

Comparative Study on Different Queuing Models to Reduce Waiting Time in Brahmaso Clinic

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***Abstract*—**The Brahmaso Humanitarian Aid Organization (BHAO) is the most popular philanthropic organization in Myanmar. It provides various kinds of aids for human including healthcare service with free of charge. It stands only on donation from public. Total of sixteen units for health problems are provided. The purpose of this paper is to perform a comparative study for reduction of total patients' waiting time in the clinic by considering for different departments of clinic such as patient's registration and pre-checkup department, consultation department, and treatment and pharmacy department under the general diseases unit using different queuing models. Different parameters such as arrival rate, service rate, utilization factor, average number of patient in the system, average number of patient in the queue, average waiting time in the system, and average waiting time in the queue are analyzed and compared for different multiserver queuing models. Actually, waiting on a queue is usually unpleasant for everyone, but reduction in waiting time requires planning and extra expenditures. This paper is an attempt to compare the parameters of queuing theory in a local clinic and the calculations performed in this paper is based upon the actual observed data collected from Brahmaso Humanitarian Aid Organization charity special clinic for 14 days which is located in Mandalay city, Myanmar. The required data and information are collected from "pamphlets", "direct observation", "daily and monthly records", "yearly reviewed report" and "interviews". Multiple servers M/M/2 to M/M/3 and M/M/4 to M/M/5 queuing models have been considered in order to reduce waiting time and also analyze and compare queuing parameters and performance measures of the system.

***Index Terms*—** arrival rate, service rate, waiting time, queuing theory, multiserver queuing model, general disease.

I. Introduction

The Brahmaso Humanitarian Aid Organization was established in 1998 with five working plans, namely, funeral services, health, natural disaster relief, donations of blood, liver and kidney and education. Total of sixteen units for health problems are provided under health care clinic and the main unit is general disease (internal medicine) unit in which relatively very high numbers of patients were taken treatment there. Therefore, this study mainly focused to reduce the waiting times for general disease unit. The health care clinic is opened from 8 a.m. to 12 noon only on Wednesday and weekends. A large number of patients' traffic can be seen from early morning to the noon in front of the clinic on those days. Queuing theory deals with one of the most unpleasant experiences of life, called waiting. Queuing is quite common in many fields, for example, in traffic management, in a supermarket, at a petrol station, at the banks, at health care centers etc. [1]. Therefore, to reduce the waiting times of arriving patients is a major challenge for all services all over the world, particularly in the developing countries [2]. Nowadays all the organizations are focusing to customers in particularly the health care organizations have advanced and progressed [3].

According to the survey results, the clinic of BHAO is opened 13 days or 14 days per month and average numbers of 4300 patients are taking treatments on these days and hence round about 330 patients are served per day. Again, according to their reviewed records, the patients from 92.85% of townships in Mandalay region, 52.94% of all states and regions, and 20.90% of townships in the whole country were received treatment at BHAO charity special clinic.

Although the operation of the clinic is started at 8 a.m., but the patients and their attendants arrive to clinic round about at 6 a.m. in the morning to queue for service. There is only one registration department for all patients and every patient makes a patient registration book. Then nurses examine for required pre-checkup for consultation such as body temperature and blood pressure of each patient. Then the staffs from registration department were classified according to diseases and guided the patients where they must continue to receive consultation and treatment.

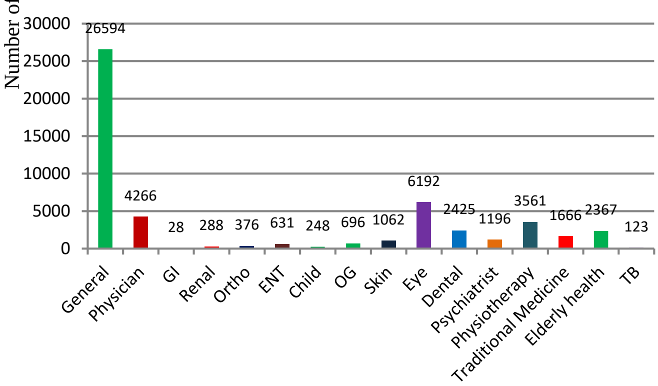

Fig. 1. Comparison of the number of patients according to types of diseases from April 2018 to March 2019.

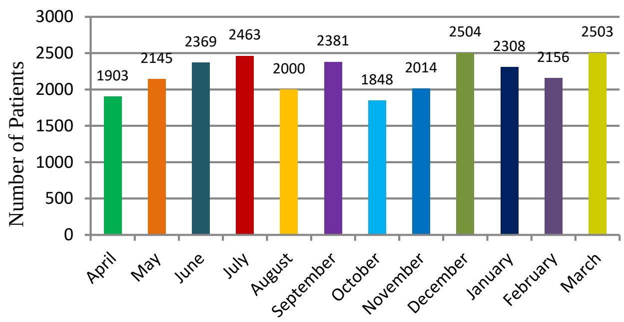

Fig. 2. The number of general disease patients monthly from April 2018 to March 2019.

By analyzing the patients and diseases records, the numbers of general disease patients were very high compared with other diseases. Therefore, in this paper the waiting times for patients from that unit were specifically considered to reduce.

There are 46 physicians, 40 senior and junior general specialists, 38 senior and junior nurses, 20 medical skill workers, 100 volunteers and 36 staffs in the clinic. Most of the physicians and specialists are in-service from General Hospital (Mandalay) and some have already retired from government servants and working as honourable professors. All these physicians and specialists came alternately to the clinic voluntarily.

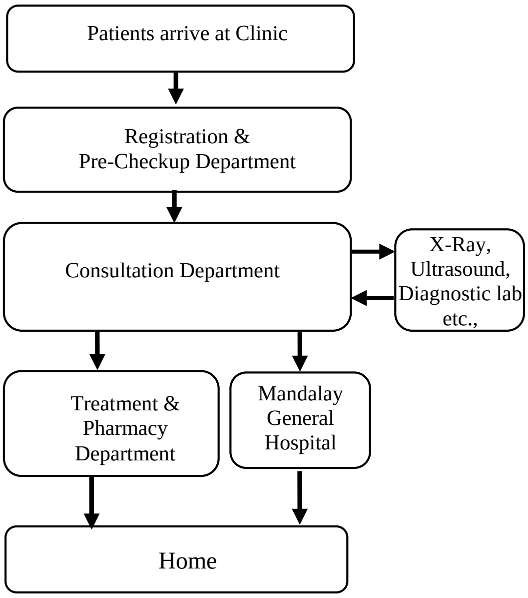

Fig. 3. The flow chart of BHAO charity special clinic

There are total of four servers in consultation department for general disease and consulted by physicians and specialists alternately. If the patients are needed to check by X-ray, ultrasound, and other diagnostic tests, they checked in respective department and resubmitted the results back to physicians and specialists. Then specialists examined the tested results and determined the type of diseases. Sometime the patients were necessary to operate surgery urgently, in this case they advised to go to Mandalay General Hospital for operation and treatment. Otherwise, they give instruction to take treatment and pharmacy in treatment and pharmacy department in the clinic. The patients were needed to wait (queue) in three departments in general diseases unit, namely, registration and pre-checkup department, consultation department, and treatment and pharmacy department. The waiting time for consultation department and treatment and pharmacy department are needed to reduce. Therefore we considered by increasing servers there. The waiting time for registration and pre-checkup department was also considered to get the totals waiting time for the whole system (clinic). Multiserver queuing models were used in all three departments.

II. Materials and Method

Although a lot of contribution and application of queuing theory in the field of health care are found in the literature, considerable challenges and difficulties are still remained to reduce waiting time in health care centers. Queuing theory is a mathematical approach to the study of waiting lines. In the BHAO charity special clinic, multiserver queuing model M/M/3 is used at registration and pre-checkup department, M/M/4 and M/M/2 are used in consultation department and pharmacy and treatment department respectively. In this paper, we considered multiple servers M/M/5 instead of M/M/4 in consultation department and M/M/3 in the place of M/M/2 in treatment and pharmacy department in order to analyze queuing parameters, and performance measures of the system to reduce waiting time. The descriptions of the queuing models that we used in this research are presented as follows:

A. Multichannel Queuing System

The multichannel queuing model is known in the Kendall's notation as the M/M/c model, where M/M represents the Poisson probability distribution of arrivals and departures and the positive integer *c* is the number of parallel servers in the system [4]. Exponentially distributed random variables are denoted by *M*, meaning Markovain or memoryless [1]. This is commonly used to analyze the queuing problem. In this paper, we considered single queue line served by multiple servers and this type of queuing model can also be seen at a bank teller or many airline tickets counters [5].

Most of the queuing models are assumed the probability distribution of the arrival time and the service time as an exponential distribution and the number of arriving patients per unit of time follows Poisson distribution. The exponential distribution incorporates the assumption that the service time is independent on the time spent in the queue and the Poisson distribution involves a "memoryless" waiting time until the arrival of the next customer (patients) respectively [6].

Consider the Probabilistic queuing model (M/M/4: FCFS, Priority) for multiservers with queuing discipline First Come First Serve and priority (Buddhist religious servants, old-aged patients and patients who need the service immediately for many reasons are priority) queuing system in which arriving customers is following Poisson's process with arrival rate λ and the service process is exponential distribution with service rate μ [7].

Traffic intensity (ρ) is the known values in a calculation of performance measure of the system. For multichannel queuing system, the traffic intensity can be obtained as $\rho = \frac{\lambda}{c\mu}$, the larger the value of λ, the longer the queue will be. If the arrival rate of patients in the system were more than service rate. i.e., $\lambda > \mu$ and hence $\rho > 1$, then the queue length was increased.

For multiservers queuing model, the probability that the system should be idle,

$$P_0 = \left[\sum_{n=0}^{c-1} \frac{1}{n!}\left(\frac{\lambda}{\mu}\right)^n + \frac{1}{c!}\left(\frac{\lambda}{\mu}\right)^c \frac{c\mu}{c\mu - \lambda}\right]^{-1} . \qquad (1)$$

The average number of patients in the system,

$$L_s = \frac{\lambda\mu\left(\frac{\lambda}{\mu}\right)^c}{(c-1)!\,(c\mu-\lambda)^2} P_0 + \frac{\lambda}{\mu} . \qquad (2)$$

The average number of patients waiting in the queue,

$$L_q = L_s - \text{average number being served}$$

$$= L_s - c\left(\frac{\lambda}{c\mu}\right)$$

$$= \frac{\lambda\mu\left(\frac{\lambda}{\mu}\right)^c}{(c-1)!\,(c\mu-\lambda)^2} P_0 . \qquad (3)$$

Average waiting time a customer spends in the system,

$$W_s = \frac{L_s}{\lambda} . \qquad (4)$$

Average waiting time of a customer in the queue,

$$W_q = \frac{L_q}{\lambda} . \qquad (5)$$

Traffic intensity for multiserver, $\rho = \frac{\lambda}{c\mu}$.

The probability of not queuing on the arrival = $1 - \rho$.

B. Model Parameters in Queuing Theory

To characterize a queuing system we have to identify the probabilistic properties of the arrival time, service times and service disciplines. The parameters that we have to determine to analyze the different queuing models are described in following table.

TABLE I. PARAMETERS AND THEIR DEFINITIONS IN QUEUING MODELS

Parameter	Definition
n	Number of patients in the clinic
c	Number of parallel servers.
λ	The arrivals rate in the clinic.
μ	The service rate in the clinic
$c\mu$	Serving rate when $c > 1$ in a system
ρ	Traffic intensity
P_0	Steady state probability of all idle servers in the clinic.
P_n	Steady state probability exactly n patients in the clinic.
W_q	Average waiting time a patient spends in the queue
W_s	Expected time a patient spends in the system
L_q	Average number of patients in the queue
L_s	Expected number of patients in the system

III. Results and Discussion

Multiserver queuing models can be applied to treat the condition in which there are several servers in parallel and each patient in the waiting line can be served by more than one service. Each service facility is prepared to deliver the same type of service [5]. In the Brahmaso clinic, three different multi servers queuing models have been used to serve at three different departments, namely, three servers at registration and pre-checkup department for all patients, four servers and two servers for consultation department, and treatment and pharmacy department respectively for general disease patients. Observed data shows total of 4480 patients were arrived at registration and pre-checkup department in 14 days with arrival rate $\lambda = 1.3333/min$, service rate $\mu = 0.5211/min$ and number of servers $c = 3$. Therefore traffic intensity $\rho = 0.8529$. This reveals that the service system was adequate at registration and pre-checkup department. After passing registration and pre-checkup department, they continued respective departments to get the consultation and treatment according to their types of diseases. The study for this case is on the basis of actual observed data collection in 14 days of service for 2503 patients from general diseases unit.

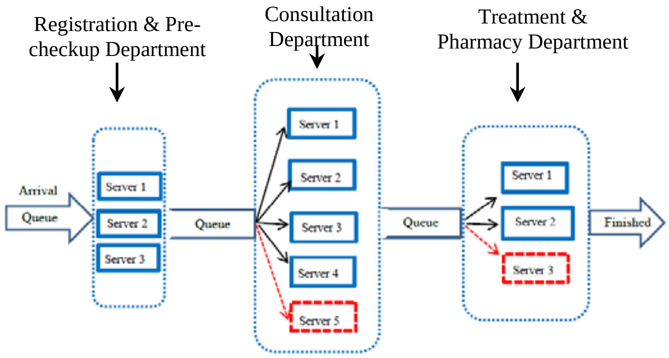

Fig. 4. Single queues with multiserver queuing model at BHAO clinic.

A. Multiserver Queuing Models for Consultation Department

Now we consider four parallel servers of the same services with single queuing line in consultation department. We focused the arrival time as well as the time service began and ended for 2503 general disease patients in the BHAO charity special clinic. A total of 14 days were used for the data collection at consultation department. Based actual observed collected data;

The total waiting time of 2503 patients for 14 days = 3480 minutes.

Total service time of 2503 patients for 14 days = 12515 minutes.

Using the model parameters for the multiserver queuing model, the arrival rate,

$$\lambda = \frac{\text{Total number of patients}}{\text{Total waiting time}}.$$
$$= \frac{2503}{3480}.$$
$$\lambda = 0.7193/min.$$

The service rate,

$$\mu = \frac{\text{Total number of patients}}{\text{Total service time}}.$$
$$= \frac{2503}{12515}.$$
$$= 0.2/min$$

Using the model parameters for the multiserver M/M/4 queuing model with arrival rate, $\lambda = 0.7193/\text{min}$, service rate, $\mu = 0.2/\text{min}$, and the number of servers $c = 4$, the probability that the system should be idle, (1) becomes

$$P_0 = \left[\frac{1}{0!}\left(\frac{\lambda}{\mu}\right)^0 + \frac{1}{1!}\left(\frac{\lambda}{\mu}\right)^1 + \frac{1}{2!}\left(\frac{\lambda}{\mu}\right)^2 + \frac{1}{3!}\left(\frac{\lambda}{\mu}\right)^3 + \frac{1}{4!}\left(\frac{\lambda}{\mu}\right)^4 \frac{4\mu}{4\mu - \lambda}\right]^{-1}$$
$$= [1 + 3.5965 + 6.4674 + 7.7533 + 6.9712(9.9133)]^{-1}$$
$$= 0.01137.$$

From (2),

$$L_s = \frac{0.1439(3.5965)^4}{3!\,(0.8 - 0.7193)^2}(0.01137) + 3.5965$$
$$= 10.6022 \approx 11 \text{ patients}.$$

From (3),

$$L_q = \frac{0.1439(3.5965)^4}{3!\,(0.8 - 0.7193)^2}(0.01137)$$
$$= 7.0057 \approx 7 \text{ patients}.$$

From (4),

$$W_s = \frac{L_s}{\lambda} = \frac{10.6022}{0.7193} = 14.7396 \text{ minutes}.$$

From (5),

$$W_q = \frac{L_q}{\lambda} = \frac{7.0057}{0.7193} = 9.7396 \text{ minutes}.$$

Traffic intensity,

$$\rho = \frac{\lambda}{c\mu} = \frac{0.7193}{4 \times 0.2} = 0.8991\,.$$

The probability of not queuing on the arrival,

$$= 1 - \rho = 1 - 0.8991 = 0.1009.$$

The traffic intensity $\rho = 0.8991$ of consultation depart-ment with multiserver queuing model M/M/4 shows the probability of queuing on arrival process. This represents the inadequate service system of the clinic. In this situation, we considered to reduce the waiting time for patients by increasing one more servers in that department (ie., M/M/5 queuing model).

Using the model parameters for the multiserver queuing model M/M/5 with the same arrival rate, $\lambda = 0.7193/\text{min}$, service rate, $\mu = 0.2/\text{min}$, and the number of servers $c = 5$, the average values for P_0, L_s, L_q, W_s, W_q can be obtained with the same formulas as follows:

$P_0 = 0.0229.$

$L_s = 4.6452 \approx 5$ patients.

$L_q = 1.0487 \approx 2$ patients.

$W_s = 6.4579$ minutes.

$W_q = 1.4579$ minutes.

$\rho = 0.7193.$

$1 - \rho = 1 - 0.7193 = 0.2807.$

B. Multiserver Queuing Models for Treatment and Pharmacy Department

Again, the parameters of the two parallel servers of the same services in treatment and pharmacy department were considered. The arrival rate, $\lambda = 0.9571/\text{min}$, service rate, $\mu = 0.49/\text{min}$, and the number of servers $c = 2$, and the total number of 3215 patients for 14 days were used. By applying the same formulas of as above, we obtained the following average values;

$L_s = 42.2888 \approx 43$ patients
$L_q = 40.3356 \approx 41$ patients
$W_s = 44.1844$ minutes.
$W_q = 42.1435$ minutes.
$\rho = 0.9766.$
$1 - \rho = 1 - 0.9766 = 0.0234.$

Then we assumed for the multiserver queuing model M/M/3 by increasing one more servers in that department with the same arrival rate λ, service rate μ, and the number of servers $c = 3$, the average values of parameters become,

$L_s = 2.7421 \approx 3$ patients.
$L_q = 0.7889 \approx 1$ patients
$W_s = 2.865$ minutes.
$W_q = 0.8242$ minute.
$\rho = 0.6511.$
$1 - \rho = 0.3489.$

Finally, we compared the results that obtained by increasing one more servers at consultation department, and treatment and pharmacy department to reduce the waiting times for patients. The comparison of the results can be seen following table.

TABLE II. COMPARING THE RESULTS OF MULTISERVER QUEUING MODELS

Comparison	**Multiserver M/M/3 at registration dept.**	**Comparison of total results by increasing a server at consultation dept.**		**Comparison of total results by increasing a server at treatment and pharmacy dept.**	
		M/M/4	***M/M/5***	***M/M/2***	***M/M/3***
Traffic intensity	0.8529	0.8991	0.7193	0.9766	0.6511
Expected number of patients in the system (L_s)	7 patients	11 patients	5 patients	43 patients	3 patients

Average number of patients in the queue (L_q)	4 patients	7 patients	2 patient	41 patients	1 patients
Expected time a patient spends in the system (W_s)	5.1158 minutes	14.7396 minutes	6.4579 minutes	44.1844 minutes	2.865 minutes
average waiting time of patients in the queue (W_q)	3.1968 minutes	9.7396 minutes	1.4579 minutes	42.1435 minutes	0.8242 minutes
The probability of new patient Arrival	0.1471	0.1009	0.2807	0.0234	0.3489

The comparison of the waiting times in the system and the waiting time in the queue before and after increasing server can be seen in Fig. 5.

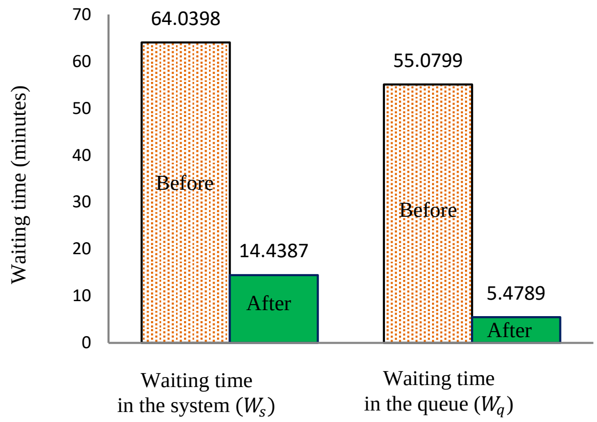

Fig. 5. Comparison of waiting times before and after increasing server

Total waiting time at the clinic for the general disease patients can be reduce from 64 minutes to 15 minutes by increasing one more server at consultation department, and treatment and pharmacy department of BHAO charity special clinic.

From the above comparison analysis it has been observed that waiting time of patients could be reduced by using multiple servers M/M/5 rather than M/M/4 server queuing model. The average number of patients in the queue is also less. The multiserver queuing model M/M/5 can be reduced 20% of traffic intensity from M/M/4 queuing model. The waiting times and the numbers of patients in the system have also been dramatically reduced in M/M/5 queuing model. On the other hand, the probability of new patients arrival in M/M/5 is higher than M/M/4.

IV. Conclusion and Recommendation

In this paper, the queuing characteristics at the Brahmaso Humanitarian Aid Organization charity special clinic are analyzed using multiserver queuing models in three departments under general diseases unit. The total waiting time for general disease patients in BHAO clinic was reduced and discussed comparatively increasing multiserver queuing models M/M/2 to M/M/3 and M/M/4 to M/M/5. According to the calculation results, it was obviously seen that the waiting time in the system has been reduced by increasing a server to queuing models M/M/4 and M/M/2. Therefore an increase in server of multiserver queuing system increases the efficiency of the clinic and reducing time compared to the original multiserver queuing systems.

As we have already mentioned in the introduction of this paper, the patients from 92.85% of townships in Mandalay region and other states and regions in the whole country came to the Brahmaso Humanitarian Aid Organization charity special clinic to take medical consultation and treatment. Most of the patients are deprived and in this situation, the management team of BHAO should be considered the patients' difficulties such as transportation and accommoda- tion charges. We recommend that one of the best ways to help and solve their difficulties is to provide the sufficient servers to reduce the waiting time for the patients. It has been observed that waiting time of patients could be reduced significantly by increasing a server to multiple servers M/M/4 and M/M/2 at consultation department and treatment and pharmacy department.

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