



## RESEARCH ARTICLE

# Multilevel Feedback Queue Scheduling Technique: Model Proposal to Reduce Risk and Enhance Performance of Health-care Systems

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## ABSTRACT

In recent decades, computer technology has been highly developed and applied in numerous aspects of daily life, and the health-care sector is becoming more aware of the significance of information development. Health-care systems, including their divisions, can indeed use software applications to minimize risk and enhance performance. This study used the multilevel feedback queue (MLFQ) technique, assigning a time slot to each queue for MLFQ scheduling (MLFQS) so that it changes dynamically with each round of performance. Implementing MLFQS techniques (MLFQST) enhances patient satisfaction, minimizes risk, and ultimately delivers high-quality care to patients. It also optimizes patient flow and resource allocation, reducing wait times and delays. The technique divides the ready queue into several queues with different priorities, and each queue has its own scheduling technique. Based on the prioritization, MLFQST reduced the waiting time in the queue over the maximum safety requirements for optimal management by 78 arrivals per 4 h/day in a week, while the percentage of station time utilization was 22, 19.81, 17.62, and 17.62, respectively. While the average waiting time was 24.56, 29.68, 23.5, and 22.62 min, the estimated average support units used by the four stations in the system are  $W_s = L_s/\lambda = 1/\lambda - \mu = 0.215 \text{ h} = 0.215 \times 60 = 12.9 \text{ min}$  per patient in the waiting queue. The findings indicate a substantial reduction in risk, waiting times in the queue, and enhanced performance.

**Keywords:** Multilevel feedback queue scheduling technique, estimate waiting time, improve risk reduction, enhance the performance of health-care division, patient satisfaction

## INTRODUCTION

Nowadays, computing technology serves various purposes, making it impossible to imagine a world without technology.<sup>[1]</sup> Modern technology provides sectors with the capacity to perform tasks with exceptional speed and provides an area of possibilities that are only beginning to be investigated.<sup>[2,3]</sup> The most significant aspect of computing techniques is their capability to concurrently execute numerous activities, which can be achieved with an efficient scheduler, and software applications that can indeed be used in healthcare have been encouraged by this to perform better.<sup>[4,5]</sup>

Health-care centers are government-operated organizations that provide health-care services. The services focus on emergency medical care, diagnosis, and medical treatment for patients, as well as providing services and preventing diseases.<sup>[6]</sup> Health-care applications are one of the most promising advancements in delivering timely and in-demand services to end users while also collecting statistics and data for presentation to provincial public health authorities.<sup>[7,8]</sup>

Overcrowding in health-care facilities can lead to longer wait times, decreased quality of care, and an increased risk of disease transmission.<sup>[9,10]</sup> Factors affecting waiting times for health-care services include service availability, priority groups, service hesitancy, and the risk of epidemic disease or virus mutations.<sup>[5,11]</sup>

The operating system has several significant goals, including facilitating user deployment, ensuring efficient operations, guaranteeing dependability, and optimizing performance and control. The requirement for processor

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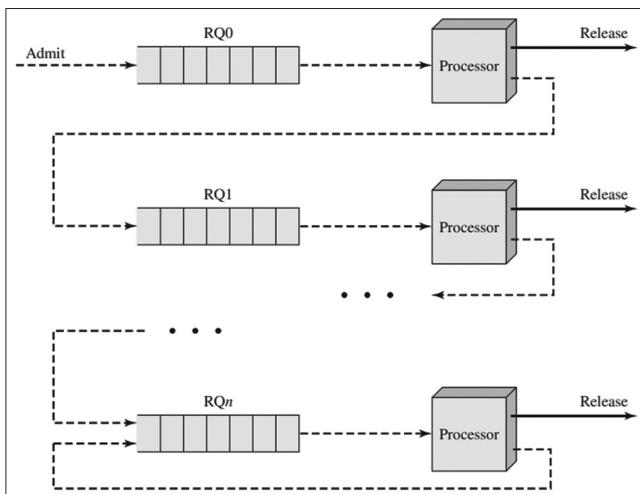
scheduling arises mainly from the use of multitasking operating systems in modern computer systems. The scheduler is a specialized system software that manages the allocation of resources from the queue to the services.<sup>[12]</sup>

In operating system management, a multilevel feedback queue scheduling technique (MLFQST), is designed to provide a balance between responsiveness and fairness.<sup>[13]</sup> Processes with high priority are able to dash and are less likely to be delayed by processes with lower priority. However, processes with lower priority are still able to run periodically, ensuring that they eventually receive central service unit time.<sup>[14]</sup> The technique also allows for dynamic adjustment of priority levels based on the behavior of processes, ensuring that methods that use central serves unit time efficiently are given higher priority.<sup>[15]</sup>

Figure 1 illustrates the feedback scheduling technique by showing the path that a process will follow during the several queues. This approach is known as multilevel feedback, meaning that the operating system allocates the processor to a process, and the process block is pre-empted, feeding it back into one or different priority queues.<sup>[16,17]</sup>

Hence, models can help determine how infectious diseases will be managed under different scenarios and inform public health decision-making. For example, models can help identify which interventions, such as social distancing measures, are likely to be most effective in reducing the spread of the risk of epidemic disease or virus. Analyzing the performance of queue systems can help identify bottlenecks and areas for improvement. This can be done using mathematical models and simulation techniques, which can help predict system behavior and optimize performance.<sup>[18,19]</sup>

In the “multilevel feedback queue scheduling model,” arrivals ( $\lambda$ ) represent the individuals that enter the system and join the queue. The queue is a waiting line where individuals reside and wait for their turn to be served by a server or station ( $\mu$ ). Individuals or jobs that are ready and waiting to be served are placed in the ready queue or waiting list.<sup>[20]</sup> This list is typically stored as a linked list data structure. Multilevel feedback queue (MLFQ) can help improve efficiency and reduce wait times, but it can also be more complex to manage and may require additional resources.<sup>[21]</sup>



**Figure 1:** Illustrates the feedback scheduling<sup>[17]</sup>

The study presents an MLFQST model proposal aiming to examine the impact of healthcare system prioritization based on medical needs on the treatment of urgent cases and explore the use of predictive models to optimize health-care system performance. The model also presented and offered valuable insight into optimizing service administration, reducing wait times, improving risk reduction, enhancing the performance of health-care divisions, and ultimately increasing patient satisfaction.

## Related Work

Di Pumpo *et al.*<sup>[22]</sup> propose implementing queueing theory as an approach to predicting the most effective number of health-care workers to schedule daily at a vaccination site. It considers the potential variations caused by health-care workers needing to adhere more perfectly to their scheduled arrival time. In addition, it aims to provide safety indicators related to physical distancing during the pandemic, as well as performance indicators regarding the utilization time of each unit and the average waiting time for areas of study. In addition, Lu *et al.*<sup>[23]</sup> Combine computer software with data mining technology to realize performance appraisal program analysis and incentive performance pay distribution. The software then calculates the performance appraisal results regularly. This article uses self-developed performance management software in a domestic large-scale tertiary hospital to analyze assessment programmers and distribute incentive performance contributions. Moreover, Chen *et al.*<sup>[24]</sup> explore a dynamic scheduling policy and a capacity scheme to optimize patient flow. Through wireless sensor networks and intelligent health-care systems, smart hospitals can build this scheduling policy and capacity scheme. The study quantifies systems using formal modeling. Process algebra for performance evaluation can be used to model the dynamic scheduling policy and capacity scheme by clearly defining the patient flow and providing scalable performance analysis through fluid flow approximation. Strielkina *et al.*<sup>[25]</sup> Illustrate basic scenarios involving a select few models of healthcare IoT systems, utilizing the principles of queueing theory. The models describe the flow of requests and attacks on vulnerabilities, as well as the process of recovery through restarting and eliminating ones. Franco *et al.*<sup>[26]</sup> Developed a mathematical model that enhances patient scheduling and resource allocation decision-making for vaccination centers, taking into account congestion and workload limitations. Health-care centers are faced with making decisions in response to the unexpected conditions caused by the pandemic, which has resulted in a vaccination procedure that differs from conventional processes such as the seasonal flu vaccine. Ghahremanloo *et al.*<sup>[27]</sup> Developed a method to evaluate health-care units' data envelopment analysis (DEA) efficiency, effectiveness, and productivity (EEP). Based on inputs and outputs, traditional DEA models evaluate decision-making units using linear programming. Each outcome's aims are used to assess health-care facilities. By controlling inputs and outputs, the developed model can improve the performance of non-productive divisions. Chmielewska *et al.*<sup>[28]</sup> proposed a methodology that uses a McKinsey 7-S Framework diagram to diagnose hospital operations and provide a more comprehensive assessment of performance

than merely focusing on monetary results. The study highlights the importance of non-financial factors in improving hospital performance, with physicians as the main contributors. Alnedawe and Aljobouri<sup>[29]</sup> developed a new model based on machine learning (ML) that has been effectively deployed in the health sector. Medical imaging sources (radiography and computed tomography) have aided in the development of artificial intelligence strategies to tackle the coronavirus outbreak. As a result, a classical ML approach for coronavirus detection from computerized tomography images provides insights into how queuing theory can be applied to improve the management of vaccine supply chains during crises. Elalouf and Wachtel<sup>[30]</sup> present a paper that conducts a systematic literature review to identify which models and theories can provide efficient emergency department (ED) performance and enhancement methods. This question helps identify and classify existing state-of-the-art subjects, gaps and limitations, managerial implications, and future research prospects. Our review aims to help readers navigate the vast academic literature on queuing applications in EDs.

### METHODS

The primary method for addressing the issue of flow is that individuals enter health care as arrivals, wait in a queue to receive services, and then go to the next phase of the process or quit it. One of the most critical strategic characteristics of the health-care system's quality and improvement services is the utilization of time allocation and scheduling techniques.

A method based on the "Multilevel Feedback Queue Scheduling Technique" is proposed in this study. This has proved to be the most efficient. However, there is scarce literature and mechanisms to utilize in numerous authentic contexts in which dependence on topics respecting their scheduled times would be unwise.<sup>[22]</sup> In relation to this subject, the scientific literature provides many tools, such as queueing theory,<sup>[22]</sup> data mining technology,<sup>[23]</sup> wireless sensor networks, intelligent health-care systems,<sup>[24]</sup> IoT systems,<sup>[25]</sup> ML,<sup>[29]</sup> and MLFQST is well supported in the literature and does not require highly demanding computational or technical

abilities. It is simple to support in the literature,<sup>[22-24]</sup> and many health-care sectors have successfully used it.

The proposed model, MLFQST used first-come, first-served ( $\infty$ |FCFS) and involved selecting techniques to collect data at the local health-care center related to distribution with a known variance and mean. After collecting data over 6 days, calculate the average delivery rate by dividing the overall arrival and service interest rate by the obtained data. System performance was assessed using parameter measures to predict system behavior and optimize performance. The time part was considered to be 4 h/day for the simulation, as this was the amount of time sped for patients to flow and receive service in a conventional hospital-based system.

The conceptual paradigm for health-care service, depicted in Figure 2, is designed to provide efficient and effective health-care services to a large number of patients seeking services. The system's design considers the critical factors that impact health-care service performance, ensuring that patients receive prompt attention and high-quality care.

The framework of the proposed method is shown in Figure 2. Which outlines the sequence of steps for the algorithm. In the first queue (q1), a quantum number of 2 is set, and a First-Come-First-Serve (M|M|1): ( $\infty$ |FCFS) is applied. This means that arrivals with a waiting time (WT) no longer than the quantum number are performed in q1 using FCFS. The remaining arrivals are moved to the second queue (q2) for performance. In q2, the WT of the remaining arrivals is calculated using the average of the WT of the arrivals that were performed in q1. The resulting average value becomes the new quantum number for the remaining arrivals. Arrivals with a WT that is less than or equal to the latest quantum number are then performed in q2 using the FCFS technique. The remaining arrivals that were not executed in q1 or q2 are moved to the third queue (q3). The description mentions that only a minimal number of arrivals are entered into q3, and the ( $\infty$ |FCFS) is used to assign the server to the remaining arrivals in q3.<sup>[29]</sup>

In Figure 3, the proposed scheduling design approach, when an arrival starts performing, it first enters q1 and is scheduled in

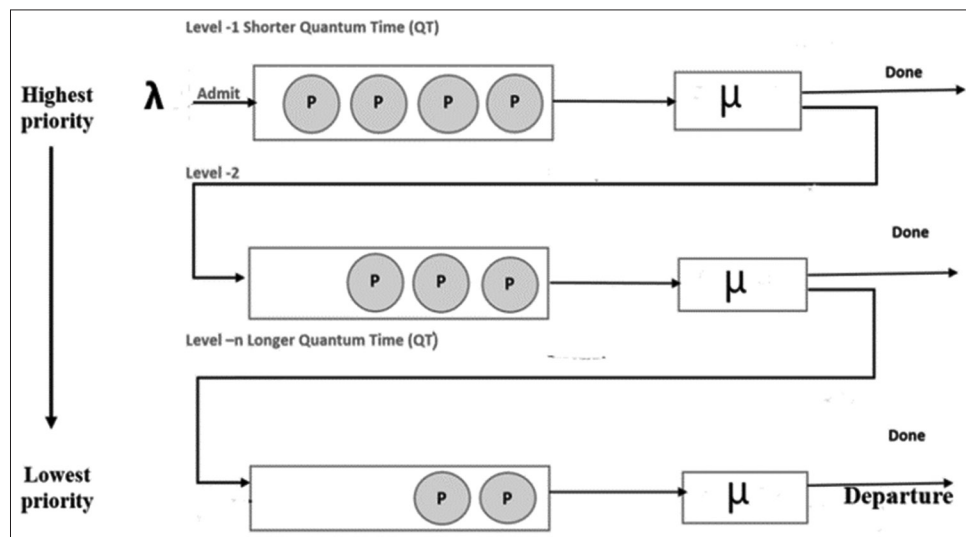


Figure 2: Illustrate feedback queue scheduling model proposal

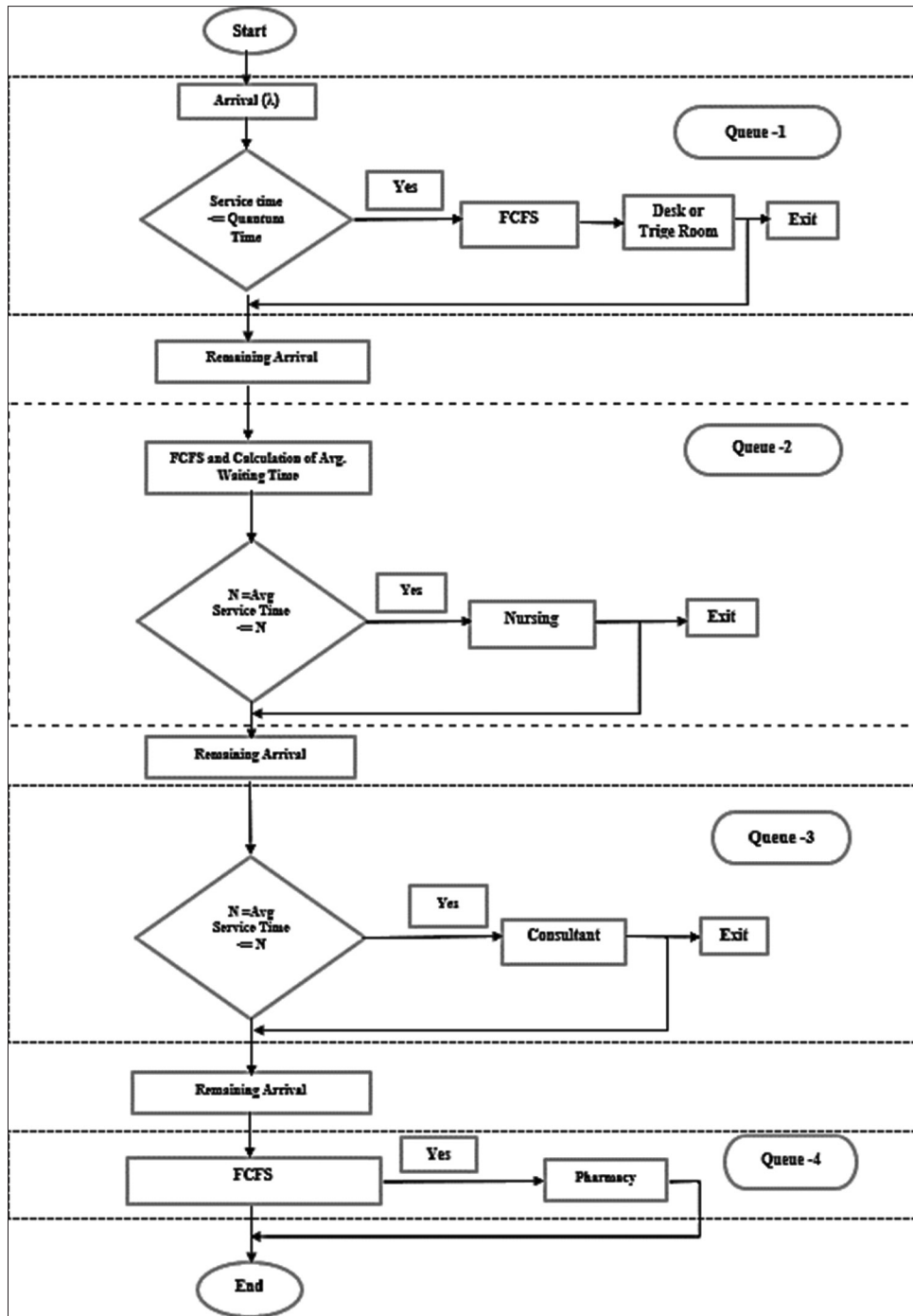


Figure 3: Flowchart for proposed scheduling technique<sup>[29]</sup>

a  $(\infty | FCFS)$  manner. If the arrival is completed, it is performed in 1 unit or gives service for I/O operation within this time; its priority remains the same, and it stays in q1. However, if the arrival is not completed within 1 unit, its priority is reduced, and it is shifted to q2. If an arrival is in q1 and is pre-empted by another arrival, it goes back to the head of q1 when it becomes ready again. If an arrival is in q2 and completes its performance within the time slice allotted to it, it is moved back to q1, and its priority is increased. If the arrival is not complete within the time slice, it is shifted to q3. Arrivals in q3 are scheduled in a round-robin manner with a time slice of eight units. If an arrival

completes its performance within the time slice, it is moved back to q2. If it is not completed within the time slice, it is shifted to q4. In q4, all arrivals are scheduled in a  $\infty | FCFS$  model.<sup>[31]</sup>

### Helpful Queuing Theory in Healthcare

The health-care framework includes waiting lines, workers, server schedules, availability, operating techniques, and priority services offered. Waiting lines refer to the queues of patients waiting for treatment; workers refer to the health-care professionals providing the treatment; server schedules refer to

**Table 1:** Analysis of arrival time, service time, and time spent in the 4-queue

Start and End Time	High Priority						Low Priority	
	IT Room		Consultant -1		Consultant -2		Consultant -3	
	Arrival	Service	Arrival	Service	Arrival	Service	Arrival	Service
An Average Per-Week	14.75	16.5	13.75	23.75	12	17.5	12	16.25
	16.5	20.75	15	21.25	13.5	17.25	13.25	16
	14.75	15.75	13.75	20	11.75	13.5	11.75	14.5
	15.25	16	13.75	18.5	13	16.25	13	15.75
	13.5	14	11.75	17.25	10.25	15.5	10.25	14.5
	13.25	14	11.25	18	10	14	10	13.5
Total Arrival Per week	88	98.25	79.25	118.75	70.5	94	70.5	90.5
Total Average	14.67	16.17	13.21	19.79	11.75	15.67	11.71	15.08

**Table 2:** An Average of Arrivals ( $\lambda$ ) and Service Time ( $\mu$ )

Parameter Measures	IT. Team		Consultant - 1		Consultant - 2		Consultant - 3	
	Arrival Time ( $\lambda$ ) for Whom Check at IT	Service Time ( $\mu$ )	Arrival Time ( $\lambda$ ) for Whom Check at Consultation	Service Time ( $\mu$ )	Arrival Time ( $\lambda$ ) for Whom Check at Approval - ID	Service Time ( $\mu$ )	Arrival Time ( $\lambda$ ) for Whom Will Tacking Medicine	Service Time ( $\mu$ )
Average of Arrivals ( $\lambda$ ) and Service ( $\mu$ )	14.67	16.17	13.21	19.79	11.75	15.67	11.71	15.08

**Table 3:** Analysis of system performance assessment-based parameter measure

Parameter Measures	IT. Team	Consultant - 1	Consultant - 2	Consultant - 3	System Performance Assessment by the 4-Servers
$P = \lambda/\mu$	0.895	0.667	0.749	0.778	0.772
$Lq = \lambda^2/\mu(\mu - \lambda)$	7.697	1.339	0.445	0.364	2.461
$Wq=Lq/\lambda$	0.093	0.067	0.025	0.020	0.051
$Ls = \lambda/\mu - \lambda$	8.593	2.007	2.996	3.524	4.280
$Ws=1/\mu - \lambda$	0.390	0.101	0.170	0.200	0.215

**Table 4:** Analysis of arrival time, waiting time, service time, and total time spent in the queues

The Average Number of Arrivals Waiting in a Queue (Lq)	The Average Time Spent in Queue (Wq)	The Average Number of Arrivals in a System (Ls)	The Average of Time Spent in the System (Ws)
2.461	0.051	4.280	0.215

the working hours and shifts of the healthcare professionals; availability refers to the availability of resources such as equipment and supplies; operating techniques refer to the procedures used for treating patients, and priority services offered refer to the prioritization of certain patients based on their medical needs. Priority non-pre-emptive arrivals wait for the new service time, which means that when a patient arrives with a higher priority than the patients currently being served, they will be added to the queue and will wait for their turn to receive treatment. The health-care system is designed to prioritize patients based on their medical needs to ensure that urgent cases are treated first.<sup>[32]</sup> The use of a feedback queue in a multi-server system allows for better utilization of resources

and reduces waiting times for patients compared to a parallel multi-channel queue. The feedback queue ensures that patients with higher priorities are given priority access to the available servers. The expectation method of the queuing model measures the following steady-state method,<sup>[9,20,33]</sup> and formula:

The probability of an arrival in the service system at a given time (P).

$$P = \lambda/\mu \tag{1}$$

The average time spent by arrivals waiting in line (Wq).

$$Wq = Lq/\lambda \tag{2}$$

The expected entire time in the system, including service (Ws).

$$W_s = 1/\mu - \lambda \quad (3)$$

The average number of arrivals waiting in a queue (Lq).

$$L_q = \lambda^2/\mu (\mu - \lambda) \quad (4)$$

Expected number of arrivals in a system, including waiting and service (Ls).

$$L_s = \lambda/\mu - \lambda \quad (5)$$

The average arrival (in time) into the average service ratio for the multi-server with the feedback waiting time model gives the moving flow act.  $P = (1/\mu)$  average service time ( $\mu$ )/ ( $1/\lambda$ ) average service time If the system capacity is less than the visitor's arrival time, the wait duration will rise, i.e.,  $\lambda > \mu$ , so  $\rho > 1$ , This queuing system's average arrival rate is lower than the average service rate,  $\alpha$ .

## RESULTS AND DISCUSSION

In data analysis, the researcher constructed a multi-station model that incorporates feedback queues to illustrate and discuss the findings, ultimately resulting in patient waiting times. This study aimed to improve the standard of service, control risk, and optimize performance at a major healthcare facility in the Akre region. The study proceeds by presenting the response rate and social background of the residents under investigation. As a result, the researcher obtained the current data by conducting meetings and observing individuals' private evaluations of their current performance enhancement level. In addition, the researcher chose specific techniques to collect data upon the researcher's arrival in order to provide medication to patients. As a consequence, the researcher modeled the local healthcare center using a multi-station model. It includes feedback queues that handle arriving patients and estimate the model's parameters. Based on the findings, there is a certain number of patients entering the system every hour, with an average rate of arrival and entry occurring every minute. According to the data concerning patient arrivals and the service proposal, the current healthcare system is functioning efficiently in terms of serving patients. Additionally, there is a notable gap between the actual and predicted waiting times for patients [See Table 1].

The existing system of health care has a waiting time of 14.67, 13.21, 11.75, and 11.71, and a service time of 16.17, 19.79, 15.67, and 15.08 minutes, respectively. MLFQST reduced the waiting time in the queue over the maximum safety requirements for optimal management as shown in Table 2 and 3. The results indicate a significant decrease in risk, waiting times in the queue, and improved performance. It also indicates that the healthcare center is incapable of satisfying the demand, and if the case remains, the waiting queue will become infinite. Therefore, it is essential to find prospective enhancements to the system with the aim of improving its capacity and reducing the waiting time for patients.

The results show that patients at station IT-1 have longer waiting periods, with an average waiting time of 0.390 minutes for each shift. In addition, the evaluation of the system's efficacy in managing patients in the queue reveals

that all stations are operating optimally, with an average waiting time of 0.215 minutes. The analysis of this method is based on queueing theory from a theoretical perspective as shown in Table 4. The MLFQ scheduling technique is efficient when used in healthcare facilities under a minimized time and control approach. The estimated average support units utilized by the four stations in the system are  $W_s = L_s/\lambda = 1/\lambda - \mu = 0.215$  hours =  $0.215 * 60 = 12.9$  minutes. Therefore, making significant changes to these patients could potentially reduce the number of patients waiting in the queue and the time required to receive service. Researcher found that MLFQST significantly reduced waiting times in the medication queue over 4 hours, with a notable increase in station time utilization. This technique reduced the average waiting time for patients, estimated at 12.9 minutes per patient in the waiting queue. Implementation of MLFQST resulted in improved efficiency and reduced wait times, offering valuable insights for healthcare centers to optimize medication management and enhance patient satisfaction.

## CONCLUSION

The paper begins with a novel about scheduling to expect the actual waiting time for medication patients in healthcare, named the MLFQST, which is also used in operating systems to manage the allocation of resources, such as central processing unit time, to various processes or tasks. Most of the mathematical and statistical studies provide solutions for issues in the health-care sector. This study has found that most techniques are well-behaved and well-patient satisfaction. The best evidence available during therapy suggests that most mathematical and statistical paradigms avoid harm to the existing health system and staff satisfaction. Therefore, this scheduling technique is able to optimize and effectively handle the timing of treatment administration at the public health clinic. The most important part of this study is to clarify and minimize the actual waiting time for patients, which improves the health system's performance and the quality of the services provided to the patients; both need to ensure customer satisfaction in the future. If there are clear roles in this study that government agencies can adhere to, patients will be better able to plan their outings and will be less likely to have infections another time. Specifically, the study found that implementing medication time using the MLFQ scheduling technique reduces average line length, arrival time, and doctor overuse, leading to improved safety and satisfaction for patients.

## Limitations and Future Work

Limitations of this study may include the need for further validation of the proposed model in real-world health-care settings to assess its effectiveness practically. Future research could focus on incorporating more factors, such as specific demographic characteristics or logistical constraints, in the queueing models to enhance their accuracy and applicability. In addition, exploring the impact of varying prioritization strategies and addressing hesitancy in the models could provide valuable insights for optimizing vaccination programs. Further investigation into the adaptability of the proposed queueing theory model to evolving virus mutations and

potential modifications in vaccination strategies would also be beneficial for guiding future public health interventions.

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