Application of Queueing Theory in Engineering

M. Ragapriya

Department of Mathematics, Annapoorana Engineering College, Tamil Nadu, India

Abstract:- **Queueing theory is a major topic of applied mathematics with phenomenon of waiting and arises from the use of powerful mathematical analysis. In this paper is study the application of queueing theory in engineering also we analyse the basic features of queueing theory.**

Keywords:- **Arrival process, service process, waiting time, queue length.**

I. INTRODUCTION

A queueing system which consists of the customers and the servers. Waiting line or queues are in the schools, hospitals, bookstores, libraries, banks, post office, petrol pumps, theatres etc., all have Queueing problems. Queues are very familiar in our daily life. Queueing theory is a branch of operations research because the results are used for making decisions about the resources needed to provide service. Many valuable applications of the queueing theory are traffic flow (vehicles, aircraft, people, communications), scheduling (patients in hospitals, jobs on machines, programs on computer), and facility design (banks, post offices, super markets). ***A.K.Erlang (1878-1929) Danish Engineer*** who is called the ***father of queueing theory***. He published his articles relating to the study of congestion in telephone traffic. A queueing theory is the mathematics of waiting lines. A queueing system can be described by the flow of units for service, forming or joining the queue, if service is not available soon, and leaving the system after being served.

Queue Length

Probability distribution of queue length can be obtained with the help of the given Probability distribution of the arrival and service process. A large queue indicates poor service facility or a need for more space. A small queue indicates excess of service facilities.

Waiting time in Queue

It refers to the time spent by the customer in the queue before the commencement of his service.

Waiting time in system

A basic concept in the analysis of a queuing theory is that of a state of the system. It involves study of a system's behaviour overtime.

State of the Queuing system

1. Transient state
2. Steady state
3. Explosive state

Transient state

A queuing system is said to be in transient state when its operating characteristics, arrivals, waiting time and service time of the customers are dependent on time.

Steady state

A queuing system is said to be in a steady state when its operating characteristics, arrivals, waiting time and service time of the customers are independent on time.

Explosive state

If the arrival rate of the system is more than its servicing rate, the length of the queue will go on increasing with the time and will tend to infinity.

Classification of Queuing Models

Model I (M/M/I) : (∞/FCFS)

Model II (M/M/I): (∞/SIRO)

Model III (Birth-Death process) (M/M/I) : (∞/FCFS)

Model IV (M/M/I): (N/FCFS)

Model V (M/M/C): (∞/FCFS)

Model VI (M/E/I): (∞/FCFS)

Model VII (M/M/R): (K/GD); $K < R$

Model VIII – Power supply

Model IX – D/D/I

Model X – M/D/I

Model XI (M/G/I) : (∞/FCFS)

Kendall Notation

A/S/m/B/K/SD

A: arrival process

S: service time distribution

m: number of servers

B: number of buffers (system capacity)

K: population size

SD: service discipline

Arrival process

The number of customers arriving per unit of time is called arrival rate. Random arrivals are described by the Poisson distribution.

Service time distribution

The number of customers served per unit of time is called service time. The service times are described by the exponential distribution.

Service Discipline

This is the manner by which customers are selected for service when a queue has formed. The most common discipline is FCFS – First Come, First Served. The other disciplines are LCFS – Last Come First Served and SIRO – Service In Random Order and GD – general service discipline and including priority.

Number of Servers

A queuing system is called one server model, when the system has server only and a multi- server model when the system has a number of parallel channels each with one server

Notations used in queuing system

λ – Mean arrival rate of customers

μ – Mean service time

L_s– Average number of customers in the system.

L_q– Average number of customers in the queue.

W_s– Average waiting time of a customer in the system

W_q– Average waiting time of customers in the queue.

n – Number of customer in the system.

p– Utilization factor for the service system.

c – Number of service Channels.

Little's formula

In his connection, it is relevant to mention one of the important and useful relationship in queuing theory which holds under fairly quite general conditions. It is known as Little's formula, a rigorous proof of which was given by Little (1961) .It is given by = λW where λ is arrival rate, = E(L) is the expected queue length under steady state and W is the steady state expected waiting time in the system.

Queue Networks

Network of Queues can be described as a group of nodes where each of the nodes represents a service facility of some type. Customers can arrive from outside the system to any node and may leave the system from any node. Therefore, customers may enter the system at some node, can transverse from node to node in the system and finally can leave the system at some other node, not all customers necessarily enter and leave at the some node or taking the same path once after entering the system. Also customers can return to nodes already visited, skip some nodes entirely or even choose to remain in the system forever.

Classification of Networks

1. Open Networks
2. Closed Networks
3. Mixed Networks

Open Networks

In an open queuing network, customers enter the system from outside and after service at one or more queues, eventually leave the system.

Closed Networks

A closed queuing network does not have any external arrivals or departures. It represents a situation where a fined number of jobs circulate in the system, moving from one queue to the next, getting served at individual queues. No jobs enter the system nor does any job leave the system.

Mixed Networks

Network has multiple job classes and is open with respect to some classes but closed with repeat to the others.

Series Queues

In Queuing model in which there are a series of service stations through which each calling unit must progress prior to leaving system. There are several types of network of Queues for which customers are not allowed to visit previously visited nodes. The first series model to be considered is the sequence of queues with no restriction on the waiting's room capacity between the stations. For example, a physical examination for a patient undergoes through a series of stages lab tests, electrocardiogram, chest X -ray, etc.

II. APPLICATION OF QUEUEING IN DAILY LIFE AND ENGINEERING

Traffic system

The vehicular traffic flow and explore could be minimized using queuing theory in order to reduce the delay on the roads. The role of transportation in human life cannot be overemphasized. A basic model of vehicular traffic based on queuing theory. It will determine the best times of the red, amber, and green lights to be either on or off in order to reduce traffic congestion on the roads. Queuing also helps to reduce fuel consumption thereby saving money for the Government to tackle problem of other sectors of the economy.

Banking

Today banks are one of the most important units of the public. Most banks used standard queuing models. It is very useful to avoid standing in a queue for a long time or in a wrong line and to give tickets to all customers. Bank is an example of unlimited queue length [1]. Queuing is used to

generate a sequence of customers' arrival time and to choose randomly between three different services: open an account, transaction, and balance, with different period of time for each service.

Toll plaza

Computer simulation is one of the popular approaches to the design of toll plazas. Toll plaza configurations such as toll collection methods, number of toll booths, and types of vehicles have been used here. Toll plaza performance measures such as average queue length, average waiting time, maximum queue length, and maximum waiting time at the tolls were compared between two different types of representations of projected traffic volumes. Toll plaza designing factors such as lane selection options, electronic toll collection(ETC)rates, and number of manual tolls were combined with traffic flow measure the specified toll performances .Finding appropriate values of input parameters for a traffic simulation model is always a challenge to simulation model builders as well as to traffic engineers. For generating traffic flow in a simulation model, deterministic traffic counts for a time period can be used as an input parameter into the model rather than considering a probabilistic distribution.

Railway station

In the country like India where Railway is one of the most popular and cheapest means of transportation, it is always difficult to book confirmed tickets for the journey. The population that the country has it doesn't match up with number of trains running various routes especially those connecting the metro cities. Indian Railway is trying to meet the ever increasing demand of over billion people. The queuing system is used to avoid the inconvenience of passengers and it is feasible and the results are effective and practical.

Computer system

Many jobs arrive sequentially at a computer system in accordance with a Poisson arrival process, and the execution time of a job is a random variable. Jobs are executed in the order of arrival, if the computer is busy when a job arrives, the job is placed in a queue. In the terminology of queuing theory the computer is the "server" and the jobs are "customers". The logical structure of the single server queuing model can be restored with a simple device. Let the server represent the combined resources of computer and operator

Construction management

Construction management we apply queueing theory in to activities such as concreting and earth moving

Concreting operation requires many agents such as crane, concrete pump, concrete truck, placement crew.

Earth moving activities have several agents the excavators and loader, dump trucks in this both case the simple queueing system is used. In civil engineering there are many activities involved we use queueing system to minimize total caste.

Application in communication system

Applicability of queueing theory through Markov process is also found in the field of communication system. This chain is based on the condition that the past, present and future all of them are independent. The natural laws of jump chain done within Markov chain process is also one of the examples of the queueing theory in communication system.

Applications in Health Care Systems

Queuing theory is "The mathematical approach to the analysis of waiting lines in Health care setting".Queuing system is very beneficial in the health care systems as well. One of the biggest hurdles in health care organizations is the fact that patients have to wait in long queues for their turn to be assisted. Queuing system minimizes the time that customers have to waste in waiting and utilizing their resources and servers. These servers include the nurses, hospital beds, doctors and other health care services. When a person chose to stop waiting in a queue, he complies with the phenomenon of reneging. This decision is dependent on the length of the queue and the amount of stamina that a patient has to wait in a line. Health care organizations attain dysfunctional equilibrium through exceeding server capacity by reneging. This example can be understood through the example of emergency units in the hospital (Tian & Zhang, n.d). Most of the patients quit emergency departments without even getting treated for their health problem due to capacity, arrival rate and utilization. Statistics and data collected from this amount of number of people leaving, health care organizations determine the rate of revenue loss. The Same queuing method can also be utilized to minimize the reneging factor in health care organizations. One way of doing this is by categorizing patients according to the service they require. Also we use the telecommunication system to avoid queue length by reserving previously appointment to consult a doctor.

III. CONCLUSION

In conclusion, queuing theory has a much-diversified range of applications. It enjoys a very dominant place in the contemporary analytical techniques. Information is obtained on the basis of analysis done by the queuing systems. Queuing theory plays a very important role in the development of everyday social life. All the applications discussed above are practical and their worth is portrayed in the actions of everyday life. This theory also explains the mathematical, as well as, social study of waiting lines in everyday life. Queuing analysis can give very effective results in health care, production, communication, construction and in many other various engineering field.

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