be attended to by the doctor.

Ws = 0.12500 this means that patients spent 0.12500 hour in the system. The time spent before joining the queue, waiting in the queue to be served and time spent after being served before departure.

In scenario 3, the arrival rate per hour is 9 patients, 13 of them were served within an hour by 3 doctors. The number of patients in the queue and system is 1.55761 and 2.24991 respectively. The patients spent 0.17306 hour and 0.24999 hour in the queue and system.

Table 1.7: M.B. Hospital, Udaipur Admission Department Analysis

Current Model	**7.00-8.00 A.M.**	**11.00-12.00 P.M.**	**5.00 - 7.00 P.M.**
INPUTS:			
Number of servers	3	3	3
Mean Service time (min. / server)	39	45.87	44.27
Arrival Rate (Units / Hour)	18	22	22

Queuing output analysis for M.B. General Hospital is performed for the three scenarios with the same number of servers and different arrival rate.

Table 1.8: Comparative Analysis of Application of Queuing theory in Admission unit of M.B. Hospital, Udaipur

S*	C	Lambda	Mu	L'daeff	P_0	Ls	Lq	Ws	Wq
1	3	18.0000	39.00000	18.0000	0.11469	1.19154	0.73001	0.05416	0.03318
2	3	22.0000	45.87000	22.0000	0.11970	0.92165	0.44204	0.04189	0.02009
3	3	22.0000	44.27000	22.0000	0.12423	0.98787	0.49092	0.04490	0.02231

S*= Scenario

In scenario one, where the arrival rate (Lambda effective) =18 patients; number of servers were 3 and service rate (Mu) is 39 patients. The system performance parameters are as follows:

Lq = 0.39560. This implies there are 0.39560 patients in the queue waiting to be served by doctors.

Ls = 0.85713. This measures the average number of patients in the system. That is, there are 0.85713 patients in the system.

Wq = 0.02197, meaning that patients spent 0.02197 hour on the queue waiting to be attended to by the doctor.

Ws = 0.04761 this means that patients spent 0.04761 hour in the system. The time spent before joining the queue, waiting in the queue to be served and time spent after being served before departure.

In scenario 2, the arrival rate per hour is 22 patients, 45.87000 of them were served within an hour by 3 doctors. The number of patients in the queue and system is 0.44204 and 0.92165 respectively. The patients spent 0.02009 hour and 0.04189 hour in the queue and system.

In scenario 3, the arrival rate per hour is 22 patients, 44.27000 of them were served within an hour by 3 doctors. The number of patients in the queue and system is 0.49092 and 0.98787 respectively. The patients spent 0.02231 hour and 0.04490 hour in the queue and system.

Table 1.9: Laddha Hospital, Banswara Admission Department Analysis

Current Model	10.00- 11.00 P.M.	2.00 -3.00 P.M.
INPUTS:		
Number of servers	4	3
Mean Service time (min. / server)	21.37	18.09
Arrival Rate (Units / Hour)	15	15

Queuing output analysis for Laddha Hospital, Banswara is performed for the two different scenarios with four and three servers and for different arrival rate. The statistical presentation of queuing theory application is similar as above.

Table 1.10: Comparative Analysis of Application of Queuing theory in Admission unit of Laddha Hospital, Banswara

S*	C	Lambda	Mu	L'daeff	P_0	Ls	Lq	Ws	Wq
1	4	15.00000	21.37000	15.00000	0.14685	2.35477	1.65286	0.15698	0.11019
2	3	15.00000	18.09000	15.00000	0.11744	4.85436	4.02518	0.32362	0.26834

S*= Scenario

In scenario one, where the arrival rate (Lambda effective) =15.00000 patients; number of servers were 4 and service rate (Mu) is 21.37000 patients. The system performance parameters are as follows:

Lq = 1.65286. This implies there are 1.65286 patients in the queue waiting to be served by doctors.

Ls = 2.35477. This measures the average number of patients in the system. That is, there are 2.35477 patients in the system.

Wq = 0.11019, meaning that patients spent 0.11019 hour on the queue waiting to be attended to by the doctor.

Ws = 0.15698 this means that patients spent 0.15698 hour in the system. The time spent before joining the queue, waiting in the queue to be served and time spent after being served before departure.

In scenario 2, the arrival rate per hour is 15.00000 patients, 18.09000 of them were served within an hour by 3 doctors. The number of patients in the queue and system is 4.02518 and 4.85436 respectively. The patients spent 0.26834 hour and 0.32362 hour in the queue and system.

Table 1.11: General Hospital, Banswara Admission Department Analysis

Current Model	**7.00-8.00 A.M.**	**11.00-12.00 P.M.**	**5.00-7.00 P.M.**
INPUTS:			
Number of servers	2	4	4
Mean Service time (min. / server)	17.61	24	21
Arrival Rate (Units / Hour)	14	16	16

Queuing output analysis for General Hospital, Banswara is performed for the three different scenarios with two, four and four servers and for different arrival rate. The related statistical staging of queuing theory application is same as above.

Table 1.12: Comparative Analysis of Application of Queuing theory in Admission unit of General Hospital, Banswara

S*	**C**	**Lambda**	**Mu**	**L'daeff**	**P_0**	**Ls**	**Lq**	**Ws**	**Wq**
1	2	14.00000	17.61000	14.00000	0.12956	3.87811	3.08311	0.27700	0.22022
2	4	16.00000	24.0000	16.00000	0.14814	1.99999	1.33333	0.12499	0.08333
3	4	16.0000	21.0000	16.00000	0.13820	3.19999	2.43809	0.19999	0.15238

S*= Scenario

In scenario one, where the arrival rate (Lambda effective) =14.00000 patients; number of servers were 2 and service rate (Mu) is 17.61000 patients. The system performance parameters are as follows:

Lq = 3.08311. This implies there are 3.08311 patients in the queue waiting to be served by doctors.

Ls = 3.87811. This measures the average number of patients in the system. That is, there are 3.87811 patients in the system.

Wq = 0.22022, meaning that patients spent 0.22022 hour on the queue waiting to be attended to by the doctor.

Ws = 0.27700 this means that patients spent 0.27700 5hour in the system. The time spent before joining the queue, waiting in the queue to be served and time spent after being served before departure.

In scenario 2, the arrival rate per hour is 16.00000 patients, 24.00000 of them were served within an hour by 4 doctors. The number of patients in the queue and system is 1.33333 and 1.99999 respectively. The patients spent 0.08333 hour and 0.12499 hour in the queue and system.

In scenario 3, the arrival rate per hour is 16.0000 patients, 21.00000 of them were served within an hour by 4 doctors. The number of patients in the queue and system is 2.43809 and 3.19999 respectively. The patients spent 0.15238 hour and 0.19999 hour in the queue and system.

1.6 Specific Results

Poisson arrivals and exponential distribution were used to describe the hospital admissions and service times (length of stay) respectively. The steady state analysis of admission unit of the study area hospitals using the M/M/∞ to model was presented. The analysis is made on the basis of collected data at various time frames.

Application of Queuing theory in admission unit of private / public hospitals of study area:

G.B.H. American Hospital, Udaipur: - Three different scenarios were identified based on 7.00- 8.00 A.M., 11.00- 12.00 P.M. and 5.00- 7.00 P.M. time frame. Considering the comparative analysis of three scenarios it was found that rate of patient's arrival at hospital is highest in morning hour shift 7.00- 8.00 A.M. in comparison with other time shifts. Time spent in system by patients 4.28 minutes, 7.5 minutes and 14.9994 minutes consecutively according to time frames. So it can be identified that patients spent less time (4.28 minutes) in 7.00- 8.00 A.M. shift in comparison with other time shifts apart of this issue that is only two servers are there.

M.B. Hospital, Udaipur: - Three different scenarios were identified based on 7.00- 8.00 A.M., 11.00- 12.00 P.M. and 5.00- 7.00 P.M. time frame. Considering the comparative analysis of three scenarios it was found that rate of patient's arrival at hospital is highest in 11.00- 12.00 P.M. hour shift in comparison with other time shifts. Time spent in system by patients 2.8566 minutes, 2.5134 minutes and 2.694 minutes consecutively according to time frames. So it can be identified that patients spent less time (2.5134 minutes) in 11.00- 12.00 P.M. shift in comparison with other time shifts where there are only three servers in services at admission unit that is because of patient flow is lesser.

Laddha Hospital, Banswara: - Two different scenarios were identified based on 10.00- 11.00 A.M. and 2.00- 3.00 P.M. time frame. Considering the comparative analysis of two scenarios it was found that rate of patient's arrival at hospital is highest in 10.00- 11.00 A.M. hour shift in comparison with other time shifts. Time spent in system by patients 9.4188 minutes and 19.4172 minutes consecutively according to time frames. So it can be identified that patients spent lesser time (9.4188 minutes) in 10.00- 11.00 A.M. shift in comparison with other time shifts because there are four service channels at admission unit.

General Hospital, Banswara: - Three different scenarios were identified based on 7.00- 8.00 A.M., 11.00- 12.00 P.M. and 5.00- 7.00 P.M. time frame. Considering the comparative analysis of three scenarios it was found that rate of patient's arrival at hospital is highest in 11.00- 12.00 P.M. hour shift in comparison with other time shifts. Time spent in system by patients 16.62 minutes, 7.9994 minutes and 11.9994 minutes consecutively according to time frames. So it can be identified that patients spent less time (7.9994 minutes) in 5.00- 7.00 P.M. shift in comparison with other time shifts where there are only four servers in services at admission unit that is because of patient flow is lesser.

1.7 Conclusions

In present scenario rapid growth of technologies is increasing expectation of patients for health care environment, which is recognized as customer satisfaction a measure of quality. In the delivery of medical service, individual patient needs, expectations and experiences will undoubtedly vary for several of reasons. Knowledge of the use of waiting line model / queuing model to determine system parameters is of value to health providers who seek to attract, keep and provide quality health care to patient in the ever-competitive "marketplace".

Queuing theory is one of the most prevailing and tested mathematical approach which can be used for analyzing waiting lines performance parameters for healthcare centers. Effective application of the model can help to improve access to quality at any unit of hospital system which is viewed as key to increase quality with special reference to resource utilization, availability of facilities & services, waiting time reduction and queue management methodologies. It is worth mentioning that queuing models are not the end in itself in decision making, they are just the beginning of the structuring of decision making framework.

1.8 Suggestions

This study attempts to study the applicability of waiting line model in health care system to measure its effectiveness and to identify the relationship between the servers and waiting lime delays. So overall composition of research paper focuses on, mathematical analysis of queuing model and other important analysis which works on identified constructs that persuades patients and their opinions.

The recommendations for improving the service quality, reducing the patient waiting time and increasing the satisfaction of patients could be classified under administrators, patients and doctors head.

1.8.1 Suggestions for Administrators

Administrative capabilities as a strategic tool for improving the service quality of hospital in terms of patient's satisfaction, reduction in waiting time, availability of resources plays a significant role. So that administrative group of a hospital should focus on following issues:

1. Systematic parking must be in hospital premises so that patients and their relatives waiting time for parking could reduce.
2. Separate reception unit for specific care like for admission unit, IC Unit, emergency department, so that this separation could maintain systematic flow at a particular unit which directly affect waiting time of a patient.
3. By increasing the number of servers / doctors for all the time frames according to patient flow.
4. Hospitals administrators must concentrates on infrastructure, availability of services and facilities, specialty and patient to hospital relation etc.
5. A proper record keeping system must be developed which can assist in various manners of service delivery and quality.
6. The medical equipment and technology need to be upgraded to meet international standard.
7. By the systematic arrangement of patients arrivals which can be done by different appointment systems.
8. By improving the timely distribution and arrival of services may reduce unnecessary patient congestion.
9. Paramedical staff must be trained for proper behavior with patients and enabled with technical equipments for fast service delivery.

10. Paramedical staff must be well trained for primary treatments of patients.

1.8.2 Suggestions for Doctors

Doctors are itself a resource of a hospital which should also be managed systematically for proper rendering of services to patients. Timely arrival of doctors is a big issue which affects the waiting time of a patient significantly. Doctors should perceive following issues for service quality management and improvement in patient's satisfaction:

1. On time arrival of doctors could manages the waiting time delay of patients.
2. Proper classified direction of patients to doctor according to problem or disease could improve the delays.
3. Schedule of doctors / their visiting hours must be displayed on information board for patients so that they could identify that the doctors for whom they are looking for are available or not without joining the queue.
4. The doctors should display the corresponding information regarding the reports they requires for particular checkup.
5. Proper appointment must be scheduled for average flow of patients.
6. Proper guidelines should give to patients so that they can make it sure that where they could go for proper service.
7. Doctors must come with all the essential apparatus they required during checkups.
8. Next visit of patients must be guided properly so that they could ensure that they should come for next checkup or not.
9. Proper card system must be developed for patients require regular checkups, which can reduce the checkup time delay.
10. Doctors always should be ready to handle the over crowd of patients during any calamity for seasonal diseases.

1.8.3 Suggestions for Patients

Generally improvement in the patient flow, systematic service availability to patients and reduction in service delay time for patients can be achieved by following ways:

1. Patients should follow the guidelines published by hospitals and doctors on information board.
2. Should follow proper appointment time frame assigned to you to visit a doctor or to avail a service like report collection.
3. Should be very careful for the uses of resources like electricity, water etc., should not waste the resources.
4. Should be aware about the camps organized for awareness related to specific disease.

5. Relatives and others should follow the visiting hours for patients and doctors as well.
6. Should be sensitive towards the uses of free facility provided by hospital administration or government as well.
7. Should contribute to keep hospital clean and clear.
8. Be care full for the notices and information published on information board.
9. Be cooperative with the hospital management for managing the resources and facilities.
10. Systematic and proper treatment is Patinet's right.

Furthermore, hospital management should reveal various unidentified issues in front of researchers so that researcher could develop a model to facilitate the issue to improve the service quality and delivery. A proper cooperation with researcher and policy makers may definitely give a proper direction to service delivery. They should know that relationship between size and quality of service is a vital issue in capacity planning. Also important is quality information concerning cost structures and revenue characteristics and how these affect capacity and resource allocation decisions.

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