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QUEUING THEORY IN THE HEALTHCARE SECTOR

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ABSTRACT

This essay provides an outline of how queueing theory is used and applied in the healthcare industry. The mathematical study of waiting lines or queues is known as queuing theory. In particular, queuing theory is a methodical strategy to reduce system inefficiencies and boost patient satisfaction. The use of it entails minimising expenses by cutting back on waste and delays. Therefore, it is crucial to plan and implement a queue system that takes the condition and changing circumstances into account. An effective and all-encompassing plan is proposed for handling uncertainty in order to handle changes. The subsequent essay also makes an effort to clarify the SWOT analysis of the queueing theory's readiness in relation to the COVID-19 pandemic in India and elsewhere. We also discuss the different ways that the theory allows for quicker resource allocation and lower consumption, proving to be an outstanding gem. Numerous proposed queuing models have not yet been adopted by hospital administrators due to a lack of real-world validation. As a result, it is necessary to investigate the relevance and implications of queuing theory by putting a straightforward queuing model to the test at a busy hospital in India. This essay aims to assess this theory, examples of its application in healthcare institutions around the globe, and its benefits.

Keywords: Queueing Theory, Healthcare Sector, Waiting Rooms, Efficiency, Supply Chain.

I. INTRODUCTION

In multi-specialty hospitals, the operations of the hospital services, in particular the outpatient division, are essential to delivering high-quality healthcare. In hospital operations, the outpatient department (OPD) frequently serves as a profit centre to both invest in new technology and to reduce losses on inpatient services. It is crucial to plan a hospital's outpatient department (OPD) with the notion of maximising use and facilitating speedy turnover because the OPD serves as a link between the hospital and the community. To meet the needs of the OPD, effective communication between the medical services and the support line services is essential. For the benefit of patients and their welfare, it is crucial to focus on waiting time optimization in hospital operations. Long lines indicate a lack of organization, bad management, and insufficient budget, which lowers patient happiness and diminishes the caliber of hospital operations' services. Queuing theory comes in very handy in this situation. In order to optimize the supply of fixed resources at changeable demand conditions, industries frequently apply to queue theory to analyze and model processes that include standing in lines. However, the healthcare sector sees itself differently from other industries. The performance complexity of a system can be understood using a variety of analytical approaches. The queuing theory is a method for analyzing queue-based systems, which comprise clients, servers, and queues. We will examine the numerous issues hospitals confront while also offering a number of ideas and resolutions for those issues.

Like the COVID-19 epidemic, other emergencies that call for quick and effective remedies also show queuing theory to be quite useful. During the pandemic, improvising production processes and the following distribution of goods was a crucial task, which this theory helped to alleviate to the best of its ability. The theory's application to scheduling issues at other clinics throughout the world is also examined in the study.

The following aims make up the paper's organisational structure. First, we want to draw attention to and emphasise the different issues that the healthcare sector is currently facing. Second, we'll use the queuing model to offer solutions to a couple of those issues. Additionally, we will determine the waiting times at various OPDs and provide a study based on them. Additionally, after conducting an analytical analysis of the issue and using queuing theory, we recommend actions to reduce the number of delay points and boost productivity in order to achieve a high patient satisfaction rating. Finally, we formulate solid and precise conclusions based on the results and talk about some ramifications of our findings as well as the study's shortcomings.

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II. LITERATURE REVIEW

In general hospitals, studies on waiting times have long been conducted with a focus on doctor and patient consultations. The queueing theory will be used in this industry to cut down on staff and patient wait times. The manufacturing schedule for many medical and healthcare items can benefit from it as well.

Queuing theory is a natural fit for simulating patient flow in a healthcare context because it has been widely used in industrial settings to examine how resource-constrained systems react to different demand levels (Boyd & Gupta, 2004). The theory allows for the quantitative analysis of a number of interrelated processes, including getting in front of the line, standing in line, and receiving service. The theory makes it possible to derive and calculate a number of performance metrics, such as the typical wait time in the system or queue, the anticipated number of customers waiting for service, and the likelihood of running into the system in different states, such as empty, full, with a server available, or needing a certain amount of time to be served. The calling population, arrival procedure, and queue configuration make up a queueing process. The definition is when a consumer shows up for service, waits if it is not instant, and then departs the system after obtaining service. The analytical technique and the simulation method are the two types of methods that can be used to address the queuing problem (Aziati & Hamdan, 2018). Studies on waiting times in hospital operations that concentrated on the doctor and patient consultations in general hospitals discovered that features of healthcare providers, consultation, and patient characteristics were the factors influencing waiting times. The use of queuing theory to service operations in hospital settings has already been extensively published. Unfortunately, most hospital operations in India underuse this crucial instrument. In-depth research has also been done on queuing analysis to improve efficiency in emergency rooms and other medical departments. The focus of service quality is on how effectively the service supplied satisfies the customers' expectations and meets their demands. When expectations are higher than reality and the perceived quality of the service is subpar, customers get dissatisfied (Yaduvanshi et al., 2019).

The French mathematician S. D. Poison was the first to create an effective queuing theory (1781-1840). He used this distribution function to explain the likelihood of a specified event following numerous occurrences. When telephone companies struggled to determine how many operators to assign to a particular shift in the late 1800s, queuing theory saw its most significant use. At that time, all calls were turned on by the operator who physically connected a line to a switchboard. Each client needed the assistance of his operator. At this point, supervisors had to decide how many operators to retain on the boards to deal with the issue of operators who would stand inactive for long periods. (Ailobhio et al., 2020).

In the modern world, escalating demands and delays in healthcare have become the norm. In the current research, a tertiary eye care hospital, the workload at the registration desk had grown year over year, and it was normal for lines to get backed up and extend past the registration window (Tyagi et al., 2021).

Using knowledge and economies of scale, third-party logistics service providers can provide support activities like material handling, shipping, and storage while manufacturing organizations concentrate on their core competencies (Amjath et al., 2022). To lessen the effects of disruptions on the transplantation supply chain, this article provided a new transplantation network design model that created a new hybrid resilient optimization method and scenario-based optimization (Salimian & Mousavi, 2022).

Control sub-cycles and data sub-cycles are the two categories used to categorize each processing cycle. Each cycle is handled according to its allocation plan. When all of the sub-classes have been received, the tenure of the data dissemination sequence is started. The control cycle propagates from the device to the classes. The congestion estimation's control and paused sequences are now stopped (Alsiddiky et al., 2020). A queueing paradigm with two multi-server queues with finite buffers and a common arrival process was examined. These lines are in opposition to one another (Dudin et al., 2020).

By evaluating the anticipated number of packets lost due to buffer overflow in 6LoWPAN-based, resource-restricted IoHT, this paper developed an estimating methodology to mitigate congestion (Verma et al., 2022).

With multiple priority classes of users included in the system queue, we extended the hypercube queuing model to analyze urban EMS in this study (De Souza et al., 2015). In this article, we define the impact measurements of traditional and adoption-guarantee animal shelters and offer strategies that support the accomplishment of their goals (Turken et al., 2021).

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Time becomes a precious asset in most industrialized nations with high standards of living, which decreases the willingness of customers to wait for services. Second, management is beginning to understand that how they treat their consumers will have a big impact on whether or not they stay loyal to them in the future. The development of technology, including computers, the internet, and other tools, has enabled businesses to produce services more quickly and without spending any money. Hospital administrators, doctors, and managers continue to look for ways to provide these treatments more quickly while keeping in mind that keeping patients in line may negatively impact how well their services are received. Pregnant women typically arrive or request services at antenatal care facilities at random, which most often creates a line. The purpose of queueing analysis and how it is used in health care sector is to keep management expenses as low as possible while prioritising the needs of the consumer. An attempt is made to reduce the cost of providing healthcare services by applying queueing theory by reducing system delays and inefficiency to a minimum.

Principles of the Queuing Model

- Arrival rate assumes a Poisson distribution with mean arrival rate given as lambda (λ).
- Population size is assumed infinite.
- Service time assumes an exponential distribution with mean service rate (μ).
- The service discipline in this research, is a First Come First Serve (FCFS).
- We assume that service behaviour is normal and there is no unusual customer behaviour i.e., Customers do not leave or change queue
- The mean arrival rate is greater than the mean service rate.
- The waiting space for customers in the queue is infinite (Ailobhio et al., 2020).

III. METHODOLOGY

The research methodology used to place items in queues before the work is finished is presented in this section. Before we proceed with the approach, there are a few fundamental aspects and concepts in the queuing theory that need to be grasped. The arrival process, service and departure processes, the number of servers available, the queuing discipline (such as first-in, first-out), the queue capacity, and the number of customers being serviced are the six components that make up a line as it is studied using queuing theory.

Since queuing theory may be used in a variety of contexts, different approaches are used in different industries to allow easier flow.

There are also 3 types of queuing systems:

1. Mobile queue
2. Virtual queue
3. Online queue

We apply the principle to effectively manage the lines that patients wait in clinics and hospitals. Waiting lines in healthcare settings can be analysed using the queueing theory. Queuing analysis can be employed as a short-term measure or for facilities and resource planning because most healthcare systems have excess capacity to tolerate random changes. Patient flow management is a crucial component of enhancing the effectiveness of hospital service operations in the healthcare and preventive medicine sectors. Due to the in-depth analysis of a substantial amount of data regarding a small number of units or instances over a short period of time, the research methodology employed in this paper is a case study. The purpose of this project is to use queuing theory to reduce waiting times in hospital surgeries.

Both the subjective and the objective methodologies we used in our study produced different results. Our study attempted to identify potential bottlenecks and collect data on the length of time spent at each stage of obtaining a consultation at a typical clinic. The length of time that patients spent in line, at the registration desk, travelling to the doctor's office, and waiting for a consultation at the doctor's office were all observed using an objective manner. Next, we gathered more data and information pertinent to this investigation. Utilize a queuing model to optimise the outpatient department's arrival pattern and wait times after reviewing a few papers.

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The subjective method took into account the patients' perception of the delay, the causes of the delay, as well as their psychology and opinions on how quickly they were registered, received consultations, had their investigations completed, and were given the results of those investigations. In order for us to come up with a comprehensive answer, more data for the subjective approach was obtained and will be further studied.

IV. ANALYSIS

170 research papers out of the 200 selected. The histogram considers six time periods namely 1971-80, 1981-90, 1991-00, 2001-10, 2011-20, 2021-22. The highest number of research papers pertinent to our research topic was 81 found in the period 2011-2020. This was closely followed by 2021-22 wherein 55 research papers were published regarding the topic.

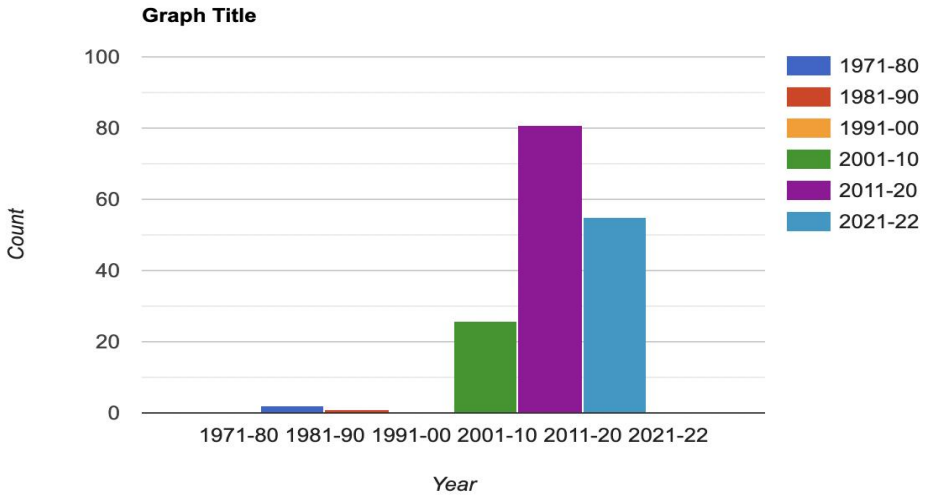

Figure 1: Count of Years of Publication

From 2001-2010 there were 26 papers published related to the topic at hand. 1971-80 only saw 2 research papers published relating to our topic, whereas 1981-90 only saw 1. We were unable to find any research papers published between 1991-2000. This pattern clearly shows how modern the queuing theory is in the healthcare sector, and also how Covid-19 played a big role in more research done for the same. This analysis also tells us how operations research is becoming more and more important as the years go on, as the importance of smooth and economical operations keeps on increasing.

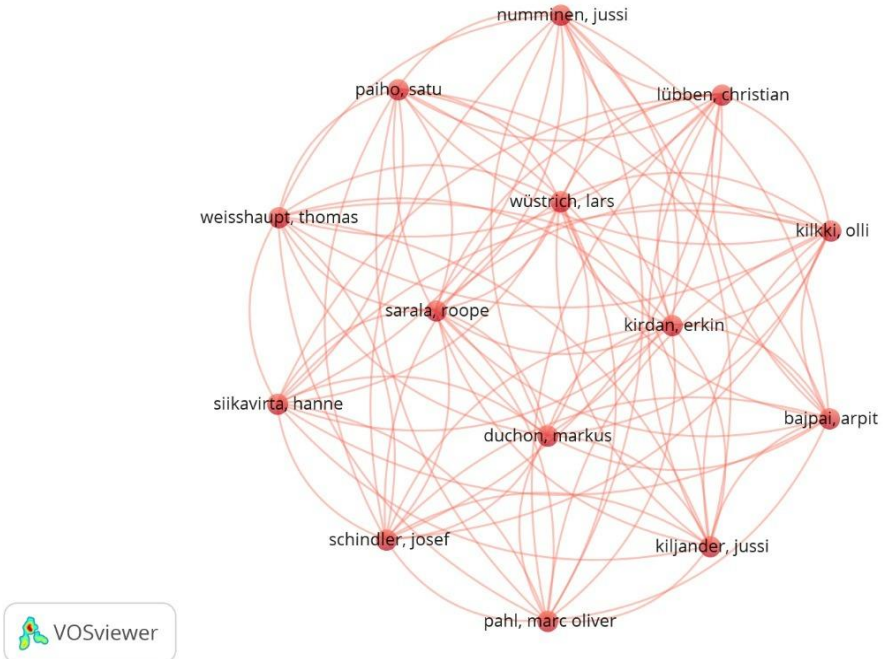

Figure 2: Co-occurrence of citation network from authors of the selected research papers with full counting

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Totally 475 authors have participated in the publication of the queuing theory in healthcare sectors research papers. Among them, Sarala, Roope; Wustrich, Lars; Kirdan, Erkin; Duchon, Markus; have 4 papers that mostly focus on queuing theory in the Healthcare Sector. The main collaborators with him are Bajpai, Arpit; Schindler, Josef. The total link strength is 91.

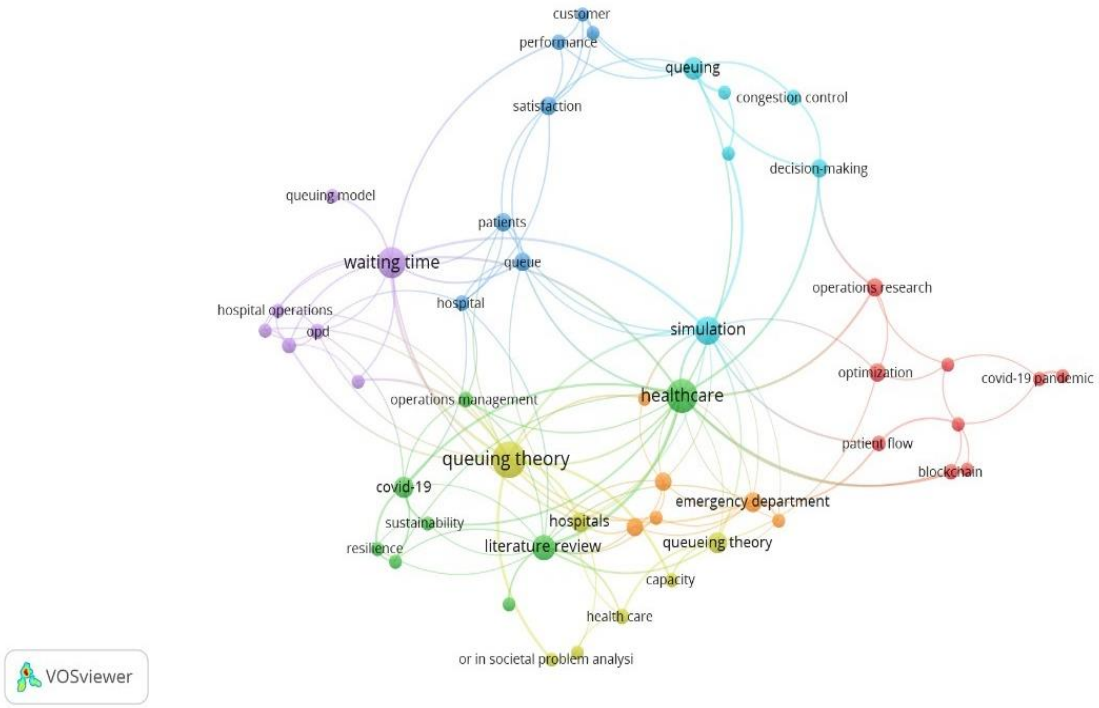

Figure 3: Co-occurrence of keywords used in the selected contributing papers with fractional counting

The above figure represents a bibliometric analysis of queuing theory in the healthcare industry. In total, 200 contributing articles, the above figure presents the keyword network obtained from the keywords used in each of the contributing articles. It is evident that healthcare, queuing theory, waiting time, and simulation are the top keywords. The figure presents the fractional keyword network obtained from the keywords used in each of the contributing articles. Some other words that have re-occurred a lot in the articles are - patients, operations management, sustainability, and emergency department. The words Pandemic and covid-19 have also been seen a lot in the papers over the past two years.

V. RESULTS/ FINDINGS AND DISCUSSIONS

This study demonstrated how queuing theory analysis may be used to enhance patient flow and shorten wait times in bottlenecks. In other words, it can shorten the lines that patients must wait in for any emergency medical operation. With the appropriate kinds of data, there are a number of potential future research projects that may be carried out. This data also reveals how operations research is growing in significance as time passes and the value of efficient and effective operations rises. Queuing theory must be correctly applied in light of the research on the Covid-19 pandemic and its conclusions in order to achieve the best outcomes. Every sort of disaster results in huge financial and human losses and necessitates a crisis response. Persons must be immediately rescued, any necessary medical care must be provided, and the harm to people and property must be contained. To answer "what-if" questions, plan, organise, and be ready for the tragedies in such scenarios, queuing models are widely used in conjunction with simulation. The queuing model suggests that its use in a crowded setting may have the potential to swiftly quarantine and reduce COVID-19 infection cases, improving down hospitalizations, reducing death rates, and bringing the epidemic under control within the bounds of available healthcare resources at any governmental institution. The results of the analysis showed that by raising the level of medical service capacity at the outlets at the lowest feasible total costs, which include waiting and service expenses, average queue length, waiting for arrival times, as well as overutilization of consultation doctors, could be decreased. The cost of line-waiting time declines as services get better. This

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could be accomplished by enlarging the service facilities or by utilising cost-optimization techniques that ensure waiting is an enjoyable and less stressful activity.

VI. CONCLUSION

Based on all the papers found by our team, we can indefinitely conclude that "queuing theory in the healthcare sector" is a modern topic for the current day and age. Healthcare systems have economies of scale and thus, the beds which are simple by design and cost, the higher the quantity of beds per patient, the fewer beds should be needed to reduce time to serve each patient and thus saving lives and money for the patients and the hospitals. The healthcare industry is plagued with delays around the world. We are accustomed to waiting for a doctor's appointment or surgery appointment, and when we arrive at the clinic, we wait to be seen again, delays in surgery and diagnostic tests are common. There are a lot of consequences for waiting – delayed treatment, lower patient satisfaction,

Queuing theory deals with delays caused by mismatches between demands, economic impact, etc.

The healthcare industry is plagued with delays around the world. We are accustomed to waiting for a doctor's appointment or surgery appointment, and when we arrive at the clinic, delays in surgery and diagnostic tests are common. Especially during covid, where only the people who could spend a lot would be given treatment first. Corruption and Political pressure also played a big role in the same. Queuing theory deals with delays caused by mismatches between the patient and the system. As this paper has shown, service systems are exceedingly complex as a result of sources of variability that are both predictable and unpredictable in terms of the demands for services and the turnaround times for delivering those requests. Decisions about how and when to allocate staff, equipment, beds, and other resources in healthcare facilities in order to minimise the delays experienced by patients are frequently even more difficult than in other service industries due to budgetary restrictions on the one hand and the potentially serious negative effects of delays on the other. In order to understand the impacts of various options, it is crucial that these decisions be made using the greatest available information and methods. Because queueing models require little data, are easy to apply, and are quick, queueing theory is a very effective and useful technique. They can be used to quickly assess and contrast a variety of service provision choices because to their simplicity and speed. Queueing models can be helpful in gaining insights beyond the most fundamental problem of determining how much capacity is required to achieve a specified service standard. These insights include the proper level of specialisation or flexibility to use in resource allocation, or the effect of various priority methods for allocating patients' services in a particular sequence. Even though queueing models don't need a lot of data, the kind of operational data needed as input is usually absent in healthcare settings. In particular, service times are typically rarely tracked even though demand or arrival data are frequently recorded. As a result, gathering data for a queueing study may be necessary to determine, for example, the length of time a care provider spends with a patient. However, as information technology systems proliferate in the healthcare industry, this kind of data will become more widely accessible. It's crucial to ensure that all of the data required for the model is gathered and/or calculated while creating the data inputs for it. On the demand side, this entails taking into account all care demands, even those that may have previously gone unmet due to insufficient capacity. For instance, some patients who must wait a long time to see a doctor in a hospital emergency room leave the ED before being treated. The model will overestimate the capacity required to fulfil the intended performance level if these are not included in the data gathering system being used to measure demands. It's crucial to account for all of the server time spent on tasks directly related to the patient's care on the service side. For a doctor, this can entail performing a direct examination of the patient as well as evaluating the patient's medical history and test results. A queueing analysis of a specific healthcare system also has to identify one or more delay measures that are crucial to the facility's pursuit of service excellence. These metrics ought to take into account both clinical facts and patient opinions. For instance, although patients who arrive at a hospital emergency room with non-urgent issues may not need treatment right away from a clinical standpoint, it is obvious that extremely long wait times to see a doctor will result in high levels of dissatisfaction, and possibly even departure, which could ultimately result in lost revenue. Due to a lack of understanding of both patient expectations and the impact of delays on clinical outcomes for the majority of health conditions, determining what would be an appropriate delay standard in a particular healthcare facility is not a simple task. In conclusion, healthcare administrators are becoming more

and more aware of the necessity to utilise their resources as effectively as possible in order to ensure the survival and success of their institutions. This is especially true given the potential of abrupt and severe demand spikes caused by terrorism, epidemics like SARS and avian flu, or other outbreaks. Effective capacity management is essential to this goal as well as to enhancing patients' capacity to receive the most appropriate care in a timely manner, as this chapter has attempted to show. Effective capacity management, however, must consider a variety of complex issues, such as trade-offs between bed flexibility and care quality, demands from different sources and patient types, time-varying demands, and the frequently conflicting perspectives of administrators, physicians, nurses, and patients. All of these persistent problems make it difficult for hospital administrators to reduce spending and raise the standard of service. Managers must be informed by operational and performance data in order to handle these difficulties, and they must use this data in models to derive insights that are not possible to derive from experience and intuition alone. Queueing analysis should be employed as frequently in the healthcare industry as it is in the other main service sectors since it is one of the most useful and efficient techniques for comprehending and assisting decision-making in managing vital resources.

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