

APPLICATIONS OF QUEUING THEORY IN HEALTH CARE

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ABSTRACT

Operational research embodies a wide range of techniques that can improve the way we plan and organize health services. Operation research (O.R) focuses on the application of analytical methods to facilitate better decision-making. This paper is an attempt to analyze the theory (Queuing) and instances of use of queuing theory in health care organizations around the world and benefits acquired from the same.

INTRODUCTION

Operation Research existed as a scientific discipline since 1930's. It is a discipline of applying appropriate analytical methods for decision making. OR has been studied in health care settings since 1952. One of the major uses of operational research in healthcare is in the form of Queuing theory. Queues or Queuing theory was first analyzed by A.K Erlang in 1913 in the context of telephone facilities. It is extensively practiced or utilized in industrial setting or retail sector-operations management, and falls under the purview of decision Sciences. 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 .There are many problems in health care system which can be solved using queuing theory in operational research. Few of them are discussed below:

Long waiting time at outpatient clinics before consultation
Patients need to make an appointment for a specialist. An appointment system reduces patient waiting time. A Good appointment Schedule is one that trade-offs patients waiting time for clinics overtime, constrained by patient load and staffing. Using O.R we can use techniques such as queuing theory and discrete event simulation to propose various appointment strategies under different clinics settings.

HEALTH SERVICE CAPACITY PLANNING

It is common for health care managers to project workload for physical infrastructure and manpower planning. This may be done at different departments, hospitals or even national level. It is a common method to look at past trends, estimate the historical year-on -year growth and extrapolate this growth rate to the future. However there are two potential problems. Firstly, we seldom see a definitive trend and the estimation of “growth rate” is highly dependent upon the start and end points of time intervals. Secondly, the assumption of a long lasting trend is also unrealistic. A health care utilization is often closely related to age, a more robust way to project is to use population based drivers. We can first drive the age specific utilization rate, which is the number of encounters (E.g. emergency or patient attendances, hospital admissions) as per population specific to each age group.

With rapid change and realignment of health care system, new lines of services and facilities to render the same, server financial pressure on the health care organizations and extensive use of expanded managerial skills in health care setting, use of queuing models has become quite prevalent in it. Queuing models are used to achieve a balance or tradeoff between capacity and service delays.

For application of queuing models to any situation we should first describe the “Input Process” and “output Process”. An Example is shown below with a brief description of both process:

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Setting	Input Process	Output Process
Hospital	Arrival of the patient at the registration counter	Assessment ,Triage, Provision of services, discharge
PCP office	Arrival at registration counter or front or front office desk	Assessment by PCP, Prescription and tests, and collection of bills at the exit
ER	Ambulance arrival	Assessment triage, assessment ,Triage to the inpatient setting or discharge after treatment

So why use the queuing theory in first place-the answer is to minimize total cost to the system.

These costs can be divided into two broad categories:

COSTS ASSOCIATED WITH PATIENTS OR CUSTOMERS HAVING TO WAIT FOR THE SERVICE

* Loss of business to HCO, as some patients might not be willing to wait for the service and may decide to go to the competing organizations.

* Costs incurred by society for example increased interventions and cost due to delay in care or the value of patients time.

* Decreased patient satisfaction and quality of care.

COSTS OF PROVIDING THE SERVICE (CAPACITY COSTS)

* Salaries paid to employees.

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* Salaries paid to employees or servers while they wait for service from other server, for example waiting for the pathology report, radiology report, labs, etc.

* Fixed costs – cost of waiting space, facilities, equipments, and supplies.

If the organization decides to increase the level of service provided, cost of providing services would increase, if it decides to limit the same, costs associated with waiting for the services would increase. So the manager has to balance the two costs and make a decision about the provision of optimum level of service

QUEUING THEORY AND HEALTHCARE

The health systems should have an ability to deliver safe, efficient and smooth services to the patients. Several key reimbursement changes, increasing critiques and cost pressures on the system and increasing demand of quality and efficacy from highly aware and educated patients due to advances in technology and telecommunications have started putting more pressure on the healthcare managers to respond to these concerns. Queuing theory is an example of the use in healthcare. It essentially deals with patient flow through the system, if patient flow is good then patient queuing is minimized, if it is bad then the system may suffer loss of business and patients may suffer considerable queuing delays. Health care system can be visualized as a complex queuing network in which delays can be reduced through the following ways:

- Synchronization of work among service stages (e.g., coordination of tests, treatments, discharge processes)
- Scheduling of resources (e.g., doctors and nurses) to match patterns of arrival
- Constant system monitoring (e.g., tracking number of patients waiting by location, diagnostic grouping and acuity) linked to immediate actions.

Queuing theory is now fairly extensively used in the following settings:

EMERGENCY ROOM ARRIVALS

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This is one of the areas where most of the research and applications of queuing theory have been done. Closure of several ED (Emergency Departments) in last few years and significant variation in ED patient arrival rates have led to increased crowding and prolonged waiting times. Many of the patients even leave to seek services at a different place.

Gravity of the situation can be appreciated by reading the following real life instance given below:

“A teenage girl was hit in the mouth playing softball, causing injury to her teeth. She arrived in the emergency department, which was full, at 6 pm and in a waiting room, holding a cloth to her face, bleeding for 2 hours. Finally, when a bed opened for her, the doctor saw she had significant dental injuries, including loose upper front teeth. He ordered an x-ray. Once he had the results several hours later, he called an orthodontist who fortunately agreed to see her right away. By then, it was 12 midnight.”

The major goal of queuing theory application in such a scenario is analysis of the arrival patterns of the patients over time to a particular ED or an area (city, state, and nation) and using the findings for appropriate staffing and facilities design. Several studies have been done in this field and they all show promising results. A study done by Green, et al, examined the effectiveness of a queuing model in identifying provider staffing patterns to reduce the fraction of patients who leave without being seen and their conclusion was that queuing models can be extremely useful in most effective allocation of staff.

- **Walk in patients in physician offices, out patient clinics and out patient surgeries in hospitals**

The management of healthcare facilities such as outpatient clinics is very complex and demanding to manage. The most common objectives of studies on the clinics have included the reduction of patient's time in the system (outpatient clinic), improvement on customer service, better resource utilization, and reduction of operating costs.

Analysis in such cases involves, in depth analysis of the patients arrival and flow, structure of the system, manpower characteristics and the scheduling system. Appropriate queuing models are then developed and applied for process modifications, appropriate staffing, scheduling or facility changes. Queuing theory can also be applied to hospital settings, particularly outpatient clinics and surgeries. For example, small surgeries are performed by interns or assisting staff members in a hospital and the complicated ones by the experienced surgeons or a team. The experienced surgeons or team members for support services arrive later during the day. But the interns start their work earlier than the experienced surgeons. Using queuing theory in such a case, we can determine the arrival patterns of patients or the service rate and time and appropriately schedule surgeries for better quality and efficiency.

- **Hospital Pharmacy and Pharmacy stores**

The instances of application of queuing theory in pharmacy practice are very few. Numerous pharmacies in the department of defense use automated Queuing Technology (AQT). AQT is also utilized by many other big hospital systems with significant case loads, such as University of Virginia hospital systems.

In Pharmacy, Queuing theory can be used to assess a multitude of factors such as prescription fill time, patient waiting time, patient counseling-time and staffing levels. The application of queuing theory may be of particular benefit in pharmacies with high volume outpatient workloads and/or those that provide multiple points of service. By better understanding queuing theory, service managers can make decisions that increase the satisfaction of all relevant groups- Customers, Employees and management

- **Health care resource and infrastructure planning for disaster management**

Any type of disaster cause significant human and economic damage and they all demand a crisis response. It demands immediate rescue of people, provision of medical services needed and containment of the damage to people and property.

In such scenarios, queuing models are frequently used in conjunction with simulation to answer the “what-if” questions, to plan, organize and be prepared for the calamities. For Example, if H5N1 bird flu spreads to US and causes an epidemic, it would be major crisis

situation. Policy makers and administrators are aware of this scenario and they use Queuing and simulation to plan for such activities. It gives them data regarding, how many people and in what locations would be affected, speed of disease spread, number And characteristics of healthcare workers needed, pharmaceutical supplies, vaccines, number of beds and so on.

- **Public health**

Queuing models can also be used for public health. For example, the resources needed for Mass vaccination camp in a particular area, facility and resource planning for emerging or Changing disease profiles or changing demographics.

LIMITATIONS OF QUEUING MODELS

As discussed at several places earlier, queuing models have several limitations and are Used in conjunction with the other decision analysis methods like simulation and regression. Most of these limitations are the basic assumptions for application of queuing models. Some of the limitations of queuing models are enumerated below:

- Takes average of all variables rather than the real numbers itself.
- Assumes steady state.
- Based on assumption that service time is known.
- Service times are independent from one another.
- Service rate is known.
- Service rate is greater than arrival rate.
- Service time is described by negative exponential probability distribution.

CONCLUSION

Queuing theory, is “The mathematical approach to the analysis of waiting lines in Health care setting”. Its use has been validated in industrial setting, retail sector and in service settings such as telecommunications but its adoption and use in healthcare setting is lagging behind other sectors. In health sector it is mainly used in ED wait line and staffing studies, analysis of queues in outpatient and ambulatory care settings and for disaster management. However it has scope for uses in any setting where there exist wait lines or there is the potential for the same. It can be used in inpatient, outpatient, Physician office, public health, facility and resource planning,

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emergency preparedness, mental health, long term care, pharmacy, inventory control as well as public health. However queuing models have several limitations, many of which are based on its assumptions. The limitations of the queuing models can be offset partially if they are used in conjunction with other decision analysis methods such as simulation and regression. With the increasing cost pressure, changing reimbursement mechanisms and affiliations, pressure for quality control, and awareness and demands of the patients, sooner or later we will have to tap into the benefits of engineering techniques such as queuing theory to provide smooth, safe and efficient healthcare services to our customers, internal and external customer satisfaction and for optimization of resources.

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