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Queue Management Application for Healthcare Providers

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Abstract— Increase in healthcare services demands, coupled with the traditional methods of attending to medical services that demand physical attention of the medical practitioners and everyone seeking medical attention, to physically appear in a particular location at a point in time. As a result of the high demand for medical attention congestion, long patient queues, inpatient attention due to long queues, and discomfort experienced by those physically waiting in line for medical attention. This coupled with the danger and risk faced by medical practitioners and patients, especially during the Covid-19 outbreak, calls for other efficient means of booking an appointment with a medical practitioner without facing the usual abnormal rigours. These calls for the introduction of a Virtual Queue Management Application (VQMA, a mobile APP developed using scheduling and priority algorithms to regulate the flow of people seeking medical services. This allows patients to schedule appointments online through a mobile APP, and arrive at the health centre at their appointed time. Patient appointments are categorised as critical and non-critical. The Critical category handles emergencies or life-threatening cases requiring urgent attention, while the non-critical category is divided into Regular and Delayed. It enables individuals seeking essential services to wait in line virtually. VQMA was tested and observations were made on the patient arrival rate within a 60-minute interval. The report derived from the experiments, reveals a consistent decrease or gradual reduction in average waiting time for non-critical appointments. This improvement demonstrated a 67% better performance over the existing model.

Keywords/Index Terms— Healthcare, Queue, Scheduling and Priority algorithm, Emergency, Health Service Delivery, Patient, Hospital, Waiting time

1. Introduction

Waiting is becoming inevitable in the day-to-day activities of a man, where one has to wait to be served at retail stores, filling stations, train stations, bus stations, airports, banks, schools, hospitals, and in a congested or busy road. Waiting, also known as Queueing causes inconvenience and frustration to those waiting to be served, and has either a positive or negative impact on one's daily activities. Patients' experiences while waiting to seek medical attention can positively or negatively influence their medical status. The stretch patient face in the process of receiving medical attention sometimes aids the patient's response to treatment and at the same time could lead to the patient's untimely death. A situation whereby patients with critical health conditions will have to wait for long to get medical attention, as a result of long queues, coupled with the risk of some other diseases that can be easily contacted as a result of waiting room congestion. This puts high risk on both sides of the heartcare service providers and the patients.

Queue management systems permit excellent management of patient waiting times and timely service delivery (Hassan et al., 2022). Cipta (2017) Queue automatically begins at arrival of goods and people. It is the initial state of every process, it automatically springs forth immediately after the service request begins. It can positively or negatively impact customer satisfaction and the profitability of the business, based on the waiting time. Waiting time (starting at the arrival time) is the time it takes anyone in a queue to get the services demanded. The interval spanning from the moment of arrival to the initiation of service is designated as the waiting time. Waiting time can be adjusted (increased or reduced) using different techniques to meet up with the organizational target. Waiting time is very crucial in health care services, (Med et al. 2015 and Hassan et al., 2022) stated that waiting time is the primary determinant that exerts a substantial impact on the comprehensive satisfaction of a patient in health care services, when solved will promote Uniform access to medical services represents a fundamental component of the healthcare infrastructure (Ebbevi et al., 2021).

A virtual queue management system involves the non-physical organization or placement of customers in a waiting line to receive a service. This system allows customers to wait remotely, free from confinement to any specific waiting spot and successfully reduces the time patients spend waiting in the hospitals (Titarmare and Yerlekar, 2018). Thamrin (2020) It also reduces the cost of providing and maintaining medical facilities (Abdallah, 2020). Titarmare & Yerlekar, (2018) defines a virtual queue management system is defined as a mechanism that assigns customers to an intangible waiting line or queue, eliminating the need for physical waiting. Thinupathieswaran et al. (2021) divulge in their work the application of a zero-queue maintenance system for the healthcare system (ZQMS). This involves a virtual process to streamline and improve queue management, thereby minimizing wait times for end-users. This approach has prompted many healthcare sectors to strive for the most streamlined and briefest queues, to elevate patient satisfaction and improve the quality of services This decreases nurse workload to increase the quality of their services to physically and emotionally

support patients and improve patient satisfaction (Guarte et al., 2022). Exploring the relationship between queue management systems and service quality, according to Fares and Amir (2021) the paper reveals that queue management applications effectively contribute to and positively impact the quality of service experienced by people. This impact is especially crucial during a period of subdued and regulated activities, with a glaring economic meltdown caused by:

i. Lockdowns
ii. Limitations on assemblies of individuals
iii. Cessations of transport
iv. Stigma associated with COVID-19
v. Hesitancy among healthcare workers to treat individuals suspected of having TB or malaria, both of which exhibit similar initial symptoms to COVID-19
vi. Patients refrain from utilizing healthcare services as typically observed due to lengthy queues for service, which are strenuous, time-consuming, and could worsen the health situation for patients unable to stand for extended durations.

Covid-19 has restricted the number of individuals allowed in enclosed spaces. This limitation poses challenges as people endure exposure to health hazards while confined to enclosed or waiting spots in lengthy queues, striving to access healthcare services. Consequently, this scenario is marked by several deficiencies that the proposed system aims to rectify such as:
i. Time wastage due to prolonged waiting in queues.
ii. Heightened frustration among patients unable to receive timely treatment or service.
iii. Increased vulnerability of patients and customers to other infections during extended waiting periods.
iv. Inefficient utilisation of healthcare facilities.
v. Implementation issues, including gambling, reneging, baulking, and jockeying in the smart card queue system used in some hospitals, hinder its efficacy.

Healthcare and Medicare represent crucial necessities in the global community (Persis et al., 2020a). Their significance lies in addressing the healthcare challenges faced by numerous individuals seeking Medicare services. Access to safe healthcare is imperative and frequently necessitates immediate attention. However, healthcare institutions represent one of the greatest risks for the transmission of diseases. Healthcare facilities and medical practices accommodate ill individuals nearby, heightening the risk of contagion. Many patients are already vulnerable to infections due to age or preexisting conditions. It's essential to reassure people that doctors, dentists, and hospitals are taking extensive measures to minimize the spread of viruses (Andreas, 2020a). The Virtual Queue system finds its most relevant application in reducing the number of individuals in waiting areas, especially for scheduled visits. Given the unpredictability of many medical procedures, adhering strictly to scheduled appointment times isn't always feasible. Moreover, rigorous cleaning protocols between patients can further delay appointments. Consequently, patients often experience prolonged waiting times. Healthcare providers can effectively manage occupancy by minimizing unscheduled appointments. Web-based reservations facilitate the majority of patients visiting only when they have a scheduled visit. Although this

approach might not suit every scenario, it proves effective for most standard appointments. Rather than registering area and subsequently waiting in a crowded room, patients have the option to check in online, through a push notification on their mobile device, or via a quick response (QR) code displayed digitally at the health facility entrance. Subsequently, they can choose to remain in their vehicle or at home if they reside nearby. Upon the doctor's readiness to attend to them, patients receive a Short Message Service (SMS) notification prompting them to proceed inside. This streamlined process allows them to be promptly attended to without the need to occupy the reception area.

This straightforward procedure can be advantageous for a diverse array of medical professionals, including:
Primary care physicians
Hospital ambulatory care
Specialist services
Dentists
Opticians
Chiropractors along with other alternative healthcare practitioners

Virtual queue systems can enhance safety in hospital units during visitation periods. Many hospitals typically allow visitors within specific time frames. However, to mitigate the potential for infection among patients, staff, and visitors, implementing certain limitations may become necessary. Employing a virtual queuing management system enables hospitals to control visitors per patient, thereby reducing the overall crowd within the unit. Rather than employing a physical queue management system, hospitals can opt for time restrictions and scheduled appointment slots for visits. This approach ensures that although visits may need to be shorter, patients can still have valuable time with their loved ones Persis (2020b) and Deniz & Cimen (2018). Waiting lines are unavoidable in health facilities (Kuaban, 2020) while virtual reduces overcrowding and predicts the patient waiting time in the healthcare services (Burungale et al., 2018).

Effect of Covid-19 pandemic outbreak has profoundly affected humanity, paralyzing socioeconomic activities worldwide and leading to a consistent stage of deterioration (Messaoud et al., 2022). The global economy faces not only the COVID-19 outbreak but also a surge in other epidemic-prone diseases for instance according to WHO (2016) are Lassa fever, Leptospirosis, Covid-2-variant (Omicron), Meningitis, MERS, Avian influenza, Cholera, Ebola, Plague, Yellow fever, Influenza, Zika, Rift Valley Fever, among others. They are evasively devastating healthcare statuses and leaving grievous consequences in their wake Shang et al. (2021). The unreliable trading and operational practices in commerce and growth, as well as significant security concerns, have driven the global economy into its most severe economic downturn since World War II (Press Release, 2020). To address these challenges, this paper aims to improve the preference-based queuing algorithm and develop queue management software for a mobile application. This software will implement an improved priority queue algorithm, offering solutions to the aforementioned issues in healthcare service delivery.

2. Background and Related Works

The summary of the research-related work is shown in Table 1

Table 1: Summary of Related Works

Author and Year	**Technique Used**	**Contributions**	**Research Gap**
Ala and Chen (2022)	Review of related publications	Concentrated on examining the strategies and techniques to reduce or eliminate appointment scheduling problems.	Does not focus on scheduling accomplishment
Ismudoko et al., (2021)	Artificial intelligence	Reduced registration service time, patients waiting time, registration service staff and implement physical distancing during the COVID-19 pandemic	Does not put into consideration older users and potential users who are less computer literate.
Meryadi and Suardana, (2021)	A qualitative method with a phenomenological approach	Enhance work efficiency, accelerate processes, boost effectiveness, and elevate the quality of work	Focus on both online and offline registration /booking process as such does not focus on the need for the awareness of online queuing system
Pramudhita (2017)	Multi-channel, multi-phase queuing model utilizing a First-Come, First-Served (FCFS) algorithm	Patient's ability to retrieve the queue number and know the waiting time	The designed queue application is not a module that can be integrated with other module(s) that can later become integrated health facilities information system
Akpan & John (2021).	Queuing theory	Scheduling the optimal number of doctors per shift in GOPDs to reduce in-patients' waiting time and enhance their satisfaction. In addition, more doctors should be recruited to enhance the balance	The queuing system in selected tertiary hospitals is failing to meet the established performance benchmarks for modelling patient flow. Also, server

		between cost of waiting and service provision	scheduling does not match the pattern of patients' arrival
Franco et al., (2022)	A non-linear mathematical modelling approach that depicts the dynamics of both an open Jackson Network and a Generalized Network	The experiments carried out enabled the analysis of a COVID-19 vaccination case study, the outcomes of which can be utilized as a planning resource for the Foundation and additional healthcare providers to structure their vaccination strategies. This involves customizing patient scheduling to align with distinct needs and goals.	The current mathematical models exclude factors like the probability of no-shows, reneging, and deferrals, elements that could improve the models' flexibility in accommodating diverse patient behaviours.
Jahani et al., (2022).	A multiperiod queuing model that accounts for congestion in the vaccination process is suggested to reduce: (i) the expected average waiting time for vaccine recipients and (ii) the overall investment in vaccine storage and procurement.	This research formulates a queuing model for a crisis-driven vaccine supply chain aimed at facilitating the effective coordination and distribution of diverse COVID-19 vaccine types to individuals with varying degrees of vulnerability. This approach accelerates the supply and distribution processes and decreases costs associated with ordering and storage.	The study accounted only for server capacity, without imposing limitations on the daily influx of vaccine recipients to hospitals. Nevertheless, introducing a capacity constraint, particularly within the booking system, could enhance the model's precision.
Zaghloul and Abou El Enein, (2010)	The research was carried out at the ENT clinics of two of the largest and most reputable private hospitals in Alexandria. One hospital employs a block scheduling appointment system, while the other utilizes a traditional	The waiting time in the hourly block system was found to be longer for both new and returning cases compared to the standard system, contradicting previous studies that advocate for longer wait times in patient scheduling. Additionally, the access time in the hourly block system exceeded that of the standard system. Overall,	Strong academic paraphrase. This study did not address the issue of physician productivity nor other professional activities such as hospital rounds or staff meetings.

	sequential appointment system.	patients expressed dissatisfaction with the extended waiting periods; they perceived their wait as moderate in the standard system but lengthy in the hourly block system.	
Pazin-Filho et al. (2024)	A retrospective observational study approach	The study explores strategies for integrating and centralizing the queue, outlines the principles for its management, and discusses its application, enabling the institution to effectively respond to the challenges posed by the COVID-19 pandemic.	Results of the research are specific to the institution, which is essential to be strategically centralised

3. Methodology

A Virtual Queue Management system called 'Healthcare VQMA' utilizing a preference-based queue algorithm is introduced to mitigate the inherent bureaucracy in existing queue management models. The health VQMA application is accessible on the Android or iOS app stores, allowing users or patients to download and install it seamlessly. Those with the app installed on their mobile devices can commence enrollment and follow the Screen-displayed procedures outlined in the System Implementation and Testing section.

3.1 Method of Data Collection

Data gathering techniques used for both Primary and secondary data were employed to compile patient records for the design of VQMA. Multiple public healthcare centers were visited, allowing for observations of patient time patterns. Manual booking details (parameters) were gathered straight from patients who volunteered information, and additional data were obtained from the administrators of healthcare facilities for research objectives. Auxiliary investigation sources included books, internet searches, webpage exploration, journals, and newspaper articles.

3.2 Conceptual Framework

The conceptual framework of the designed system enables patients/users to log into the Queue management system and register their accounts by using their email address as a username and phone number as a password. This is the process and the user reservation ID is generated as illustrated in Figure 1 for subsequent use.

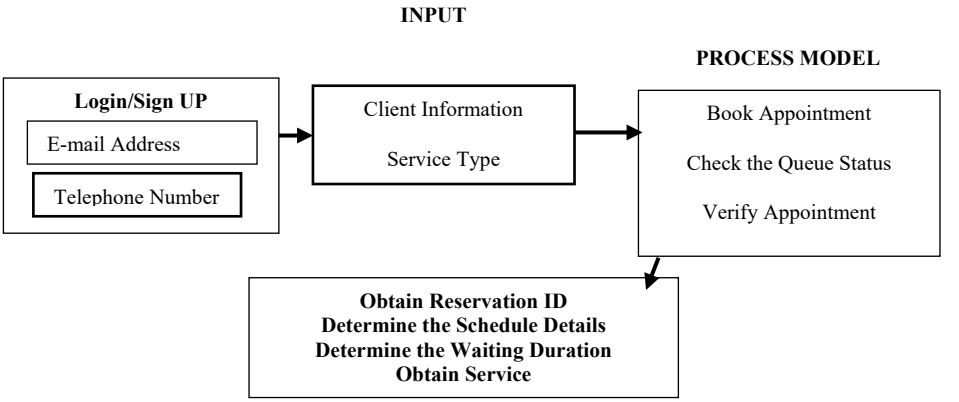

Figure: 1 Virtual Queue Management System Conceptual Framework

3.3 The System Process Diagram

The process diagram shown in Figure 2 illustrates the activities sequence right from scheduling the appointment point to receiving healthcare services.

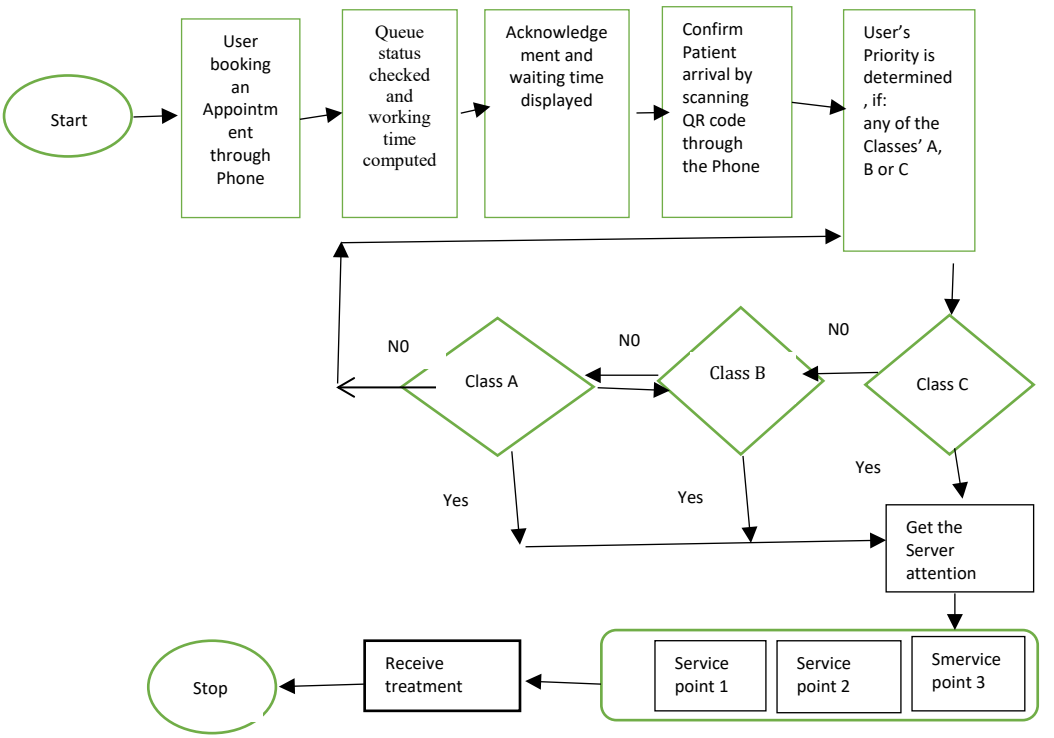

Figure 2: Process flow Diagram

The patient schedules an appointment using their Android mobile phone. Once the booking request is submitted, the system confirms receipt, assesses the queue status, and dispatches a booking ID along with the scheduled time and date to the patient. After receiving this notification, the patient can wait at a location distance from the facility until the appointed time. Later, patient verifies their appointment at the healthcare center by accessing the push notification menu on their appointment page through their mobile phone. Upon their arrival, the patient is guided to the designated service area according to the type of service requested and the time of arrival.

The system operates on a Single Channel–Multiple Phase Queue Management framework, organized with three separate service points: Class A, Class B, and Class C.

i. Class A: This is a service point designated to cater for non-critical appointments. These clients have their appointments confirmed and arrive at the healthcare center by or before the appointed time.

ii. Class B: This is a service point reserved for urgent situations, for priorities individuals' patients facing critical conditions

iii. Class C: This is a service point that handles non-urgent consultations for patients who arrived late or canceled their appointments.

3.4 Priority Queue Algorithm

This Algorithm identifies the next patient in the queue, ensuring they receive priority attention from the healthcare staff as shown in Figure 3. The algorithm enhances the use of healthcare resources by preventing any service point from remaining idle while there are still customers in the queue. Appointments are sorted according to their arrival time and the priority level of the healthcare service class. The algorithm verifies the requested service class when a patient's booking request is received, which could be any of the Classes A, B, or C. For Class A requests, the algorithm verifies the queue status to ensure it hasn't exceeded the maximum expected requests, set at 40. If within the limit, the request is placed in the queue, and the patient's booking is approved, with details sent accordingly. If the request is not for Class A service, the algorithm proceeds to prioritize Class B; otherwise, it moves to Class C.

```
IF class is A
        IF current Queue has A of length 40
                Push to [pendingQueueA]
                CALL ServicePoint1()
        ELSE
        Push to [currrentQueue]
        IF class is B
                IF currentQueue has B of length 15
                        Push to [pendingQueueB]
                        CALL ServicePoint2()
                ELSE
                Push to [currrentQueue]
                IF class is C
                        IF currentQueue has C of length 20
                                Push to [pendingQueueC]
                                CALL ServicePoint3()
                        ELSE
                        Push to [currrentQueue]
                End ELSE
        End IF
```

Figure 3: Priority Queue Algorithm

4.0 Result

4.1 Patient Registration

The designed system allows new users/patients to sign up and enter their details into the VQMA Healthcare booking system. The data required for creating an account, as detailed in Figure 4, include:

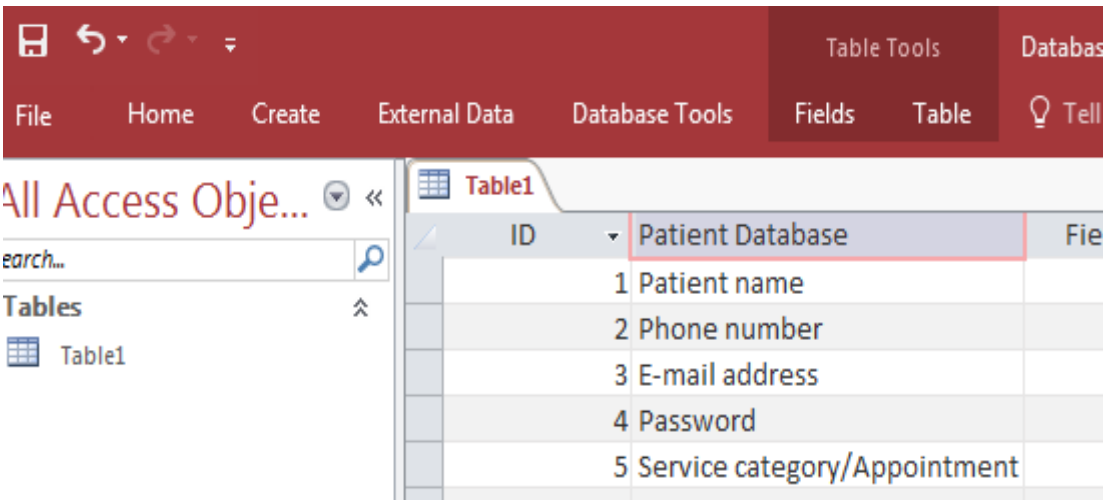

Figure 4: Patient Registration

Creating a New Account/Patient Registration

''VQMA'' begins the creation of a new account process by dispatching an activation link to the user's email address, where the patient on access their email, activate the link, and automatically become a registered user of the booking system. Figure 5 illustrates the VQMA Healthcare Sign-Up menu.

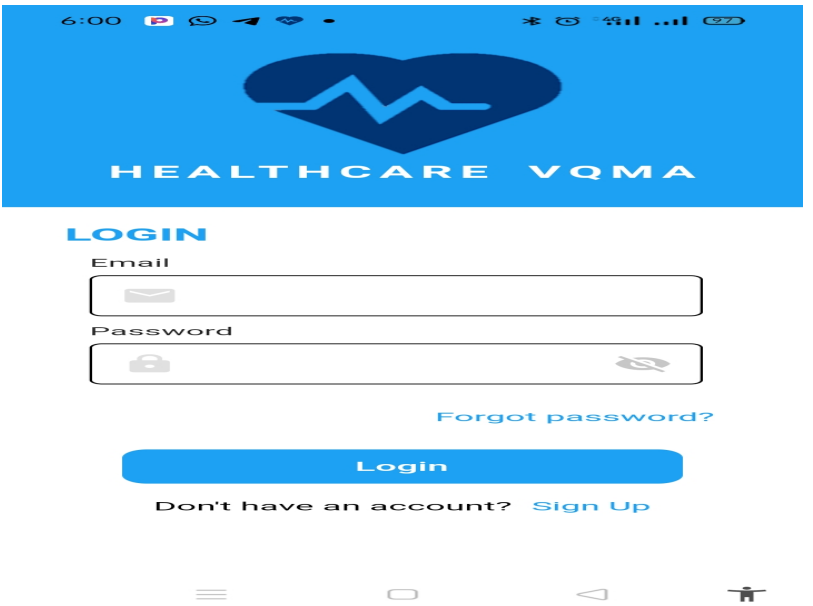

Figure 5: *Patient Registration App Sign Up*

Login Menu

This gives room to patients who have legitimate and active login details to book their appointments using their registered email address as the username and phone number as the password, which has already been established at the account setup point.

Appointment Information Menu

This allows the individual patients who have been scheduled for an appointment to view the details of their appointments by selecting the 'My Bookings' option on the welcome page menu. The details of the appointments for patients encompass:

i. Scheduled date and time
ii. Appointment Categories (Critical or Non-critical)
iii. Generated Booking ID
iv. Arrival status (Pending, Approved, or Elapsed)
v. Arrival Confirmation

The System Capacity

Healthcare VQMA is structured to support both Critical (Class B) and Non-Critical (Class A) appointment bookings per day.

Checking Queue Status

Having submitted an appointment requested Form, the system confirms reception and checks the current queue status using the formula:

$$Qs = (S_t * N * \Delta) + R * S_t.$$

Where:

Q_s = Queue Present Status, computed and rounded up to the nearest whole number

S_t = Mean Service Duration per patient

N = Count of Patients Previously in the Queue (Virtually) Before the Booking Customer's Request

Δ = Patient Influx Rate

R = Patient Remaining Service Duration

Computing Waiting Time

Anticipated waiting time for any booked/ applied patient appointment can be determined as follows:

Waiting Time= $(S_t * N + Qs) * S_t + R$

Where: St = Mean service duration per patient

Qs = Present Queue Condition

R = Remaining service duration for each patient.

Each patient class possesses a distinct projected average service time, from which the Residual time is derived as the incremental time developed upon comparison with the actual average service time.

4.2 Performance Objectives

Experiment 1 – Non- Critical Appointments

The Healthcare VQMA was tested at one of the Public Healthcare Centers, where observations were made on the patient arrival rate within a 60-minute interval. The resultant waiting time and average waiting time were recorded. Table 2 illustrates the results of the experiment

Table 2: Non-Urgent Appointment Influx Rate and Patient Time within 60 Minutes

Roll No	No of patient Arrived	Patient Arrival Rate @5minutes	Waiting Time	Average Waiting Time
1	1	5	10.2	10.2
2	1	10	10.9	10.7
3	1	15	11.5	11.1
4	1	20	11.9	11.4
5	1	25	12.2	11.6
6	1	30	12.5	11.7
7	1	35	11.8	11.6
8	1	40	11.3	11.3
9	1	45	10.9	10.9
10	1	50	10.5	10.5
11	1	55	10.2	10.2
12	1	60	10	9.8

Experiment 2 – Critical Appointments

An examination was also performed on the arrival rate of patients for critical appointments over two hours. The corresponding waiting times and the average waiting times were documented. The outcomes of this study are displayed in Table 3.

Table 3: Critical Appointments Arrival Rate and Patient Time within 2 hours

Roll No	No of Patients Arrived	Patient Arrival Rate@30minutes	Waiting Time	Average Waiting Time
1	1	5	11.5	11.5
2	1	35	11.1	11.3
3	1	65	10.5	11
4	1	95	10.1	10.7
5	1	125	9.7	10.5
6	1	155	9.3	10.2
7	1	185	9.3	9.8
8	1	215	9.2	9.6
9	1	245	9.1	9.2
10	1	275	9	9

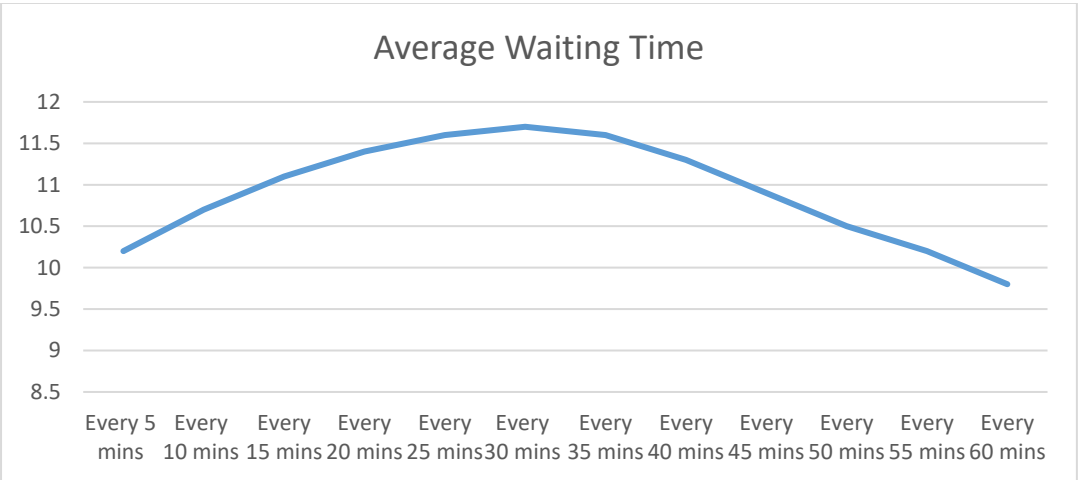

Figure 6: Average Waiting Time for Patient Arrival Time for Non-Critical Appointments.

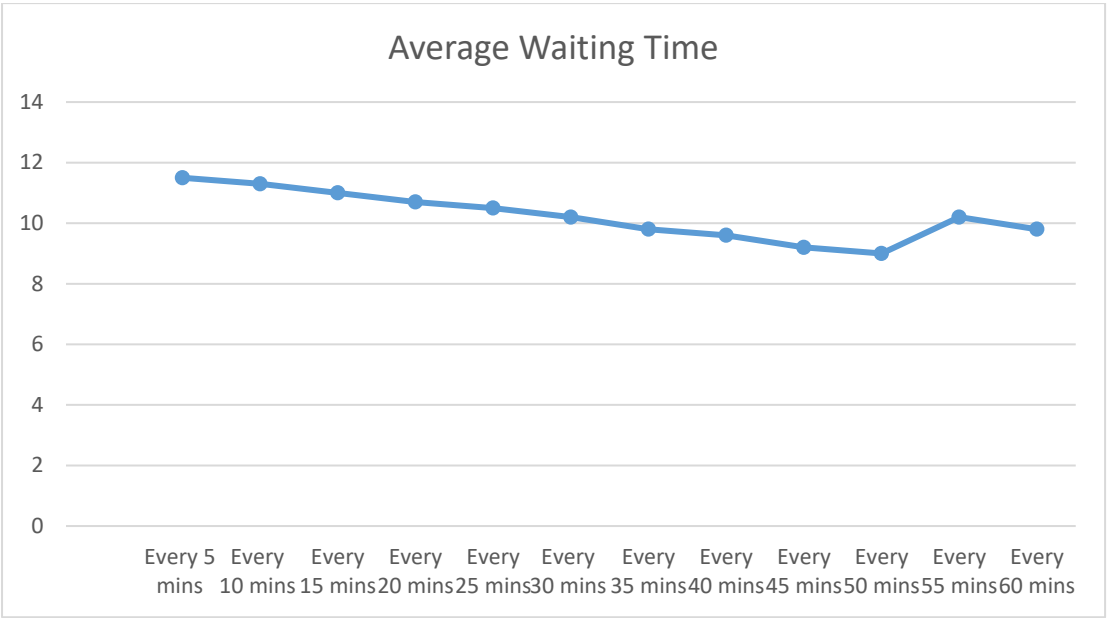

Figure 7: Chart Depicting Average Waiting Time Based on Patient Arrival Time for Critical Appointments

4.3 Comparative Analysis

The report focuses on observations made regarding the efficacy of the Current Virtual Queue Management Model. Table 4 outlines the mean waiting time and arrival particulars for each specific class, covering all three appointment categories.

Table 4: Correlation Between Patient Arrival Rate and Average Waiting Time Utilizing the Existing Virtual Model.

Column 1	Column 2	Column 3	Column 4	Column 5	Column 6	Column 7	Column 8	Column 9
	C1>C2> C3	C1>C3>C 2	C2>C1> C3	C2>C3> C1	C3>C1> C2	C3>C2> C3	C1=C2= C3	Sum Average Time (minutes)
Mean All Classes Waiting Time (minutes)	54.95	35.05	52.3	44.25	56.8	47.35	43.75	47.75
Mean Class A Waiting Time (minutes)	25.9	12.72	8.83	14.33	8.14	6.02	11.85	12.53
Class B Average Wait Duration (minutes)	82	22.53	64.9	42.62	55.25	41.85	37	49.42
Mean Class C Waiting Time (minutes)	120	82.53	93	76.33	95.33	70	81.85	88.4

4.4 Discussion of Result

Non-Critical Appointments

The report derived from the experiments, illustrated in Table 2 and Figure 6, reveals a consistent decrease or steady decrease in mean wait duration for Non-urgent Appointments utilizing the updated model, compared to a specific value upon entry. This improvement demonstrates a 67% improved performance compared to the current model.

Critical Appointments

A rise in the arrival rate at any specific point did not correspond to a proportional increase in the average waiting time for patients. This outcome stems from the utilization of a multi-phase service point approach and the implementation of an Enhanced Priority Algorithm in the candidate model, as depicted in Table 3 and Figure 7.

5.0 Summary, Conclusion and Future Work

5.1 Summary

A Virtual Queue Management Application model was introduced to mitigate prolonged patient waiting times at healthcare centers. The existing models were scrutinized, revealing inherent bureaucracy and system inefficiencies. The objective was to improve system performance, elevate patient satisfaction through reduced average waiting times, and enhance the quality of healthcare services. The resulting model, named 'HealthCare VQMA,' integrates an enhanced priority queue algorithm, accessible via

mobile devices (Android or smartphones) through app stores.

The decision to implement this model with an enhanced Priority Queue algorithm was prompted by identified limitations in existing models, aiming to effectively manage queue status and prioritize patient attention in both critical and non-critical appointments. Additionally, the system adopts a multi-service point architecture, ensuring adequate healthcare personnel attendance to confirmed appointments.

To validate the effectiveness of this model, a sequence of experiments was conducted within a public health institution, focusing on two specifically examined scenarios. Tables 2 and 3 present the observations on patient arrival rates, waiting times, and average waiting times, while Figures 7 and 8 graphically depict the experiment results. Concurrently, a performance evaluation of the existing Virtual Queue app model was undertaken, and the comparative analysis is illustrated in Figures 7 and 8, with detailed results tabulated in Table 4.

The inference drawn from this investigation indicates that patient arrival rates have a minimal negative impact on waiting times. However, the application may not be appropriate in a time of critical situation that requires an instant emergency, such as a vital accident.

5.2 Conclusion

The model reduces waiting times, corrects flaws in the current model, improves performance through enhancing patient satisfaction, and ensures maximum utilization of healthcare resources.

5.3 Future Work

A prospective direction for this research work could involve creating and implementing a desktop or Windows-based version of the application (APK). Encouraging its adoption in the majority of public hospitals and primary healthcare facilities would not only lower implementation costs but also expand its accessibility beyond the Android-based platform or smartphone devices. This initiative would enable many patients with non-sophisticated phones to afford and utilize the system

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