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Role of Queuing Theory in Service Systems and Daily Life

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Abstract:
Queuing theory is a science that deals with the management of customers in a proper format so that their service can be done effectively. It also helps the management to choose number of servers or the size of queue so that which leads to optimum use of resources. As queue is everywhere. This paper aims to study the relevance of queuing theory in our daily life.

Keywords:
Queuing theory, waiting lines, service systems, arrival rate, service rate, resource optimization, daily life applications, operations research

Introduction

Mathematics has long been recognized as a foundational science, integral to both the natural world and human civilization. From the earliest societies, mathematical principles were applied to measure, calculate, and understand the world around us. As societies grew more complex, so did their mathematical needs, leading to advancements in fields like geometry, algebra, and number theory. Today, mathematics is embedded in every aspect of our lives, from technology and engineering to finance and the arts. These mathematical principles not only help structure our physical environments but also drive innovations that power modern tools, devices, and systems.

Queuing theory, a branch of applied mathematics, plays a crucial role in managing service efficiency, especially in scenarios where demand and service rates fluctuate. This theory models real-world waiting lines to help organizations optimize processes, reduce wait times, and improve resource allocation. In sectors like banking, healthcare, and hospitality, queuing theory aids in designing systems that can handle varying customer arrival rates. By examining characteristics such as waiting time and queue length, queuing models enable service providers to make informed decisions that balance customer satisfaction with cost-effectiveness. For instance, in fast-food restaurants, implementing queuing theory can enhance service speed during peak hours, reducing customer wait times and improving the overall dining experience.

The applications of queuing theory extend across a range of industries, each facing unique queuing challenges. In healthcare, queuing models help minimize patient wait times, contributing to better and timelier treatment, especially in critical care units. In transportation, queuing theory is used to analyze and mitigate traffic congestion, helping to enhance road and toll plaza efficiency. In call centers, it helps manage large volumes of customer inquiries by optimizing agent allocation and reducing on-hold time. Queuing theory's versatility demonstrates the practical relevance of mathematics in addressing day-to-day issues, underscoring its essential role in creating smoother, more efficient systems that ultimately benefit society.

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Queueuing Theory

There are many situations in daily life when a queue is formed. Queuing theory is the mathematical study of waiting line. Queuing theory applies not only in day to day life but also in sequence of computer programming, networks, medical field, banking sectors etc. A queuing 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. Queues generate when service rate is less than the arrival rate of customers.

Characteristics of Queuing System

(1) Average Waiting Time in queue
(2) Average waiting time in system
(3) Average number of customers in system
(4) Average number of customers in queue

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.

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.

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Application of Queuing

In ATM, bank customers arrive randomly and the service time i.e. the time customer takes to do transaction in ATM, is also random. We use queuing model to derive the arrival rate, service rate, utilization rate, waiting time in the queue and the average number of customers in the queue. Queuing can help bank ATM to increase its quality of service, by anticipating, if there are many customers in the queue. [3]

The Restaurant system involves the fast-food operations in which 'fast' refer to the 'quick service.' The customers arriving restaurant do not want to wait for a long time in queues to receive food services. The customers' waiting time to get food services becomes one of the important quality factors in a fast-food restaurant.Waiting lines in fast-food restaurants always built during peak hours. In order to improve the performance of restaurant processes, some of the factors are required to consider. These factors include average queue length, waiting time to customers, system utilization, and the number of servers with respect to the average number of customers. For this purpose, queuing model is a suitable approach to understanding how to reduce the waiting time of customers by getting an optimal number of servers at a minimum total cost. Implementing Queuing theory in operations of the restaurant may be beneficial to those who proactively desire to manage revenue**.** The queuing system of a restaurant can be simulated to study how to reduce the customer's waiting time.

This is because as the customers too long waiting time could result in a huge cost to them, which is waiting cost. Giving too much service capacity of the system includes an excessive cost. [20]
A library is an organized collection of books, and some special materials like audio or visual materials, CDs, cassettes, video tape, DVDs, e-books, audio books and many other types of electronic resources. A Queuing model can help in circulation of books, counter service and allied services like reprography. The basic tasks in library are stock maintenance, membership management, selection of library materials, and planning the acquisition of materials.

In India, due to the escalating traffic issues, a large number of highways have been built in the recent past, which is maintained by tax collection at toll plazas, by various operating agencies. Due to smooth and hassle free driving on highways, the arrival rate of vehicles at Toll Plazas increases. The arrival rate goes beyond control if the traffic on the highway increases in an uncontrolled manner, with the passage of time. Thus, one of the irrefutable drawbacks of putting up Toll Plazas is the traffic congestion. The waiting time, in the service lanes, due to such congestion becomes high and terrible for the commuters on the route. We can use queuing theory to analyze the current situation, of traffic congestion, at a highway toll plaza and suggest possible solutions to encourage greater efficiency, thus reducing waiting time of the customers and money wasted because of that. Computer simulation is one of the popular approaches to the design of toll plazas. [6]

In multiprogramming system, most of the jobs heavily depends on disk for program loading and I/O files. When the disk queue has several pending requests, the operating system chooses which request has to be served next. But due to increase in processor speed and memory capacity than disk speed there may have many pending request in queue and as a result there is degradation in the performance of disk scheduling. In operating system, there exists various disk scheduling algorithms like FCFS, SSTF, SCAN, (C-SCAN), LOOK, C-LOOK to enhance the performance of disk I/O operation. Thus to enhance the efficiency of disk performance LCFS algorithm is proposed which decreases the total number of head movements and average seek time than exiting algorithms. [21]

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

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tickets to all customers. Bank is an example of unlimited queue length .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. [1]

Due to increased ownership of cars, changes in the production system (where stock is on the road and not in the warehouse), increased flexibility of the working population, etc., the demand for transport has increased exponentially. On the other hand, the supply of means for transport (roads, public transport...) does not follow this trend or with a serious lag in time. This combination of more and more traffic on the existing road network together with stabilization in investments of new roads, results in an inevitable increase of congestion. Congestion leads to an increase in travel time, decreasing flow, higher fuel consumption, negative environmental effects, etc. Efficiently tuning demand and supply will lead to a better use of the capacity and a better control of traffic demand.

In a queuing approach to traffic flow analysis, roads are subdivided into segments, with length equal to the minimal space needed by one vehicle on that road Define C as the maximum average traffic density (i.e. average maximum number of cars on a road segment). This length is then equal to 1/C and matches the minimal space needed by one vehicle on that road. Each road segment is then considered as a service station, in which vehicles arrive at a certain rate. And get served at another rate [22]. It is often observed that the speed for a certain time period tends to be reproduced whenever the same flow is observed. Based on this observation, it seems reasonable to postulate that, if traffic conditions on a given road are stationary, there should be a relationship between flow, speed, and density. This relationship results in the well-known concept of speed-flow density Road networks can then be represented by queuing systems.

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.

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.

A call center constitutes a set of resources (typically personnel, computers and telecommunication equipment), which enable the delivery of services via the telephone. The working environment of a large call centers could be envisioned as an endless room with numerous open-space cubicles, in which people with earphones sit in front of computer terminals, providing tele-services to unseen customers. Most call centers also support Interactive Voice Response (IVR) units, also called Voice Response Units (VRU's), which are the industrial versions of answering machines, including the possibilities of interactions. Most major companies have reengineered their communication with customers via one or more call centers, either internally-managed or outsourced. The large-scale emergence of call centers, noticeably during the last decade, has been enabled by technological advances in the area of Information and Communication Technology (ICT).

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Call centers can be viewed, naturally and usefully, as queuing systems. In a queuing model of a call center, the customers are callers, servers (resources) are telephone agents (operators) or communication equipment, and tele-queues consist of callers that await service by a system resource. [25]

One of the major uses of operation research in healthcare is in the form of Queuing theory. The rising cost of health care can be attributed not only to ageing population and new expensive and advanced treatment modalities but also to inefficiencies in health delivery. Queuing theory application is an attempt to minimize the cost through minimization of inefficiencies and delays in the system [26].There are many problems in health care system which can be solved using queuing theory for example, waiting time and utilization analysis, system design, and appointment systems. The organizations that care for persons who are ill and injured vary widely in scope and scale, from specialized outpatient clinics to large, urban hospitals to regional healthcare systems. Despite these differences, one can view the healthcare processes that these organizations provide as queuing systems in which patients arrive, wait for service, obtain service, and then depart. The healthcare processes also vary in complexity and scope, but they all consist of a set of activities and procedures (both medical and non-medical) that the patient must undergo in order to receive the needed treatment. The resources (or servers) in these queuing systems are the trained personnel and specialized equipment that these activities and procedures require.

Each production process in construction is closely connected with the question of costs and deadlines.An investor or customer, as well as construction companies themselves in every project have to meetthe planned completion date and the estimated costs associated with the construction. In practice, determining the duration of construction at minimum cost is still not founded on a reliable calculation, and in the planning of costs, the connection between terms and financial costs is rarely taken into account. Queuing model examines systems with operating channels, where the process of queues formation takes place and subsequent servicing of the customers by servicing centers. The main objective of the queuing theory is to determine the laws under which the system works, and further to create the most accurate mathematical model that takes into account various stochastic influences on the process. The entire construction process can be examined from the point of view of a customer who is waiting in the queue and is interested primarily in the waiting time, as well as from the point of view of servicing centers. [27]

Conclusion

Thus mathematics is very useful as it is used in receiving signals in our satellite dish, headlights, in suspension bridges, to study the path of object which is thrown upward, to study orbital motion. It is used in construction of many buildings like whispering galleries, coolers of nuclear reactor etc. It is used in surgery as well. Queuing is also very important in our day to day life. Queuing model is a suitable approach to understanding how to reduce the waiting time of customers by getting an optimal number of servers at a minimum total cost. Thus queuing models are developed for Restaurants, Bank, ATMs, Railways, Toll Plaza, Call Centers, Library, and Construction to reduce the waiting time of customers and to make the optimal utilization of the resources. These days queuing system is used to study traffic flow so that the congestion on roads can be reduced. In health care Queuing system is used to reduce the waiting time of patient and helps in providing timely treatment to the patient. Thus mathematics is used in every walk of life.

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