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Queue Management in Non-Tertiary Hospitals for Improved Healthcare Service Delivery to Outpatients

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ABSTRACT
A common problem associated with hospitals especially the non-tertiary hospitals (primary and secondary hospitals) is long queue. Attempts have been made to address this using the ticket approach, however, this does not minimize crowd in and around hospitals. In the wake of the consciousness of the need to avoid crowd with the emergence of the Corona Virus (COVID-19), it has become important to note that some diseases are transmissible when people clinch close within a vicinity especially in the hospital environment. It is therefore imperative to devise a means to reduce the usual crowd witnessed at the different units/sections in the hospital, precisely by outpatients. In this study, a centralized queue control system was developed that can be used in the different sections of hospitals. The system applied Poisson Distribution, Haversine Model, Little's Law and Kendall Notation. It is a web-based system, designed to run on the Internet as it focused on the outpatients and the fact that different sections of most non-tertiary hospitals could also be situated in different buildings or geographical area. The system was implemented using ASP.NET and Microsoft SQL. It was evaluated using data collected from non-tertiary hospitals in Benue State, Nigeria. The result showed reduced number of patients in the hospital per time and a little variation between the arrival and expected time of some patients. The system saves time for the patients, the hospital is more organized and crowds are avoided. Also, the pressure on the facilities of the hospitals at a time is also reduced significantly. Service delivery is improved and a healthier environment is assured for both patients and health workers.

Keywords
Queue, Management, Healthcare, Service Delivery, Non-Tertiary, Outpatient

1. INTRODUCTION
The advancement in science and technology have noted significant development in several industries of which the healthcare is not left out. Although in Nigeria, many hospitals still make use of the old file record system where patients data and prescribed treatments are documented [1]. Digital Improvement in hospitals is visible among few mostly private owned hospitals where the hospital management system is being utilized to serve patients better and primarily for good record keeping. There are basically three levels of health care: primary, secondary and tertiary. Primary healthcare denotes the first level of contacts between individuals and families with the health system [2]. Primary healthcare serves the community and it includes care for mother and child which includes family planning, immunization, prevention of locally endemic diseases or injuries, provision of essential facilities, health education, provision of food and nutrition and adequate supply of safe drinking water *etc.*

In Nigeria, primary healthcare is provided through primary health centres and comprehensive health centres both in the rural and urban areas. Secondary healthcare refers to a second tier of health system, in which patients from primary health care are referred to specialist in higher hospitals for treatment. In Nigeria, the health centers for secondary health care include general hospitals and specialist hospitals. Tertiary healthcare refers to a third level of health system, in which specialized consultative care is provided usually on referral from primary and secondary medical care. Specialized intensive care units, advanced diagnostics support services and specialized medical personnel on the key features of tertiary health care. In Nigeria, under public health system, tertiary care service is provided by federal medical centers, teaching hospitals and advanced medical research institutes.

One of the obvious problems affiliated with most hospitals is overcrowding of patients especially for hospitals that are known to be good at handling specific cases like women and fertility related issues, children cases, dentistry etc. It is a common practice for some persons to leave their houses to come pick up numbers and return much later so that they could be attended to on time even when they are not sure of the doctor's arrival. Securing ticket number does not even guarantee the exact time the patient would be attended to. The overcrowding experience at the hospital is not healthy for the patients and the doctors as well [1][2]. The present corona virus pandemic which is easily transmitted among people in a crowd has exposed the urgent need to social distance and possibly avoid crowds in the hospital. Prior before this pandemic a lot of people fall sick, goes to the hospital for treatment and end up contacting other transmissible illnesses via other patients while waiting to be treated thereby worsening their condition. Beside the doctors and nurses, other medical personnel are also at risk of been infected in such scenario because prior before consultation no one has an idea of the kind of sickness each person has come with and contacts must have been made with other patients even while waiting. Some researchers have worried on the queue for consultation of doctors but the challenge is quite complex as the different cases of patients in queue may require different amount of time and to think that queuing is not just done at the consultation level but also at the laboratory for testing, pharmacy for drug collection, payment of bills at the cashier etc. so exposure to people with different ailment not knowing which is transmissible may render other patients, nurses and doctors and all health workers vulnerable to be infected.

Our study shall focus on queue management at the primary and secondary level of healthcare that will reduce crowds at hospital per time where the hospital will have an idea of medical condition and reason for consultation before the patients' arrival. The proposed system will not just predict the waiting time a patient needs to complete treatment but would also take into cognizance how soon the patient can reach the hospital based on patients' location and provide the patient opportunity to accept or cancel appointment as the case may be as some patients may have reason to shun appointment at dying minute thereby wasting time that could have been utilized to service others on queue. Real time prediction for the waiting queue will cover all other departments besides consultation and this includes Laboratory, Pharmacy, finance etc. with the ultimate aim to avoid crowd and improve healthcare service delivery. The upshot from this research will by and large save time, reduce crowd in hospitals significantly and deliver quality health service reducing stress for both patients and medical personnel.

2. RELATED WORKS

Queuing is the main problem that affects healthcare services delivery with limited facilities [3]. Queues are made when the number of patients' arrival exceeds the rate of service delivery as a result of limited resources. In outpatient departments, the main quality assurance indicator is waiting time. To improve service quality, the waiting and service times are considered [4]. Long queues or waiting times in healthcare centres can lead to increase in the severity of disease and cause socio-economic costs. The results of some researches on assessing patients' satisfaction showed a direct correlation between patients' satisfaction and the waiting times, and indirect a negative effect of long waiting times on total patients' perception of service quality [3][4]. Long queues are an unwanted and unnecessary burden to the public as well as the hospital staff and cause serious pressure to the existing facilities in the hospital, with the cycle of limited facilities. This long queue of patient waiting for services at health facilities is a major source of concern and have led to unwanted burden to the hospital staff which is associated with a negative image of the hospital experience, which is unavoidable under the present system. This section considered existing works on queue management in healthcare system.

2.1 Queue Management in Healthcare Systems

Healthcare system is very sensitive and as such, queueing problem in this area has attracted a lot of attention from the academia. Researchers have so many works in this area with the view to addressing this issue. Burungale *et al.* [5] considered time as a crucial factor that should not be wasted and saw the need for a queue management system to be integrated with a hospital management system. Their system predicted waiting time based on the symptoms specified by the patient through a mobile app. The time a patient will wait is the total of all the time for treatment allotted to those before him. This is reasonable but there are instances where patients due to unpredictable nature of human character may turn down their appointment after they've been scheduled. The result of this may be keeping the doctors idle for that period and prolonging the waiting time of others on queue which the system did not consider. Also, patients who have similar issues could still have some variations which may demand more time hence, it will be difficult to work with predefined appointment time based on symptoms. For instance, two patients suffering from malaria due to variation in their immune system, the degree of severity will also vary and this could make same doctor attending to these patients to spend different amount of time.

Titarmare and Yerlekar [6] implemented a model in addition to an existing queue management system that can give alert notification to patients of a hospital, book appointment through an android application and direct them towards the nearest hospital. The fact remains that patients have different issues and sometimes some patients would prefer certain doctors based on recommendation to handle their case especially for non-tertiary health care where the patients most times are familiar with the hospitals they attend. The generalized model in this case may not properly fit into our scenario as we are more concerned with patients who are already certain about a particular healthcare center. It will be difficult to choose a particular doctor that will attend to one's case. Also, these doctors have different schedules and it's not all the time that one's appointment will coincide with the schedule of the doctor of choice.

Wangrakdiskul [7] analyzed queueing theory and instances in which it was used with healthcare providers of Public hospitals in Thailand. He attempted to reduce waiting time and to improve quality on healthcare services by proposing a model which considered the social cognitive approach and patients waiting time in the queueing management system. However, the model was not implemented and so the justification for improving healthcare quality cannot be ascertained. Bramah [8] opines that advanced mathematical models used in queuing theory have not been used by most authors. There is no doubt there are queueing systems to support hospital management but very little attention can be observed in the application of queuing theory in their models. Some queuing systems have been developed to meet and address specific issues confronting hospitals.

Prabakaran and Kumar [9] applied the queueing theory to address bed allocation problem faced by public hospitals while categorizing the need for urgency among patients to be treated, first come first served queueing principle was applied along with poisson arrival of patients and exponential services times first come first served. The result from the survey conducted using the model showed an improved system performance in the allocation of beds in emergency. In the same light of allocation of beds recommendation, queueing models like Erlang-C and loss systems were used [10] in their studies.

Our study shall concentrate on solving queueing problems experienced in not just consultation, but in pharmacy. Laboratory test section, finance etc. as it relates to outpatients in non-tertiary health care sectors. Some of these related works done were carried out in India, Thailand etc. and it will be difficult to implement same in Nigeria as the healthcare system and legislation governing these countries differ.

2.2 Queueing Theory

Queueing Theory is seen mainly as a branch of applied probability theory. It has been applied in different fields, e.g. computer systems, computer networks, machine plants etc. and several publications have emerged from researches done in different areas related to queueing theory. The theory is guided by a scenario where a population of customers visits a service center to obtain service and there is limitation on the number of customers to be serviced per time and so on the note that a new customer arrives while the service facility is busy, the customer will have to wait on a waiting line until the service facility becomes available. Three vital elements in the service center are noted in this theory: the service facility, a population of customers and a waiting line. Queueing Theory attempts to answer questions like mean utilization of the service facility, the mean waiting time in the queue, distribution of the number of customers in the queue, the mean system response time, distribution of the number of customers in the system etc.

2.3 Queueing Service Disciplines

The distribution of inter-arrival of customers, service time, number of servers, waiting line size (finite or infinite) are viewed differently among Queuing systems. There are some common service disciplines among queuing systems and these are:

FIFO (First in, First out): a customer that arrives and sees the service center is busy will go to the end of the queue.

LIFO (Last in, First out): a customer that arrives and sees the service center is busy proceeds to the head of the queue. The customer will be next to be attended to if no further customers arrive.

Random Service: in this case, customers in the queue are served in a random order

Round Robin: a time slice is designated for every customer. If the customer service is not completed, he/she will need to re-enter the queue.

Priority Disciplines: every customer has a (static or dynamic) priority, the server selects always the customers with the highest priority. This scheme can use preemption or not.

3. MATERIALS AND METHODS

This section explored the methods deployed in realizing the goal of this research.

3.1 Analysis of Existing System

This study considered non-tertiary hospitals (both public and private) in Benue State in the Middle Belt Region of Nigeria. We used the list of accredited non-tertiary hospitals in the State by NHIS. According to the list by NHIS, there are over one hundred and twenty (120) non-tertiary hospitals in Benue State. The mode of operation of these hospital could be diagrammatically depicted as shown in Fig 1. The directions of the arrows show the movement of patients vis-à-vis the care the accessed at every given point beginning from the medical record office through consultation by the physicians down to the pharmacy where the patient eventually completes the cycle of care. With this, patients queue up at every section.

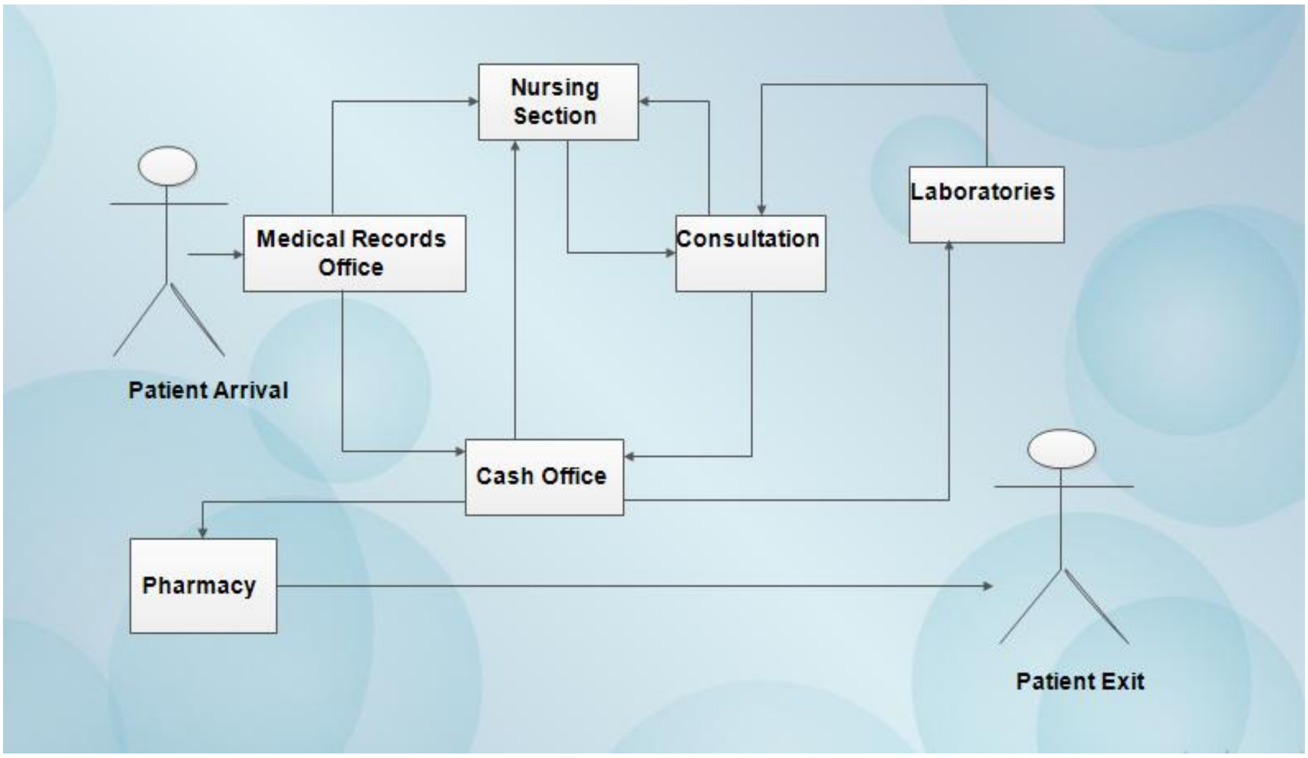

Fig 1: General Architecture of the Non-Tertiary Healthcare System

The method used by these hospitals is mostly the queue card system. Here, the patients in the queue are assigned numbers according to the order in which they arrived the facility. This method allows the patients to crowd in the waiting room until their number is called. Venturing outside of the immediate area is a constant gamble. The queue number may guarantee service according to the number priorities; however, a delay in returning may still result in the loss of a queue position. The fear of losing their positions makes patients to remain in the facility even when their turn is far. This is obtainable in all sections (medical records, pharmacy, consulting, investigation *etc.*) of the of the hospitals considered. This is shown in the Fig 2. Controlling these mammoth crowd to observing the COVID-19 procedures in this environment has become a serious challenge. Continuing with this system of queueing would exposed many patients and even the providers to this disease which has necessitated this research. Also, managing time on the side of the patients and the

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healthcare providers is also very difficult as they keep vigil in the facilities in other not to miss out their positions on the queue.

Some private hospitals provide a smart queue system as well as helpdesks and counter services for their patients. The smart queue system provides automatic queue numbers along with automatic voice calling and LED display panels on a progressive basis. However, this system requires patients to congregate in the immediate area to monitor the progress of queue numbers being served. This service only eliminates the need to stand in an organized line, but does not address the congregation of patients in the hospital which would make them more prone to contagious diseases like COVID-19 and Hepatitis, add more pressure to the facilities in the hospital and also negatively affect productive method for time utilization. Currently, to get access to service, patients have to physically wait in a queue. This system has the following limitations:

i. Waste of time for patients waiting for healthcare service.

ii. Administrative overhead for healthcare service provider to manage queue.

iii. Overcrowding the hospital facility.

iv. Loss of efficiency and protocol of organization arising from patients trying to bypass the queue, bribing their way through, favoritism or partiality and so on.

Existing data was collected from using the document review method. The data was categorized according to the section of care it was collected from, *i.e.*, laboratory, nursing, pharmacy, consulting *etc*. Over ten million (10,000,000) records were collected. The records about emergencies were exempted as emergency was not considered in this research. Attributes of the data include section code, patient number, time of arrival at the section, time of departure, residential address and occupation. Other attributes derived from these attributes considered include delay which is the difference between the arrival and departure time, distance traveled to access care which is obtained from the difference in the residential address and the facility address, the impact of this delay on the occupation. Also, the idle time of the servers is computed from the departure time of the previous patient exiting a particular section and the new patient coming to the same section.

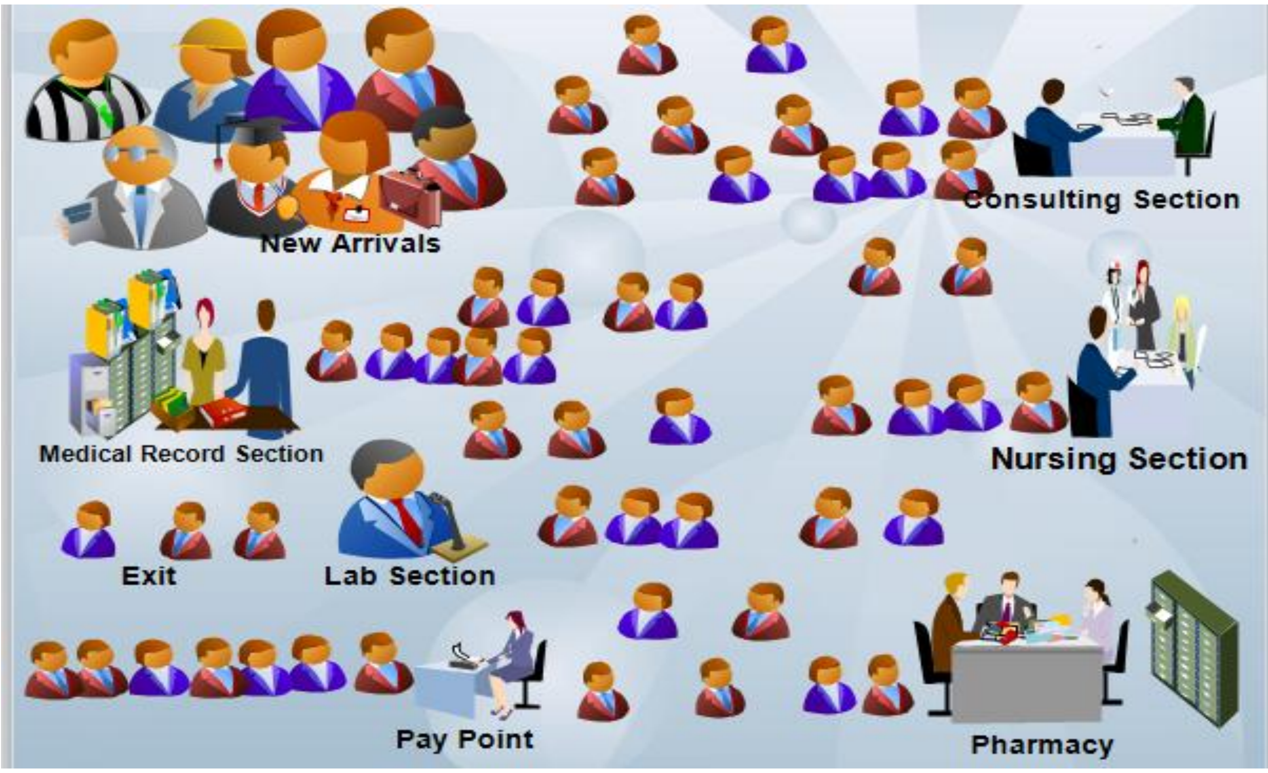

Fig 2: Existing system

3.2 Schematic View of Proposed System

In this research, we proposed a centralized queue control system which can be used in hospitals with different departments/sections. The system has the ability to support as many sections as possible where each section could have as many servers as possible. This could be set up at the control panel of the system when deploying the system. It is designed to run on the Internet due to the fact that each section is located in a different part of the building or even in geographical area, and the patients are also located outside the vicinity of the hospital. Thus, it provides real-time status monitoring.

The system has two basic components: assignment of queue position and assignment of server. The appointment booking, notification of patient, confirmation of appointment, notification of arrival by the patient and the notification of the server assignment module are all done by the queue assignment module. Also, all communication to the repository are also handled by this module. The checking of available server, assignment of server and the notification of the patient of the server assigned to it are all done by the server assignment module. The assignment of queue position is effected using the first in first out (FIFO) basis. The architecture of the proposed system is shown in Fig 3. The flow of patients in the system consist of several phases which include pre-arrival, arrival, queuing or waiting, serving, post-serving and managing.

Pre-Arrival: This involves booking for an appointment, notification and confirmation. First the patient log on to the system and booked for an appointment. The location of the patient is captured using the longitude and latitude of his/her address. This is very important as the notification to patient about his/her turn consider the distance he/she would travelled before getting to the facility. A notification is usually sent to patient reminding him/her to make it to the hospital. This would require the patient to either confirm or renege. By reneging, the system automatically notifies the next person in the queue. With this, the system is able to efficiently utilized the time of each of the provider in the system.

Queuing/Waiting: Once the booking is done, the patient could monitor flow of the queue on his/her device. This would guide the patient to get involved in other activities so as not to waste the whole day queueing up. Apart from exposure to contagious diseases, most patients would not be able to endure a period of waiting after queue entry, hence, balanced and controlled waiting period is the desired optimum service delivery. No medical director would want a completely empty waiting area as this would imply overstaffing or abandonment. This would equally guide hospital administrators to balance rightly by improving staff planning and adding more flexibility to the process.

Arrival: Upon arriving the hospital, the patient notifies the system that he/she is available. Once this is done, the coordinates (latitude and longitude) of the patient's current location are automatically captured to be sure if the patient is within the premises of the hospital. When that is established, the server assignment module is automatically notified about the presence of the patient at the hospital. This module then assigns the patient to a server and notifies the patient immediately.

Serving: This has to do with the assessment of care by the patient through the care line. Once the patient is done with a particular care provider (server), the server assignment module is notified and it automatically assigned the next server to the patient depending on the care he/she is to assess. This continues until the patient complete his/her care cycle and exit from the system. As this patient is winding up to exit from the system, the queue assignment module is notified to inform the next patient in the queue. The time at which a patient is notified also depend on the distance from where the patient booked for appointment to the hospital. The essence of this is to guard against or reduce server idle time.

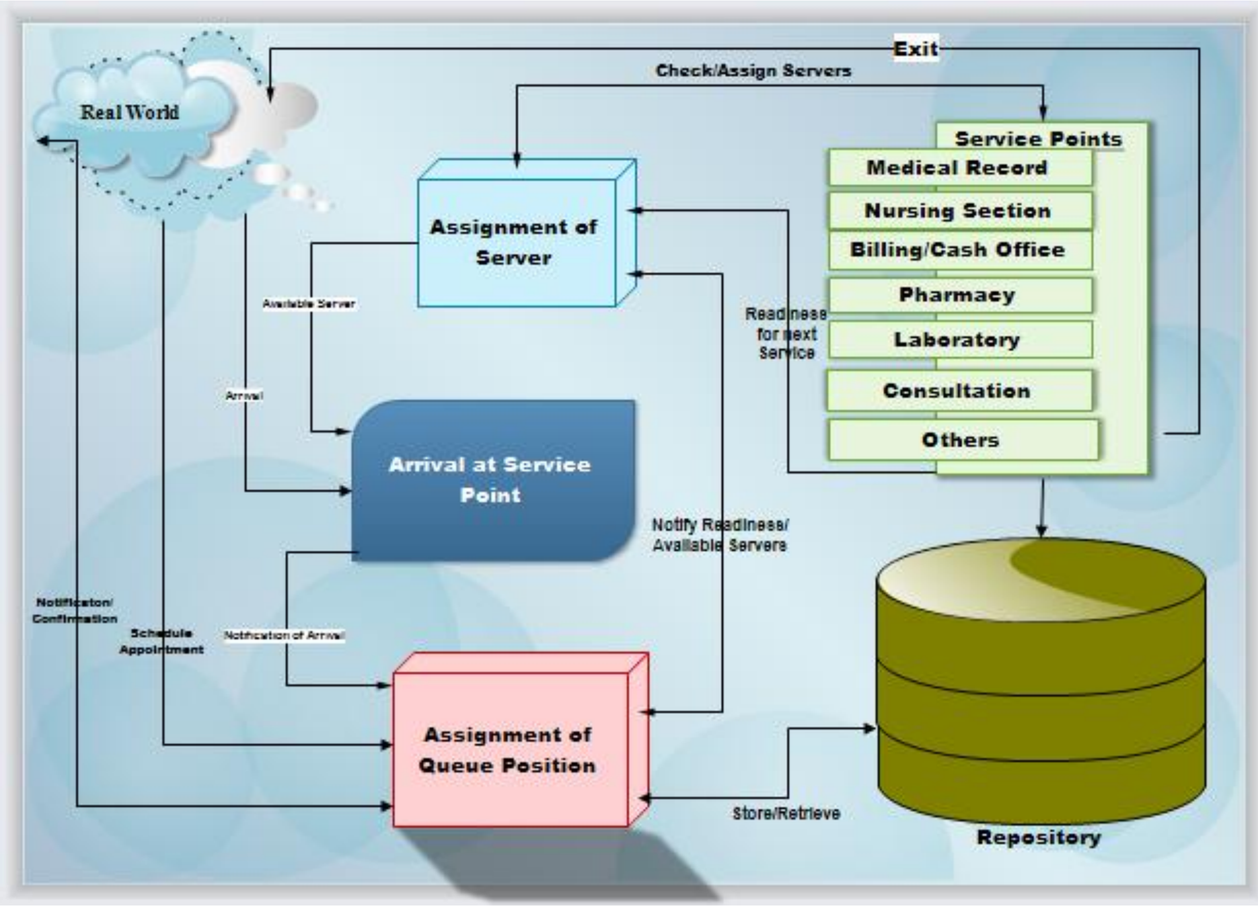

Fig 3: Proposed Architecture of the System

Post-Serving: After a patient has been served, detailed information concerning the services the patient assessed are properly documented and pushed to the repository for future reference. If the servers' closing time is due and the patients in the queue are not exhausted, they are automatically rescheduled for the next day.

Managing: Medical administrator could acquire data in this process which would enable them to evaluate the present system. This could be used to produce reports on the interaction between provider and patient, service times, server idle time and patient wait times. Also, with this information available, deficiencies in the mode of operation could be identified and addressed.

Notification: For the notification, we adopt the architecture developed by Lumauag [11]. The research was developed to send notices about school events to students, teachers, and parents about upcoming events of the school, changes in schedule of events, and suspension of classes due to bad weather, schedule of meetings, emergency meetings, deadlines of requirements and activities of their children in school. The architecture is shown in Fig 4. We applied this in the notification of the patients. The users are the patients while the school events are appointments and other activities of the patients in the system.

Computation of Distance: The geocoding and reverse geocoding are carried out concurrently. Li *et al.* [12] defines geocoding refers to the process of assigning geographic coordinates (latitude and longitude) to addresses or place names. Reverse geocoding is a process that associates geographic features with geographic coordinates. As the patient log on to the system, the geographical coordinates of the location are captured. These are converted to get the actual address of the patient. These complex features must be split into points before they can be processed by online reverse geocoding services. To compute the geodetic distance between the patient and hospital locations, we used the Haversine formula [13]. The Haversine formula is an equation important in navigation, giving great-circle distances between two points on a sphere from their longitudes and latitudes. These names follow from the fact that they are customarily written in terms of the haversine function, given by $haversin(\theta) = sin^2(\theta/2)$. The Haversine formula is used to calculate the distance between two points on the Earth's surface specified in longitude and latitude.

$$d = 2rsin^{-1}\left(\sqrt{sin^2\left(\frac{\phi_2-\phi_1}{2}\right) + \cos(\phi_1)\cos(\phi_2)\,sin^2\left(\frac{\psi_2-\psi_1}{2}\right)}\right) \quad (1)$$

Where d is the distance between two points with longitude and latitude (ψ, φ) and r is the radius of the Earth.

Fig 4: Architecture of the Notification Subsystem [11])

3.3 Mathematical Formulations for the Model

In specifying the proposed model, some properties of the arrival and service processes which are all probabilistic in nature were made. These properties are listed below.

1. Patient log on to the system for booking of appointments one at a time.
2. The probability that a patient book at any time is independent of when other patients will book.
3. The probability that a patient book at any point in time is independent of the time.

With these properties, the booking follows a *Poisson* process. This means that number of bookings in any given time period has a Poisson distribution. To properly represent this model, we adopted the Kendall Notation [14]: M/M/s/C/P/D where

M: arrival process

M: service time distribution

s: number of servers

C: number of buffers (system capacity)

P: population size

D: service discipline

Arrival process: The number of patients booking at a particular point in time is known as arrival rate. In the case of a haphazard arrival, the queue is best expressed by a Poisson distribution. Inter-arrival times are often categorized into Poisson distribution, Deterministic distribution, or a General distribution.

Service Time: The number of patients served per unit of time is refers to as service time. This is expressed as an exponential distribution.

Number of Server: A queuing system is called one server model, when the system has server only and a multi- server model when the system has a number of parallel channels each with one server. In this case, we considered a hospital system with many servers.

Queue Length: We considered finite queue length.

System Capacity: The maximum number of patients that could be accommodated in the hospital. This with COVID – 19, it drastically reduced, hence, the total number that could be accommodated would be determined by the capacity. This would be the 30% of the usual capacity. It includes those in queue and those at the service point.

Service Discipline: This is the manner by which patients are selected for service from the queue. We are using First Come, First Served (FCFS) discipline.

Other common notations include:

λ = arrival rate

μ=service rate.

λ_n =mean arrival rate of new patients when n patients are in the system.

μ_n= mean service rate for overall system when n patients are in system.

N(t)= number of patients in queuing system at time t.

$P_n(t)$= probability that exactly n patients are in queuing system at time t.

$P_0(t)$= probability that there are no patients in queuing system in time t.

M/M/s/C/P/D = inter arrival time and inter departure times are exponentially distributed in a queuing system with S servers.

The derivation for the model is adopted from Eze and Odunukwe [15]. Here, a queuing process has Poisson arrival patterns, S servers, with S independent, identically distributed, exponential service times; infinite capacity, and a FCFS queue discipline. The arrival pattern is independent, $\lambda_n = \lambda$, for all n. The service times associated with each server are also independent, but since the number of servers that actually attend to patients does depend on the number of patients in the hospital, the effective time it takes the system to process patient through the service time facility is state dependent. In particular, if $\frac{1}{\mu}$ is the mean service time for one μ server to handle one patient, then the mean rate of service completion when there are patients in the system is

$$\lambda_n = \lambda, \mu_n = \begin{cases} n\mu \quad if\ n = 0, 1, \dots, c\ i.e.\ n\ \leq c \\ c\mu\ if\ n = c+1, c+2\ i.e.\ n\ \geq c \end{cases} \tag{2}$$

The probability of zero patients in the system (P_0) and the probability of n patients in the system (P_n) are given by:

$$P_0 = \left\{ \frac{(\frac{\lambda}{\mu})^c}{c![1-\frac{\frac{\lambda}{\mu}}{c}]} + \frac{(\frac{\lambda}{\mu})^1}{1!} + \frac{(\frac{\lambda}{\mu})^2}{2!} + \dots + \frac{\left(\frac{\lambda}{\mu}\right)^{c-1}}{(c-1)!} \right\}^{-1} \tag{3}$$

$$P_n = P_0 \frac{(\frac{\lambda}{\mu})^n}{n!}\ \ if\ n\ \leq c \tag{4}$$

$$P_n = P_0 \frac{(\frac{\lambda}{\mu})^n}{C!C^{n-c}}\ \ if\ n\ > c \tag{5}$$

The capacity utilization in this system is $\frac{\lambda}{c\mu}$

We can use the above equation of $\frac{\lambda}{c\mu} < 1$

If $\frac{\lambda}{c\mu} > 1$, then the waiting line grows larger and larger *i.e.* becomes infinite if the process runs long enough. when C = 1 (there is one service facility), equations (4) and (5) reduces to

$$P_n = (\frac{\lambda}{\mu})^n\ P_0 \tag{6}$$

From equations (4) and (5), we have

$$P_n = P_0 \frac{(\frac{\lambda}{\mu})^n}{n!}\ \ if\ n\ \leq c$$

But n can only take on values of 0 or 1 if n ≤ C = 1. Thus

$$P_n = P_0 (\frac{\lambda}{\mu})^n$$

If C = 1, equation 5 also reduces to equation 6

With C service facilities, the average number of patients in the queue is

$$N_q = \frac{(\frac{\lambda}{\mu})^{c+1} P_0}{C.C![1-\frac{\frac{\lambda}{\mu}}{C}]^2} \tag{7}$$

The average number in the system (waiting plus service) is

$$N_s = N_q + \frac{\lambda}{\mu} \tag{8}$$

The expected waiting time in the queue for an arrival is

$$T_q = \frac{N_q}{\lambda} \tag{9}$$

This is derived from Little's Law.

The expected total time spent in the system (waiting plus service) is

$$T = \frac{N_s}{\lambda} \tag{10}$$

3.4 Measure of Effectiveness

To measure the effectiveness of the system, we adopt the model by Bakari *et al.* [16]. The parameters of the model are described below.

L= the average number of patients in the system

Lq= the average length of the queue

W= the average time a patient spends in the system

Wq = the average time a patient spends in the queue

W(t) = the probability that a patient spends more than t units of time in the system.

Wq(t) = the probability that a patient spends more than t unit of time in the queue. These are measures are explicitly given as:

$$L = \frac{\rho}{1-\rho} \tag{11}$$

$$L_q = \frac{\rho^2}{(1-\rho)} \tag{12}$$

$$W = \frac{1}{(\mu-\lambda)} \tag{13}$$

$$W_q = \frac{\rho}{(\mu-\lambda)} \tag{14}$$

$$W(t) = e^{-t/w}\ (t \geq 0) \tag{15}$$

$$W_q(t) = \rho e^{-t/w}\ (t \geq 0) \tag{16}$$

Assumptions

1 Single channel queue.

2 There is an infinite population from which patients originate.

3 Poisson arrival (Random arrivals).

4 Exponential distribution of service time.

5 Arrival in group at the same time (i.e. bulk arrival) is treated as single arrival.

6 The waiting area for patients is adequate.

7 The queue discipline is First Come First Served (FCFS).

4. RESULTS

The system was implemented using ASP.NET and Microsoft SQL. The system was tested with data collected in Section 3.1 and the result is shown in the figures below. Fig 5 shows patients appointment. The patient logs in and queue up. Fig 6 shows notification from the server assignment to the queue assignment for the next patient to be notify. Fig 7 shows the queue at the nursing station. Fig 8 shows the queue capacity as viewed by the doctors.

The results show that few patients are maintained in the hospital. As shown in Fig 9, the maximum number of patients that arrived in the system was 6 and this was during the day. Fig 10 shows the expected and actual arrival times. The actual arrival time is slightly above the expected arrival time at some points. This means that some patients arrived slightly late and some arrived a bit earlier. Fig 11 shows the comparison between the time a patient booked, got notification and eventually arrived at the hospital. Some got notified but arrived late. For some, it was due to distance, lack of transport system among other reasons. Fig 12 depict the services rate which was slightly below expectations. The line of best fit is higher than that of patients' arrival and this shows that some patients were staying longer than expected, and this eat into the time of the next patient that is supposed to be attended to. This could be as a result of shortage of servers or servers with appropriate expertise.

Fig 5: Patients' queue request form

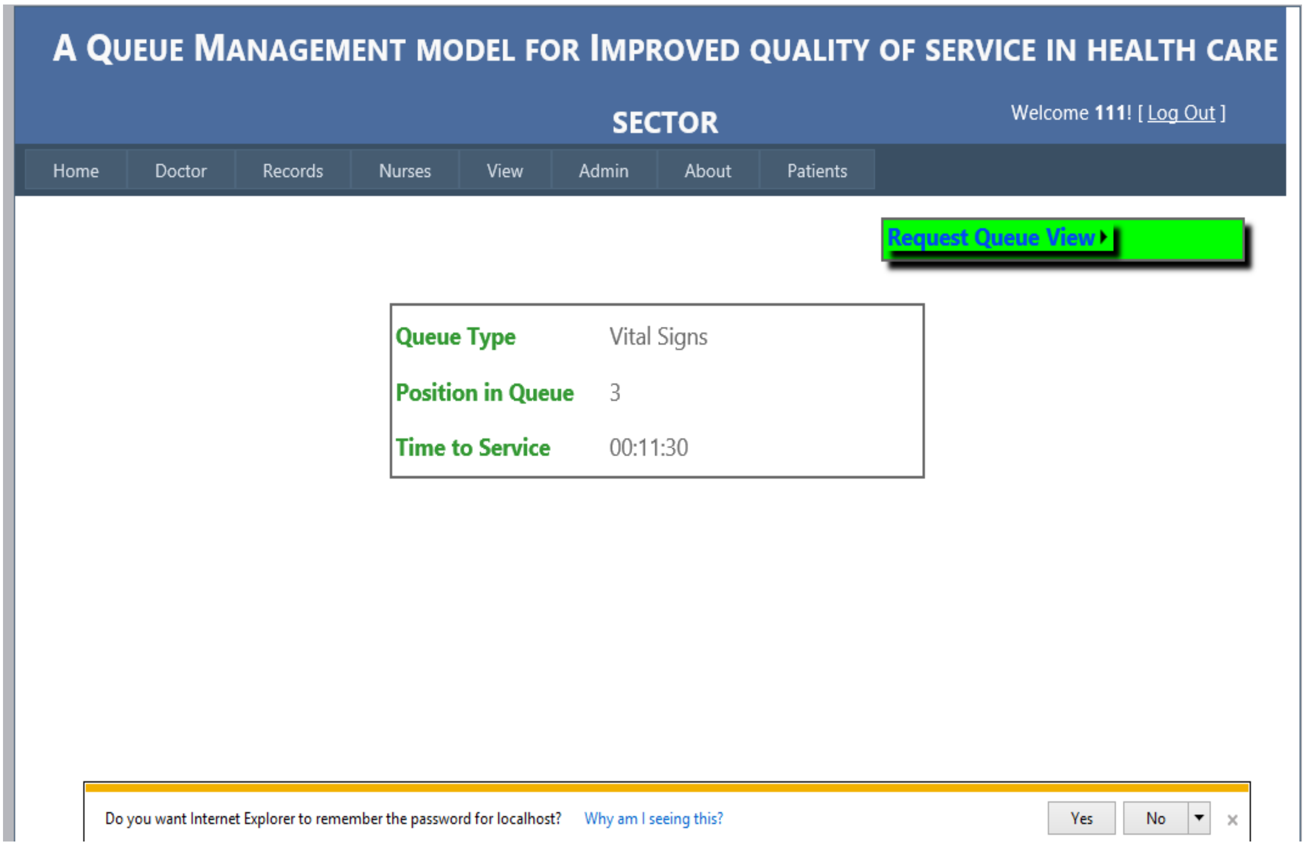

Fig 6: Patient's position in queue and time to service

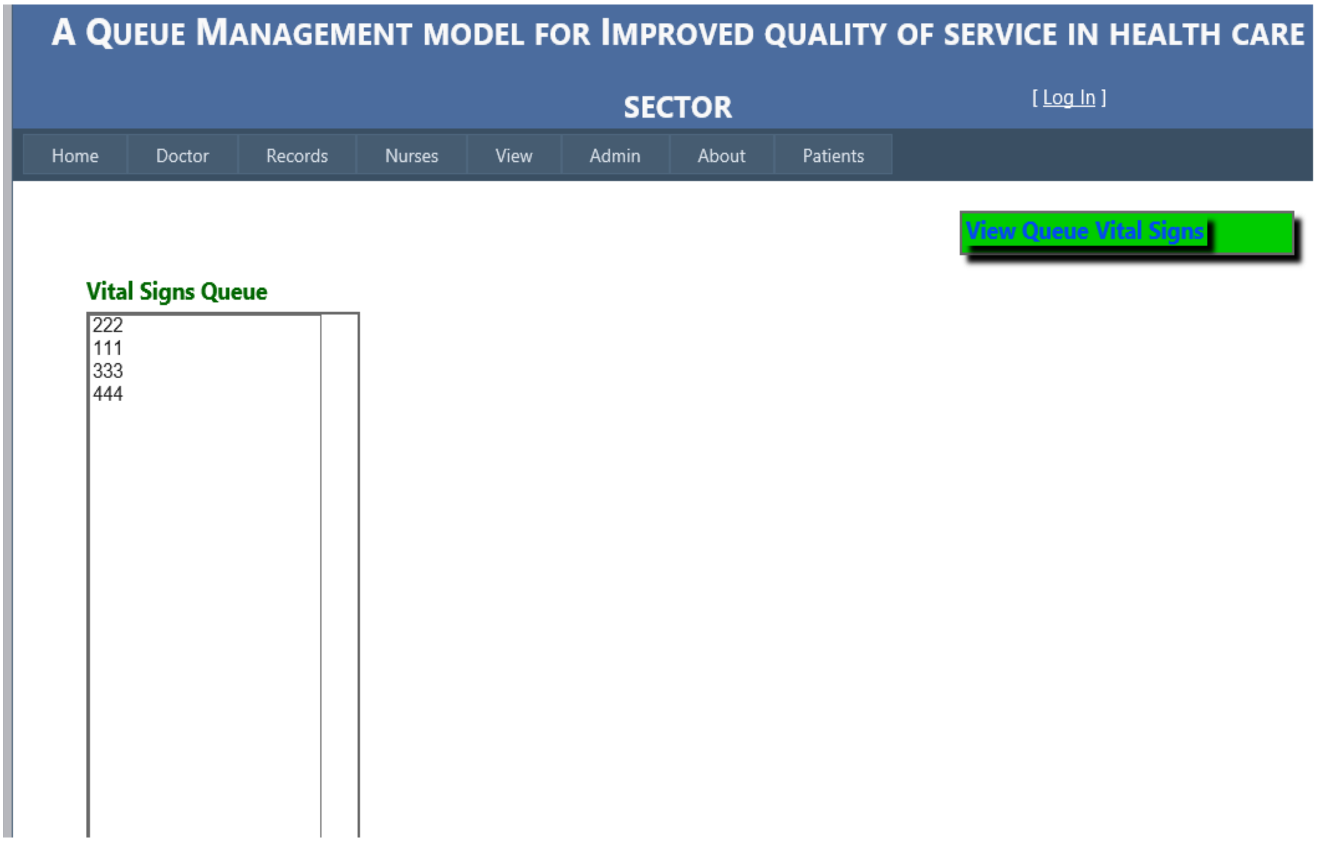

Fig 7: Patients on queue for vital signs

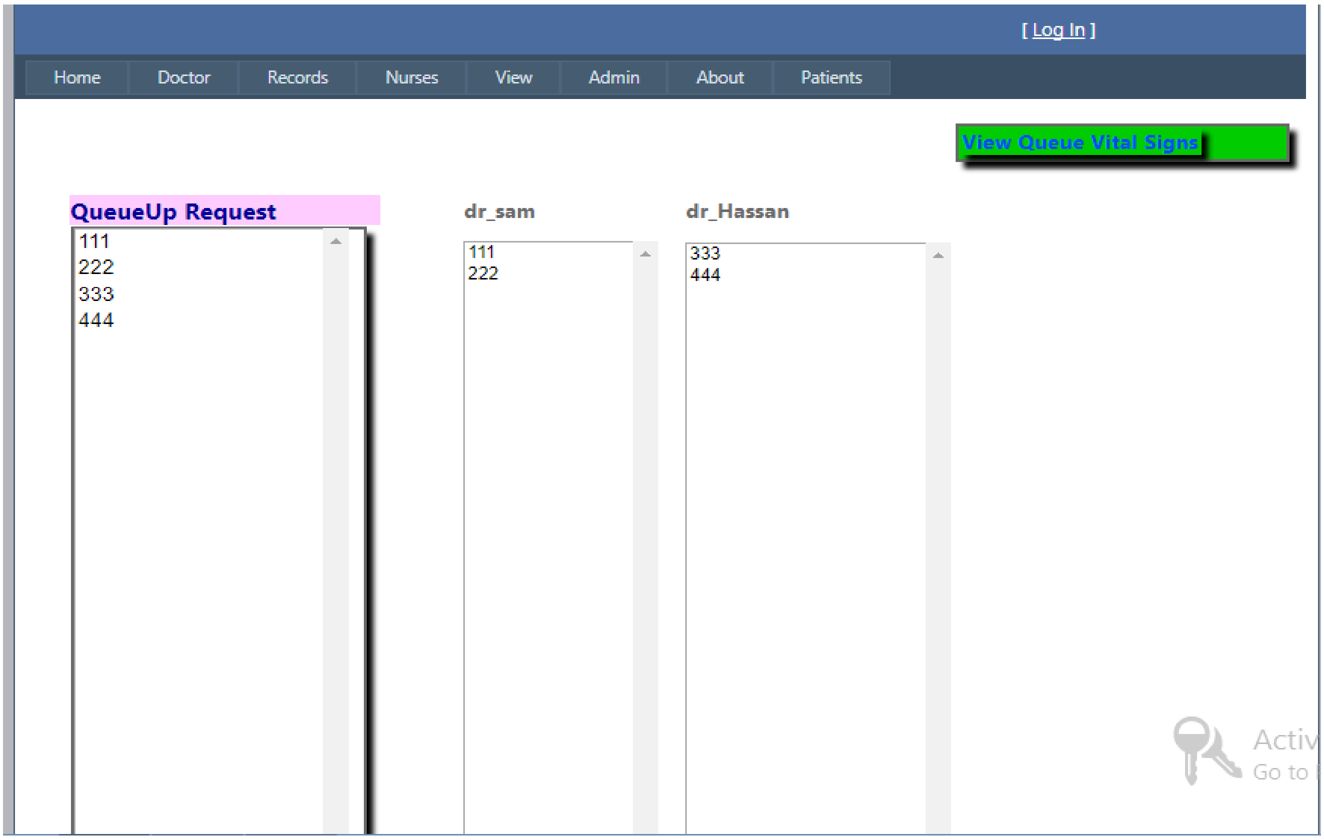

Fig 8: Patient's distribution to Doctors

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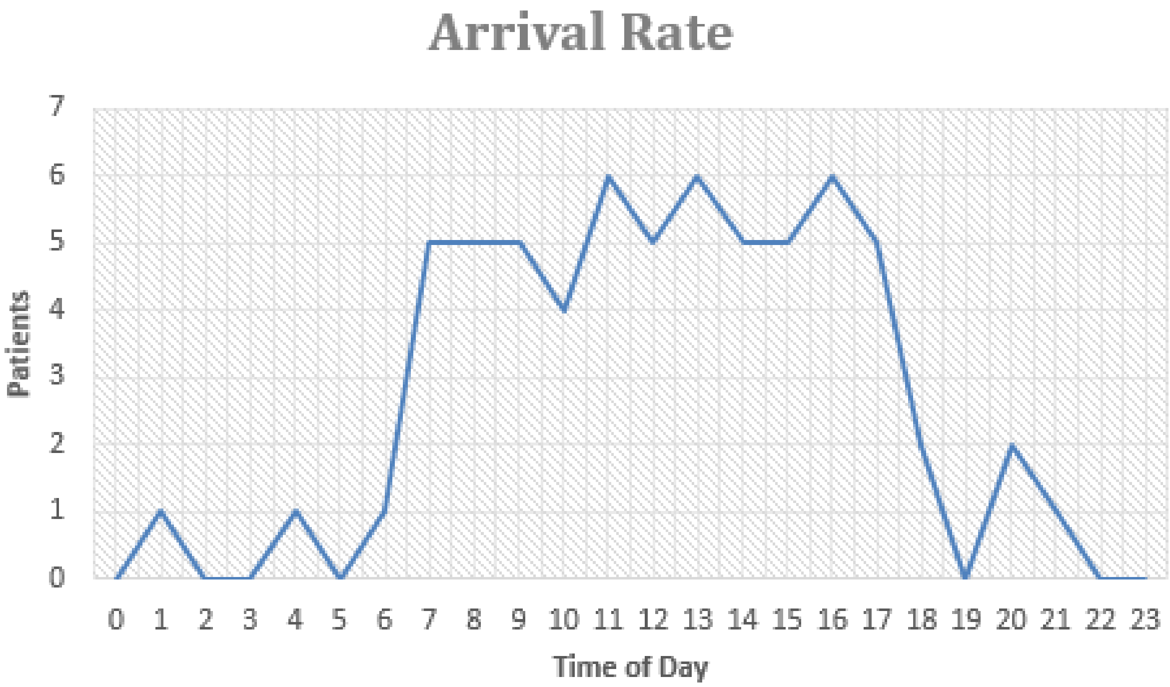

Fig 9: Arrival Rate

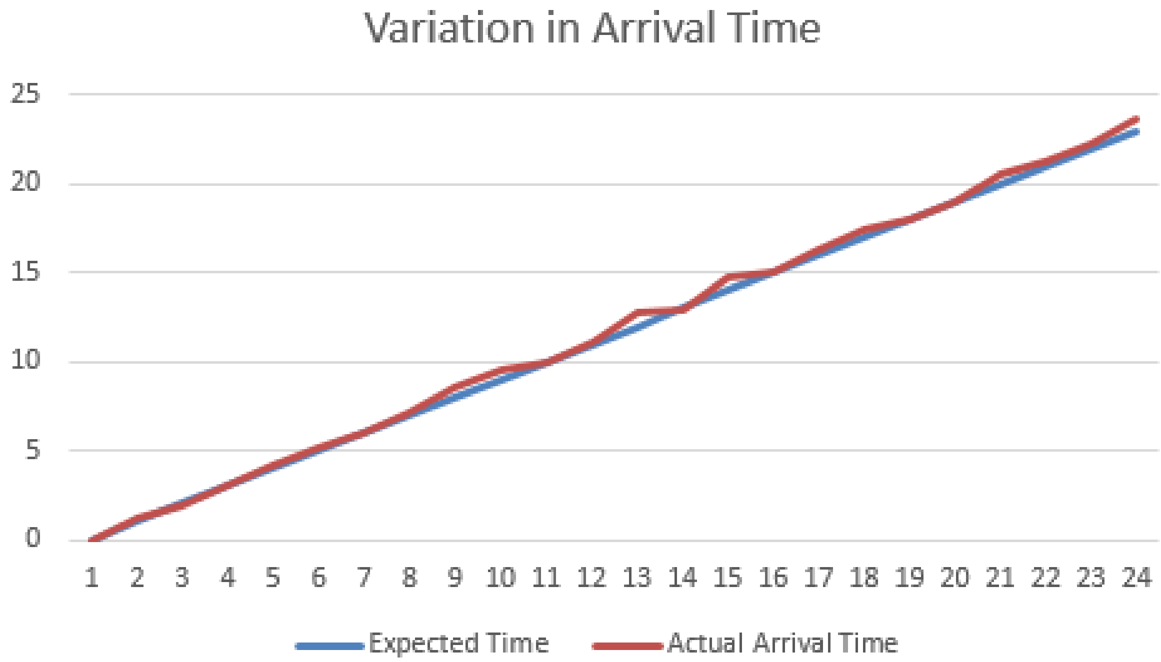

Fig 10: Variation in Time

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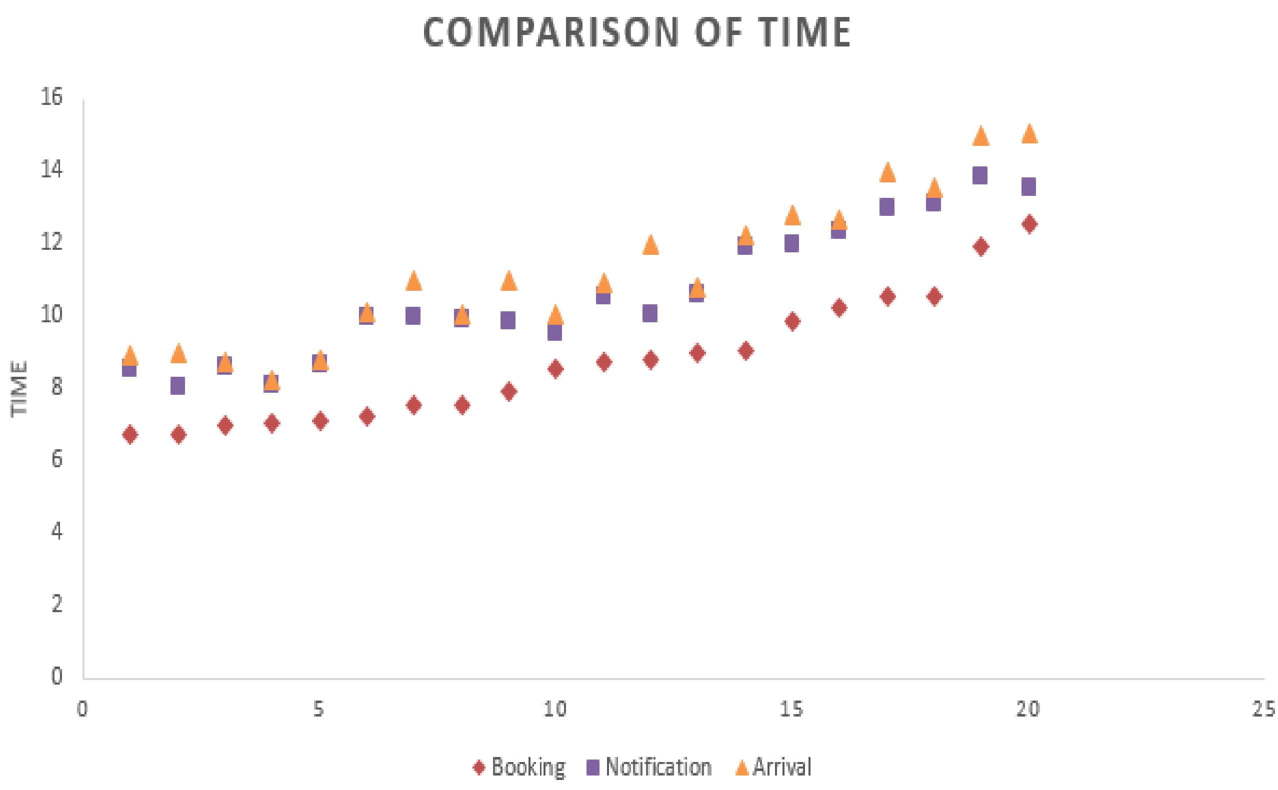

Fig 11: Comparison of Time

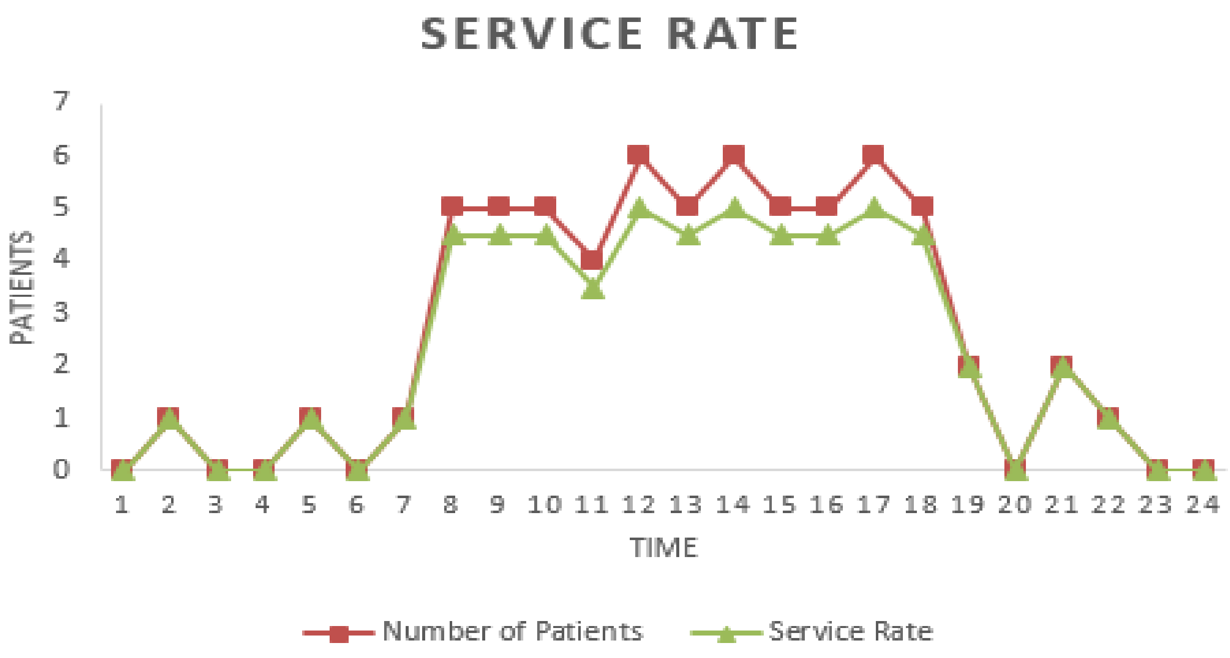

Fig 12: Service Rate

4.1 Queue Effectiveness

The effectiveness of the system was computed using equations (11) – (16) and the result obtained for each of the parameters include: average number of patients in the system was 6.7635; average length of the queue was 5.3761; average time a patient spends in the system was 0.0941; average time a patient spends in the queue was 0.0543; probability that a patient spends more than t units of time in the system was 0.7321 and probability that a patient spends more than t unit of time in the queue was 0.6723.

5. DISCUSSION

Queuing theory is a potent mathematical approach to analysis of waiting time performance in healthcare system. The use of queuing theory and modeling in improving waiting time in hospital setting and reducing cost related to various aspects of healthcare system and improving system performances. Long waiting queue is symptomatic of inefficiency in hospital services, unfortunately, that is the case in many public hospitals in Nigeria and other developing countries. In most healthcare settings, unless an appointment system is in place, the queue discipline is either first in –first out or a set of patient classes that have different priority (as in an emergency department which treat patients with life threatening injuries before others). Preater [17] showed that it is possible to minimize waiting times by giving priority to clients who require shorter service times. Ndukwe et al. [18] analyses the effect on patients waiting times when primary care patients use emergency department. They proposed priority discipline for different categories of patients and then a first in - first out discipline for each category Young [19].

This research has reduced the time at which patients spent in hospitals while waiting to access healthcare and decongested non-tertiary hospitals with a view to reducing continuous exposure to contagious diseases as existing queue management systems confine patients in one place who have different diseases unknown to each other. Diseases such as COVID – 19, tuberculosis and Hepatitis are contagious and medic advise people to avoid physical contact with such patients in order not to contact such diseases. Apart from reducing the exposure to contagious diseases, this research also reduced the over stretching of healthcare facilities especially the outpatients waiting room due to pressure by overcrowded patients (Fig 2).

The results of this study out performs that gotten by Mehandiratta [20], Ngorsed and Suesaowaluk [21] and Titarmare and Yerlekar [6]. While Titarmare and Yerlekar [6] send out notifications containing the time for patients to come to the hospital not minding how long they will stay in the system, this can lead to overcrowding. This is corrected in our research as patients are notified as the ones in the system are phased out. Their location is also considered as that determines how long it will take them to arrive the hospital. Also, there is provision for patients to confirm their readiness for the service.

Ngorsed and Suesaowaluk [21] considered cases of specialized physicians whereas, that is not practiced in non-tertiary hospitals that we considered. The general hospital that's considered here is the second level of care and here there are no specialized doctors, thus, it will be difficult to choose a particular doctor that will attend to your case. Also, these doctors have different schedules and it's not all the time that your appointment will coincides with the duty schedule of the doctor of your choice.

More attention is given to the consulting section which is where patients experienced more issues. Hence, to successfully address the issue of queue management in the hospitals, all the sections (medical record office, laboratories, pharmacy etc.) must be considered.

Capturing location at the point of booking which is considered when notifications are sent; and provision for confirmation for availability for the service is also important feature for the system. This has reduced the server idle time which has increased the efficiency both for the patients and the provider. This is the most effective way of helping patients to utilize their time instead of just queuing and waiting endlessly in the hospital for the doctor.

6. CONCLUSION

We developed a platform that allows patients to virtually queue up and stay in different locations either within the hospital or outside the hospital but still monitor the flow of the queue as it moves. The system notifies patients and also make provision for patients to confirm if they are ready to come over to the hospital. The research provides a platform for hospitals to strictly adhere to the social distance policy as few patients were maintained in the hospital as shown from the results. A little variation was observed between the actual arrival time and the expected time; a survey to find out reasons for this could be carried out and future work to improve on this gap can be done. Emergency cases were not considered in this study though but we can't rule out the fact that doctors on duty may encounter need to attend to people in this category and hence an improvement on this system can also done to capture such scenario.

7. REFERENCES

[1] Adeleke, R.A., Ogunwale, O.D. and Halid O.Y. 2009. Application of Queuing Theory to Waiting Time of Outpatients in the Hospitals. Pacific journal of science and technology, 10(2): 270-274.

[2] Afolabi, M.O. and Erhun, W.O. 2005. Patients Response to waiting time in an Outpatient Pharmacy in Nigeria. Journal of pharmacy reserve, 8(2): 118-121

[3] Helbig, M., Helbig, S., Kahla-Witzsch, H., and May, A. 2009. Quality Management: Reduction of Waiting Time and Efficiency Enhancement in an ENT-University Outpatients' Department. BMC Health Services Research, 9(21): 1-9.

[4] Ndukwe, H.C. Omale, S., and Opanuga, O. O. 2011. Reducing queues in a Nigerian Hospital Pharmacy. African Journal of Pharmacy and Pharmacology, 5(8): 1020-1026.

[5] Shanmugasundaram, S. and Umarani, P. 2015. Queuing Theory Applied in Our Day to Day Life. International Journal of Scientific & Engineering Research, 6 (4): 533-540.

[6] Eze, E. O. and Odunukwe, A. D. 2015. On Application of Queuing Models to Customers Management in Banking System. American Research Journal of Bio Sciences, 1 (2): 14-20.

[7] Bakari, H. R., Chamalwa, H. A. and Baba, A. M. (2014). Queuing Process and Its Application to Customer Service Delivery: A Case study of Fidelity Bank Plc, Maiduguri. International Journal of Mathematics and Statistics Invention (IJMSI), 2(1): 14-21.

[8] Ingole, P. V. and Nichat, M. K. 2013. Landmark Based Shortest Path Detection by Using Dijkestra Algorithm and Haversine Formula. International Journal of Engineering Research and Applications (IJERA), 3(3): 162-165.

[9] Li, D., Cova, T. J. and Dennison, P. E. 2017. Using reverse geocoding to identify prominent wildfire evacuation trigger points. Applied Geography 87: 14 – 27.

[10] Lumauag, R. G. 2016. SENT SMS: School Event Notification Through SMS. Asia Pacific Journal of Multidisciplinary Research, 4(4): 61 – 68.

[11] Mehandiratta, R. 2011. Applications of Queuing Theory in Health Care. International Journal of Computing and Business Research, 2(2): 1-11.

[12] Titarmare, N. and Yerlekar, A. 2018. A Survey on Patient Queue Management System. International Journal of Advanced Engineering, Management and Science (IJAEMS),4(4): 229-232.

[13] Ngorsed, M. and Suesaowaluk, P. 2015. Hospital Service Queue Management System with Wireless Approach. Journal of Interdisciplinary Research, 550-559.

[14] Preater, J. 2002. Queues in Health. Healthcare Management Science, 5(4): 283.

[15] Young, J. P. 1962. The Basic Model in a Queuing Theory Approach the Control of Hospital Inpatient Census. John Hopkins University, Baltimore,74-79.

[16] Bruin A. M., Bekker R., Zanten L. V. and Koole G. M. 2010. Dimensioning Hospital Wards using the Erlang Loss Model. Annals of Operations Research. 178: 23 – 24.

[17] Burungale S., Kurane K., Mhatre S., Vora D. 2018. Patient Queue Management System. International Journal of Engineering Science Invention (IJESI), 7(2): 39-41.

[18] Wangrakdiskul, U. 2014. Designing Queuing System for Public Hospitals in Thailand. Conference: Tokyo International Conference on Engineering and Applied Science, At Tokyo, Japan, 539-550

[19] Prabakaran, R. and Kumar, K. 2019. Application of Queuing Theory in Hospital Management. International Journal of Innovative Technology and Exploring Engineering (IJITEE), 8(8): 1788 – 1790.