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Impact of Queueing Theory on Different Application

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ABSTRACT
In the past, queueing theory has been used to evaluate employee schedules, workplace conditions, productivity, customer wait times, and environments associated with customer wait times. Queuing theory can be applied in pharmacies to evaluate a wide range of variables, including staffing levels, patient wait times, prescription fill times, and counselling times. Daily life frequently involves instances where a line forms. The mathematical study of waiting lines known as queuing theory can be very helpful in analysing how people queue up in their daily lives. The queueing theory is applicable not only to day-to-day activities but also to computer programming, networks, the medical industry, the financial industry, etc. In this paper, we examine the fundamental aspects of queuing theory and its uses.
KEYWORDS: *Arrival process, service process, waiting time, system time, queue length, system length.*

I. INTRODUCTION

Schools, hospitals, book stores, libraries, banks, post offices, petrol stations, theatres and other establishments all have waiting lists or queues. We see queues frequently in daily life. Because the findings are used to determine the resources required to provide service, queueing theory is a subfield of operations research. Traffic flow (vehicles, aircraft, people, communications), scheduling (patients in hospitals, jobs on machines, programmes on computers), and facility design (banks, post offices, supermarkets) are only a few of the many useful uses of the queuing theory. Danish engineer A.K. Erlang (1878–1929), known as the founder of queueing theory. He had articles written about the analysis of telephone traffic congestion published. The mathematics of standing in line is known as a queuing theory.

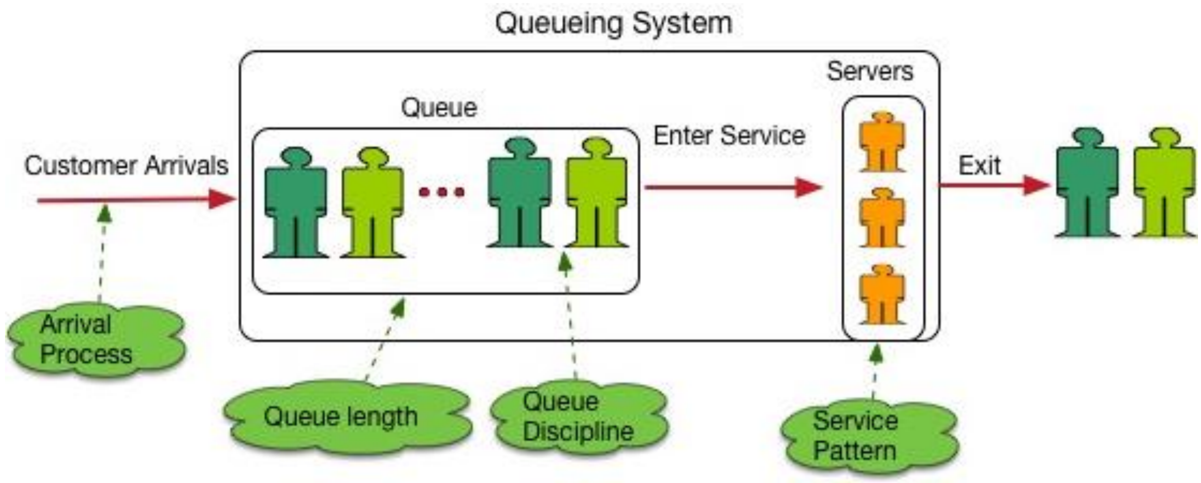

Figure 1: Representation of Queueing System

Some important terminologies associated with queuing theory are as under:

Queue Length

The provided probability distributions for arrival and service processes can be used to calculate the probability distribution of queue length. Large lines suggest a lack of room or a poor service environment. A short line suggests there are more services available.

Waiting time in Queue
It refers to the period of time the consumer waited in line before receiving his service.

Waiting time in system
It entails tracking the evolution of a system's behaviour.

Components of the queuing system

A queuing system can be completely described by
1.The input or arrival pattern of customers
2.The service mechanism or service pattern of servers.
3.Queue discipline.
4.System capacity.
5.Number of service channels .
6.Number of service stages.

The input or arrival pattern of customers

The arrival pattern is referred to as the input pattern. The period in between any two successive arrivals, if any, defines it. Additionally, it's important to understand whether multiple customers can arrive at once (a batch or bulk arrival), and if so, what the probability distribution for the batch size is. It's also important to understand how a consumer responds when they first use the technology. A client may choose to wait in line no matter how long it grows, or alternatively, if it gets too lengthy, the customer may choose not to use the system. A customer is said to have baulked if they choose not to join the line when they arrive. A consumer may join the line, but after some time decide to give up and depart. The customer is considered to have reneged in this situation. Customers may switch between waiting lines, jockeying for position, if there are two or more parallel waiting lines. These three scenarios all involve lines of impatient customers. The way in which the arrival pattern evolves over time is a last aspect to take into account. A stationary arrival pattern is one that does not change over time (i.e., one for which the probability distribution describing the input process is time-independent). Non-stationary refers to one that is not independent of time. The service mechanism (or service pattern)

The service mechanism or service pattern of servers.

The sequence of customer service times must be described by a probability distribution, which is crucial. Single or batch services are both possible. If a queue is growing, a server might operate more quickly or, on the other hand, might become impatient and work less quickly. State-dependent service refers to a situation where the availability of a service is contingent upon the number of clients in line. The key distinction between the arrival and service processes is that the former is a continuous process, whereas the latter requires clients in order to operate. Even though the service rate may be high, it is extremely likely that some clients will experience service delays due to waiting lines. Service patterns could be stochastic or predictable.

The queue discipline

The queue discipline is the rule governing how the queue is formed, how customers behave while waiting, and how customers are selected for service. "First come, first served" (FCFS), which requires that clients be served in the order of their arrival, is the most basic discipline. The "Last Come, First Served" (LCFS) discipline is used if the sequence is reversed because, in a large godown, the goods that arrive last are taken out first. The queue discipline "service in random order" (SIRO) or "might is right" may be very challenging to manage. **System capacity**
A system may have infinite capacity, meaning that the length of the line in front of the server is unlimited. If it is finite, the number of spaces available for both the queue and the person being served, if any, must be provided. When the line reaches a specific length, no more patrons are permitted, creating a finite queueing condition. This happens in some queueing processes where there is a physical limit to the quantity of waiting room.

The number of service channels

The term "service channels" describes the number of concurrently operating parallel service stations. One server or more parallel servers may be present in a system. If there are multiple servers available when a customer arrives, they can choose one at random or join a line that is shared by all the servers. The first person in the queue is then sent to the server that becomes available first. The kind of circumstance is typical, for instance, at the ticket counter or in a bank.

The number of service stages

A queuing system may have multiple stages of service, as in the case of a barbershop or grocery. A physical examination method, where each patient must go through numerous phases, is an example of a multistage queueing system. Recycling may take place in various multistage queueing processes. Recycling is a typical practise in manufacturing processes where parts that do not meet quality standards are returned back for further processing after quality control inspections are conducted at particular stages.

Motive of the study

The fundamental notions of various significant theories and practical applications of queuing theory are presented in this article. This paper intends to investigate the uses of computer systems, traffic systems, banking, toll plazas, hospitals, and library administration.

Library management

A library is a structured collection of books, as well as some specialised items like CDs, DVDs, cassette tapes, videotapes, audio books, e-books, and other kinds of electronic resources. The application of queuing in libraries covers book circulation, counter service, and related services like reprography.

Bank ATMs

In an ATM, bank customers show up at random, and the time it takes them to complete a transaction is likewise random. We calculate the average number of clients in the queue as well as the average wait time in the queue using the queuing model.

Hospitals

Queuing models are used for calculating patient wait times, service utilisation, system design, and appointment system evaluation. A queuing system aids in cutting down on patient wait times and maximising the use of servers, such as doctors, nurses, and hospital beds.

Traffic system

To lessen the delay on the roadways, the flow and movement of vehicular traffic could be minimised utilising the queuing theory. It is impossible to overstate the importance of transportation in daily life. In order to lessen traffic congestion on the highways, it will decide when the red, amber, and green lights should be on or off

Banking

Most banks employed common queuing techniques. Giving tickets to every consumer is a great way to prevent standing in a long line or in the wrong line. A bank is an example of an endless line. In order to establish a random sequence of customer arrival times and to select among three different services—open an account, transaction, and balance—each with a unique window of time—queuing is utilised.

Toll plaza

One of the popular methods for toll plaza design is computer simulation. Here, many toll plaza layouts have been used, including toll collection techniques, the number of toll booths, and the kinds of vehicles. Two alternative types of representations of expected traffic flows were evaluated in terms of how well toll plaza performance indicators such as average queue length, average waiting time, maximum queue length, and maximum waiting time at the tolls performed.

Railway station

It might be challenging to reserve confirmed tickets for a trip in a country like India where trains are among the most widely used and affordable modes of transportation. The number of trains operating various routes, particularly those connecting the metro centres, does not correspond to the country's population. The usage of the queuing system prevents people from being inconvenienced, and it is practical, with workable outcomes.

Computer system

Several jobs come sequentially at a computer system, and a job's execution time is a random variable. Jobs are processed in the order that they arrive; if the computer is already busy when one arrives, the job is queued up. The jobs are the "customers" and the computer is the "server" in the queuing theory terminology. With the aid of a straightforward tool, the single server queuing model's logical structure may be recovered. Let the server stand in for the total computing and human resources.

State of the Queuing system

(1).Transient state

(2). Steady state

(3).Explosive state

Transient state

When a queuing system's operational characteristics, customer arrivals, waiting times, and service times depend on time, it is said to be in a transitory state.

Steady state

When a queuing system's operational characteristics, customer arrivals, waiting times, and service times are independent of time, it is considered to be in a steady state.

Explosive state

The length of the queue will continue to grow over time and eventually reach infinity if the system's arrival rate exceeds its service rate.

Classification of Queuing Models

Model I (M/M/I) : (∞/FCFS)
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
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

$$P_o = \text{Prob}\begin{bmatrix}\text{system is} \\ \text{empty (idle)}\end{bmatrix} = 1 - \frac{\lambda}{\mu}$$

$$L_q = \begin{matrix}\text{average number} \\ \text{in the queue}\end{matrix} = \frac{\lambda^2}{\mu(\mu - \lambda)}$$

$$L = \begin{matrix}\text{average number} \\ \text{in the system}\end{matrix} = \frac{\lambda}{\mu - \lambda}$$

$$W_q = \begin{matrix}\text{average time} \\ \text{in the queue}\end{matrix} = \frac{\lambda}{\mu(\mu - \lambda)}$$

$$W = \begin{matrix}\text{average time} \\ \text{in the system}\end{matrix} = \frac{1}{\mu - \lambda}$$

Note:
λ is the arrival rate.
μ is the service rate.

Figure2: Some formula of Queueing Theory

	Single channel	Multi channel
Notation	λ = expected arrivals per period μ = expected service done per period	λ = expected arrivals per period μ = expected service done per period c = number of channels
Probability distribution of n units in the system	$p_n = \left(1-\frac{\lambda}{\mu}\right)\left(\frac{\lambda}{\mu}\right)^2$	$p_n = \frac{1}{\left(\frac{\lambda}{\mu}\right)^c \left(\frac{1}{c!}\right)\left[\frac{1}{1-p}\right] + \sum_{r=0}^{r=c-1}\left(\frac{\lambda}{\mu}\right)^r \left(\frac{1}{r!}\right)}$
Mean number of units in the system	$n_m = \frac{\lambda}{\mu-\lambda}$	$n_m = m_m + \frac{\lambda}{\mu}$
Average length of queue	$m_m = \frac{\lambda^2}{\mu(\mu-\lambda)}$	$m_m = \frac{(\frac{\lambda}{\mu})^{c+1}}{(c-1)!\ (c-\frac{\lambda}{\mu})^2}$
Mean time waiting for service	$n_m = \frac{\lambda}{\mu(\mu-\lambda)}$	$w_m = \frac{m_m}{\lambda}$
Mean time in the system	$t_m = \frac{1}{\mu-\lambda}$	$d_m = w_m + \frac{1}{\mu}$

Figure3: Some formula of Single Channel and Multi Channel

II. CONCLUSION

When there is a current demand for a service that is greater than the ability to meet that demand, a line will often form. The use of queueing systems is widespread in society. The effectiveness of these systems can significantly impact both the productivity of the process and the quality of human life. Queuing systems have been effectively utilised to analyse the performance of a variety of systems, including computer, communications, transportation, and manufacturing systems. Additionally, applications of the queuing theory are shown with examples. Some basic concepts of queuing theory and their applications are provided in this examination.

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