Effect of Variable Servers on Performance Measures of Model of Clinic Using Simulation

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***Abstract*—This paper illustrate the real life application of a queue. The application of queuing theory for daily-life problems has remained rather restricted. Aim of the present paper is to investigate the effect of changing the number of servers (doctors) on various performance measures. In this paper a computer model is considered which simulate an abstract model of a clinic. Various performance measures of queueing are studied taking a single server model. This model is redesigned to carry out performance measures for n-servers. On the basis of this model, effect of changing the number of servers (doctors) in this case, on various performance measures is investigated. Depending upon the practical situations one, two, three or four doctors are studied and its effect on the performance measures is taken on the excel sheet. Results help us in deciding whether there should be one, two, three or four doctors for a particular clinic.**

***Index Terms*—Arrival time, queueing model, service time, utilization factor.**

I. Introduction

Queues are very common in our day to day life. Earlang(1918) was the first person who laid the foundation for queueing theory. It was only since 1950 that the application of queueing to other fields also began. In the pre-computer era there was no possibility of getting numerical results except in very simple cases. Now through simulation one can get numerical results for almost any queueing situation. Tocher[1] wrote a book 'The Art of Simulation' in which the methods of simulation were discussed. Naylor et al.[2] published a book on 'Computer Simulation Techniques' on simulation of queues. Parzen[3] presented applications of multichannel queueing results to the analysis of conveyor systems. Jansson [4] wrote a book on 'Random Number Generators' regarding different methods of generating random numbers. Smith[5] discussed various models in a book on 'Computer Simulation Models'. Pritsker and Kiviat[6] presented some programs for simulating queues. Computer simulation applications were given by Rietman[7], however several real-life applications of queue were presented by Carter and Huzan[8].System simulation with digital computer was dealt by Deo[9]. Hall[10] discussed queueing methods for services and manufacturing. Fischer et al.[11]studied performance modeling of distributed automatic call distribution systems. Mandelbaum[12] presented queue lengths and waiting times for multi server queues with abandonment and retrials. Budnick et al.[13] wrote a book on 'Principles of Operations Research and Management'. Performance modeling of call center with skill-based routing has been discussed by Wallace[14]. Various waiting lines models have been presented by Sharma[15].

Aim of the present paper is to investigate the effect of changing the number of servers (doctors) on various performance measures.

II. Formulation of the Problem

The simplest model of queue assumes that

1) Customers arrive randomly,
2) There is only one service counter,
3) Time taken to serve a customer also varies randomly,
4) If the service counter is busy, then a queue is formed, and
5) Customers are served on a first-come-first basis.

Present model dealt with a single server queue based upon the model by Deo[9]. The model represents a clinic in which doctor is a server and his patients are customers(Fig.1). This model is generalized to n-servers. The arrival pattern of customers at a queueing system varies between one system and another, but one pattern of common occurrence in practice, is that of 'completely random arrivals'.

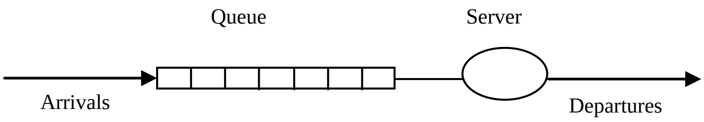

Fig. 1. Physical model.

If arrivals are 'completely random', the number of arrivals in unit time has a Poisson distribution Pn(t), which is given by

$$P_n(t) = \frac{(\lambda t)^n e^{-\lambda t}}{n!}, \tag{1}$$

where λ is the mean arrival rate and t is the time. The time between two consecutive arrivals i.e. inter arrival time is given by T, and a(T) denotes the probability density function of T. If n, the number of arrivals in time t, follows the poisson distribution, then T obeys the negative exponential law i.e.

$$a(T) = \lambda e^{-\lambda t}. \tag{2}$$

Similarly, if the time(t) to complete the service of a unit follows the exponential distribution given by the probability

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density function

$$s(t) = \mu e^{-\mu t} \qquad (3)$$

where μ is the mean servicing rate, then the number of departures will follow the Poisson distribution given by

$$\phi_T(n) = \frac{(\mu T)^n e^{-\mu t}}{n!} \qquad (4)$$

Utilization factor, which gives the efficiency of the system is denoted by ρ (=λ/ μ, λ/ μ< 1). The average queue length is the average number of patients in the system, and it is given by L (= λ/(λ- μ)). Average waiting time is the average time spent by a customer in the system which is denoted by W (= 1/(μ-λ)). The effect of changing the number of patients and number of customers on various performance measures are analyzed. The following performance measures of queues are taken into account:

1) Utilization(efficiency of the system),
2) Average queue length(average number of patients in the system),
3) Average waiting time(average time a customer spends in the system),
4) Total idle time(total idle time of the server i.e. the doctor),
5) Maximum queue length(maximum number of patients in the system), and
6) Maximum waiting time(maximum waiting time of the patient).

III. Solution of the Poblem

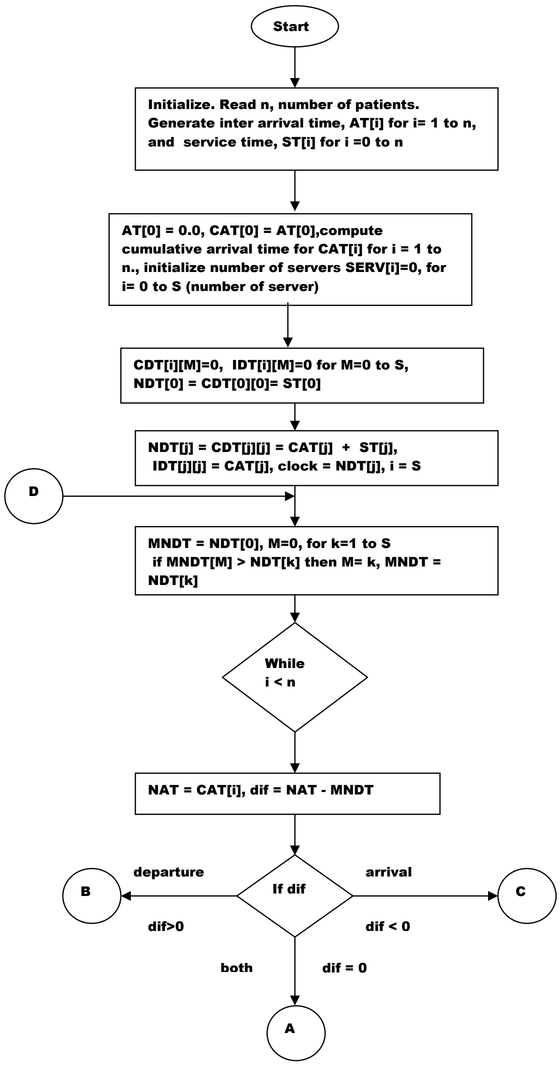
To implement simulation of model of clinic consisting various components, a programming in C is prepared and solved on computer, the flowchart for which is shown in Fig.2. In this, input inter arrival time and service time are the parameters. These times are generated with the help of a random function. A set of inter arrival time and service time with average values of λ and μ is generated. Initially there is no queue and also the server is free. Present model is tested on various datasets and result of one dataset are shown. Assuming average arrival rate per unit time λ= 3.0 and average service rate per unit time μ = 4.0, and both are exponentially distributed. The results are obtained by increasing the number of patients from 100 to 1000. Now for the same set, the procedure is repeated for two doctors, three doctors and four doctors. Excel Worksheet is used for generating various graphs from which conclusions can be drawn.

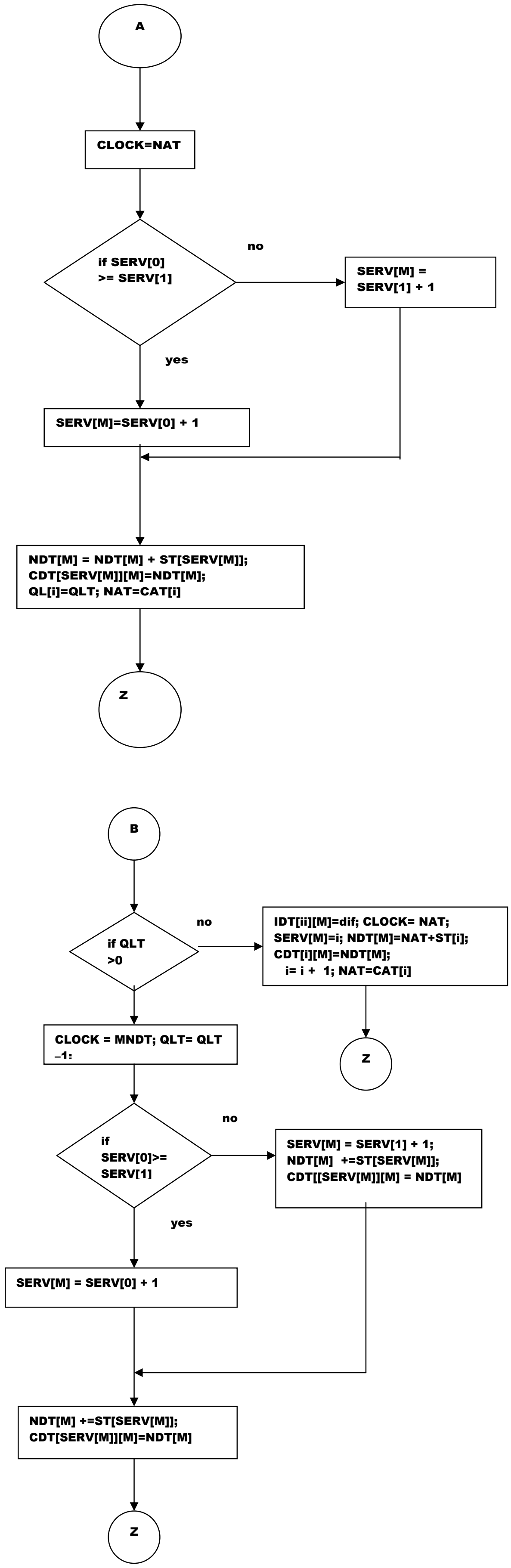
IV. Results and Discussion

Average waiting time is presented through Fig.3. It is observed that in case of a single doctor average waiting time increases as the number of patients increases. In case of four doctors, it increases and approaches zero as the number of patients increases and in case of two and three doctors, it is zero. Fig.4 shows the average queue length. In case of a single doctor, average queue length increases as the number of patients increases from 100 to 1000. In case of two, three and four doctors; average queue length is zero. Idle time is shown in Fig.5. In all the four cases, as the number of patients increases idle time also increases. Also, as the number of doctors increases from one to four, magnitude of idle time also increases. Maximum queue length is shown through Fig.6. For single server, maximum queue length increases as the number of patients increases and it becomes constant for more patients. In case of two, three and four doctors, maximum queue length is zero. Maximum waiting time is depicted through Fig.7. Maximum waiting time increases slowly for a single server. For two doctors it is zero and for three and four doctors it increases and then for more patients it becomes zero. Performance measure utilization factor is shown in Fig.8. This parameter is not affected much as the number of patients increases from 100 to 1000. But, as the number of doctors increases from one to four, utilization decreases. For single doctor, utilization is more than for two doctors and it even less for three doctors or four doctors.

V. Conclusions

In the present model the effect of number of doctors on various performance measures are studied. Depending upon the practical situation one , two, three or four doctors are studied.





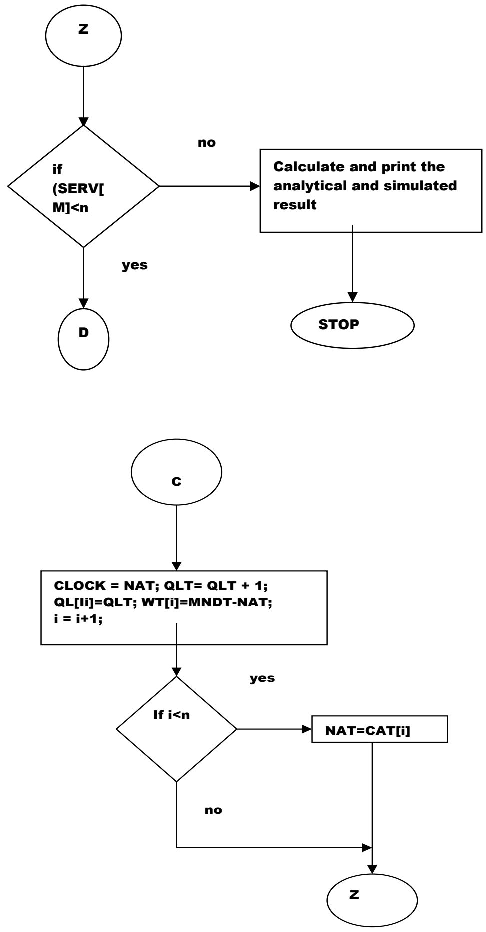


Fig. 2. Flowchart of the Program

1) If the space is less outside the clinic for patients to wait, then there should not be any queue. It is observed from Fig.4 and Fig.6 that in the case of a single doctor there is a queue and for two, three and four doctors there are no queues. Hence this can be considered for two, three and four doctors.
2) Most of the patients come from a population where they have a less time to wait, then from Fig.3 and Fig.7 it is preferred to have two, three and four doctors.
3) If the doctors are busy in other activities and are not able to devote much time to clinic, then two, three or four doctors can be assigned duties for better performance as shown in Fig.5.
4) If the utilization has to be considered, then the model having a single doctor is best as observed from Fig.8.

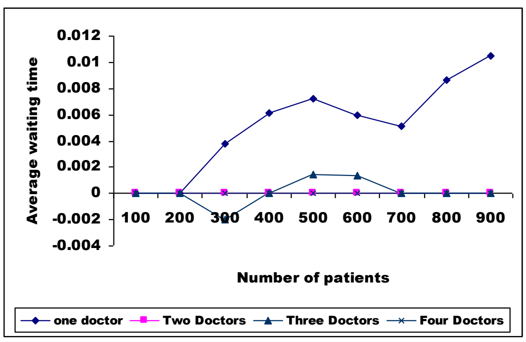


Fig. 3. Number of patients versus average waiting time(WT)

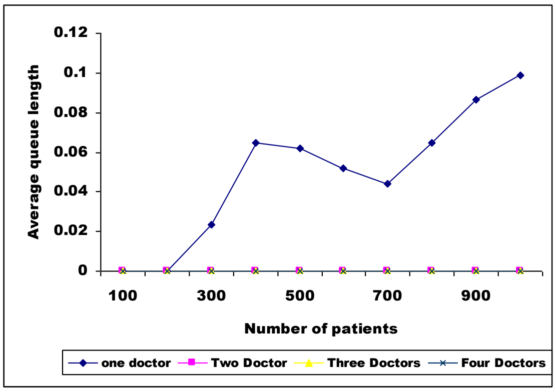


Fig. 4. Number of patients versus average queuelength(QL)

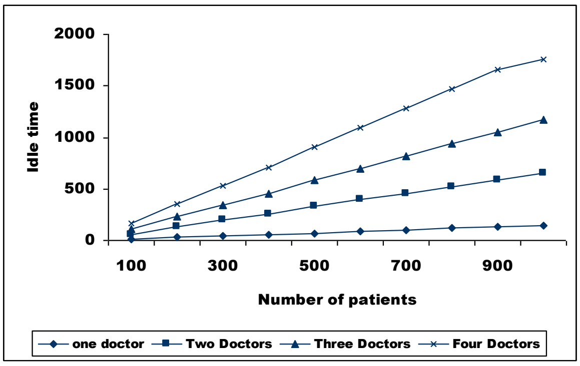


Fig. 5. Number of patients versus Idle time

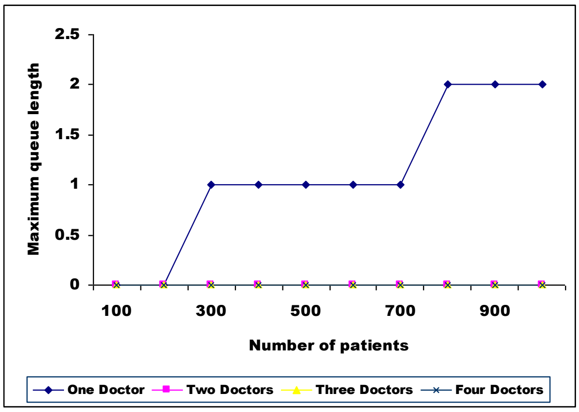


Fig. 6. Number of patients versus maximum queuelength

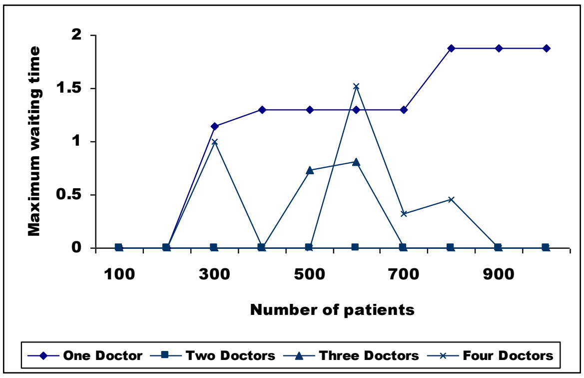


Fig. 7. Number of patients versus maximum waiting time

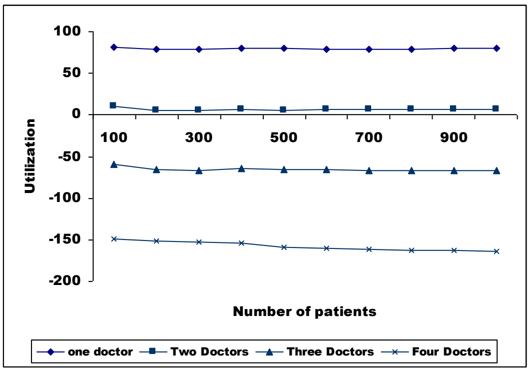


Fig. 8. Number of patients versus utilization

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Archana Sharma was born in Ajmer on 13-12-1973. She completed her M.Tech in Computer Science from Banasthali Vidyapith, India in 1999. Her field of study is Simulation and Modeling. She is working in the field of education for last 12 years. She has taught many subjects at undergraduate and postgraduate level. She has published several research papers in national and International Journals. She is currently working in the field of Cloud Computing and Educational Data Mining. Professor Sharma is member of Indian Society of Theoretical and Applied Mechanics. She worked as Editor in Journal of Management and IT 'OORJA'