OUTPATIENT QUEUING MODEL DEVELOPMENT FOR HOSPITAL APPOINTMENT SYSTEM

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OUTPATIENT QUEUING MODEL DEVELOPMENT FOR HOSPITAL APPOINTMENT SYSTEM

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Abstract

In many hospitals, Patients wait for long time in the healthcare facility before they are attended to by the health personnel. This trend is on the increase and it is a potential threat to healthcare services. In Nigeria, specialist, teaching and general hospitals with large number of patients have cases where patients may not be attended to on time while others may end up going home without receiving medical attention. An efficient queuing model for proper appointment system is proposed as the solution to the long waiting times in these hospitals in this paper. The appointment queuing system provides better utilization of resources and reduces patients waiting times in the general outpatient department before consultation with the Doctor. Arrival rate and pattern, availability of medical services and preferences, employees experience and availability of information technology are factors that affect the performance of an appointment system. This research work provides an efficient outpatient appointment queuing model for proper appointment scheduling thus, reduces patients waiting times, doctors' idle time and overtime as well as improving the outpatient's satisfaction.

Keyword: Outpatient, Queue, Hospital, Appointment System

1. Introduction

The Hospital is a healthcare facility where patients receive treatment and get effective and efficient services from specialized staff and equipment. A **queue** is an example of a linear data structure, or more abstractly a sequential collection. Queues provide services in computer science and operations research where various entities such as data, objects, persons, or events are stored and held to be processed later [1].

Queues are first-in, first-out: elements are removed in the same order in which they are inserted, and we usually imagine inserting at the "back" and removing from the "front" of a queue[2]. The queuing model is the use of the queuing principle in developing a model that provides efficient performance measures of service facilities in the hospital inflow units and outpatient services. In Nigeria, the specialist hospitals, teaching hospitals and general hospitals seem to attract the largest number of patients often making the waiting time and the queue to be very long. In some cases, some patient may not be attended to early while others may end up going home without receiving attention.

In these hospitals, queue or a waiting line of patients occurs as a result of high demand of health services meaning that the demand for health care services by the citizens exceeds the capacity of the service facility. Queuing can be dully represented with arrival process of patients (**in**) and service provision (**out**) which are the major components of every queuing system.

Thus, queuing system servers are the nurses, trained counter personnel including the IT staff and the entire equipment specially put in place for the active procedures required while clients include the walk in patients who arrive at the hospital, wait for the required service, obtain it and then leave upon service completion or walk to another department expecting supplementary service.

2. Queuing Theory

The first ever queuing theory was developed by a Danish telecommunication engineer, Agner Krarup Erlang. Erlang A. K. also analyzed a single facility M/M/s queues called Erlang C mathematical model where arrivals of customers are based on a Poisson process [3]. Erlang's model inspires mathematicians, scientist, engineers, and Computer Scientist to deal with problems using queuing theory and gave an explicit insight of an additional quality of service to limit waiting times especially in the queue. Deques, or double-ended queues, additionally support insertion and removal from both ends. Queues and deques are used for breadth-first searches of state spaces and also find use in simulation contexts [4]. Deques also occur in Hospitals since prominent patients may be added from front of queues to get quick services while the last to arrive may decide not to wait if the queue is long and then get out of the queue; creating a Deque situation.

Another major milestone in the history of queuing theory was David G. Kendall [5]. Kendall introduced the A/B/C notation called the “Kendall’s notation” which depict the characteristics of a queuing system which has become the standard in classifying queuing theory.

Phillip M. Morse published an early and informative book on queuing theory and one of the first comprehensive books on queuing theory was authored by Thomas L. Saaty in 1961 [6]. These early queuing theory books have been a source of help to educators, scholars and researchers in various fields such as mathematics, sciences, management, computer science, accounting, and healthcare to deal with waiting problems using queuing theory.

Queuing theory was applied on networks of packet switching in 1960s by Leornard Kleinrock and this development lead to the birth of the internet. In 1969, the Host computer of Leornard became the first node of the Internet and the first message to pass over the internet was transmitted from there. In reality, operations in service demonstrate features that are not captured by the early queuing models like Erlang, Jackson, etc[7].

The waiting time is a length of time in which a person certainly waits in sequence for a definite activity to commence as a result of service requested or obligated. The waiting process is a state or an act of expecting or looking forward to service that is about to be received. Usually, some patients’ waits patiently for service while others are restless and intolerant of delays (impatient) of service. Long waiting time of patients registered in urban health centers in developing country is a serious issue. Similarly, in Nigeria public healthcare systems, patients’ waits restlessly with ill health in long queue. This waiting problem has prompt some patients to influence the queue in various ways.

The healthcare system especially the hospital, can apply queuing theory in patient consultation with the doctor, patient waiting time, pharmacy, emergency room, operation room, registration and filling of patient file etc. Historically, queuing theory has been used to model work environment, productivity, patients waiting time, staffing, hospital bed and emergency

department. Mathematical models and performance measures are queuing theory tools used to effectively improve the inflow of patients through a queuing system model.

2.1 Appointment System

Hospital appointment system is an early practice in healthcare. Appointment scheduling is an administrative responsibility that ensures the smooth running of a system especially the healthcare system. Systems with appointments have an orderly arrival pattern of patients (customers).

Traditionally, healthcare appointment system has considered doctor's time more valuable to that of the patients. This has been the belief and practice in most Nigeria Government owned hospitals where doctors do not keep to working time so much that they often go on break several times before the end of the day's shift. This old practice has led to patients long waiting time due to the increase in the doctors' idle time and inadequate queuing system in these hospitals.

Modern development in appointment system has been focused on decisive time factors as regards patients and doctors. Hence, appointment system can be scheduled in two ways; static and dynamic [8].

Management of patients' appointment system has recorded early works and development in queuing model starting from the work of Welch and Bailey [6]. People have busy lifestyle as such have zero tolerance for waiting especially in hospitals for treatment. Also, patients waiting time can be greatly minimized with the use of mathematical model to evaluate the waiting time interval for patients and doctors [9]. The need to develop a queuing system for hospital appointment booking is very necessary and profitable for healthcare appointment system increases patient satisfaction as well as reducing the burden on staff having to control the calling population, depends on manual processes for selection of an appointment time for a patient and makes it easier for scheduling appointments across departments or units.

3. Analysis and Design

Analysis is the investigation of a system with intention of understanding how it operates and the procedures that are involved and how to effectively improve on the system. The researcher carried out series of interviews to get a general overview and to see the factors that affects patients waiting times in the general outpatient clinic or department in a hospital system. The data gathered and information obtained was used to model a proposed outpatient service and arrival pattern in Government owned hospitals in Nigeria.

The hospitals under review uses manual appointment system as such patients' experiences longer waiting time like 2-3hours and above on queue before consultation with a doctor. This makes patients feel neglected and maltreated compare to hospitals with computerized appointment system in place.

The appointment system in use allows all patients to be assigned to the same arrival time (single block rule) for example morning or afternoon is applied in these hospitals and patients are served based on their arrival time that is first come first serve (FCFS). The multiple phase single channel with M/M/1/I queuing model is used where patients arrives randomly following a Poisson distribution with infinite population [10].

The UPTH is managed by a three-tier managerial system consisting of; the Board of Management, Hospital Management Committee

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(BMC) and the 31 Departments while the Braithwaite Memorial Specialist Hospital (BMH) is equipped and managed by the Rivers State Government through the Rivers State Hospital Management Board and it has 18 departments. These hospitals were established to facilitate adequate training of medical students and also for the welfare of Rivers people and Nigerians respectively.

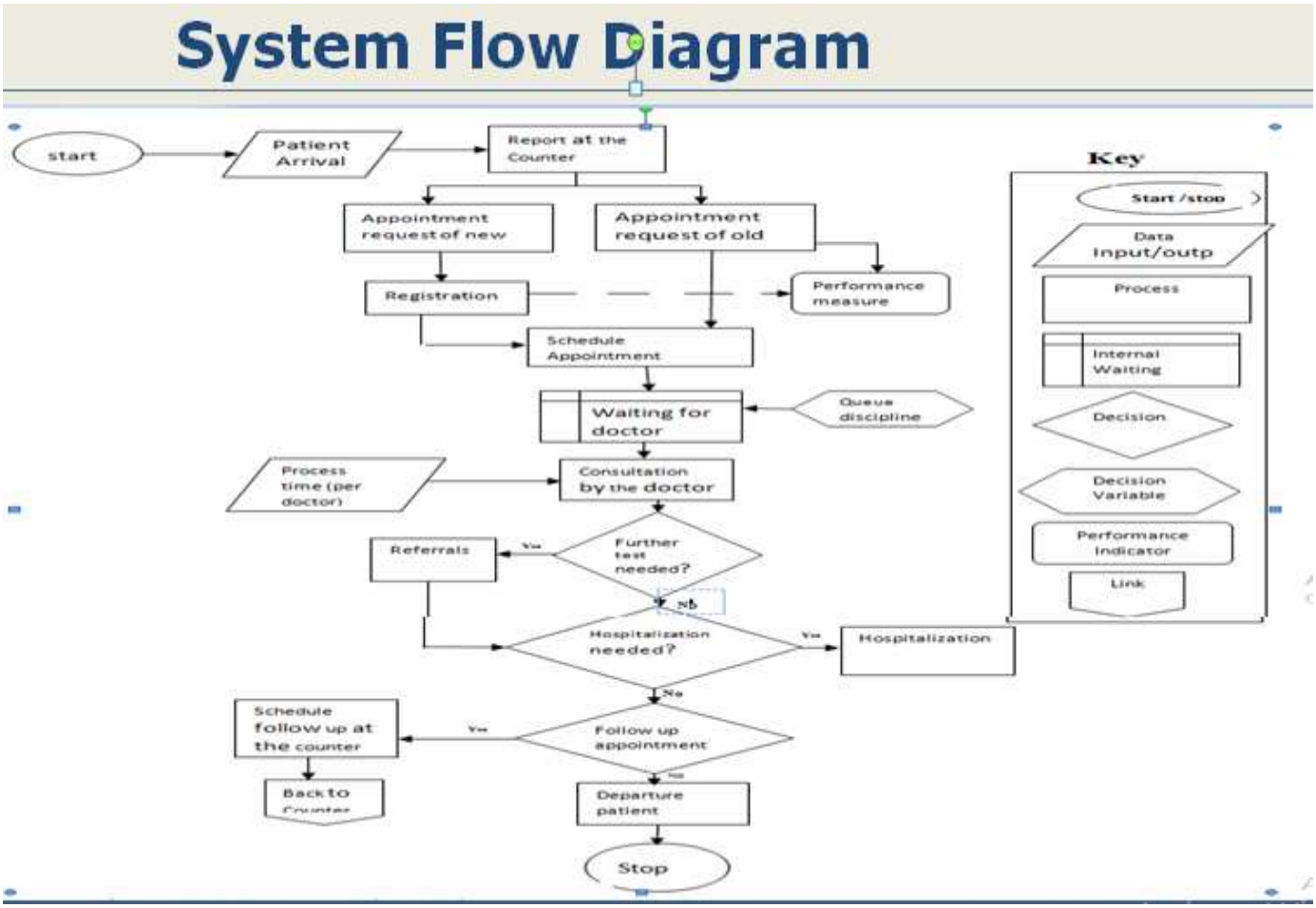

Figure 1. System Flow Diagram

These hospitals general outpatient departments use two consultation type; old (review) patients and new patients. From figure 1, the new patients are those visiting the hospital for the first time for treatment and the old patients are those who have visited the hospital previously. The system entails that on arrival at the hospital, patients request appointment at the hospital card personnel desk (counter) in the outpatient department. Upon appointments request, patient's folder is sorted and a tally with a serial number is being given based on arrival time for old (reviewed) patients and new patients must first be registered with the hospital, then a file will be created before issuance of tally.

The nurses on duty acts as the scheduler in these hospitals and calls patients to the consultation room based on the tally earlier issued which is a first come, First service (FCFS) queue discipline. Pile-up scheduling is used since there

is no specified time slot for the length of consultation with the doctor and having a consultation with the doctor.

After consultation with a doctor, the patient is either admitted, treated or referred to other department while others are scheduled for review or routine consultation.

Table 1. One Month Statistics of Patients' Visiting the General Outpatient Department.

Statistics	Mon.	Tue.	Wed.	Thur.	Fri.
Total Number of patients present	594	543	424	344	306
Total Number of patients Seen	497	454	349	300	270
Total Number of patients Not Seen	97	89	75	44	36
Total Number of Old patients	263	259	202	192	183
Total Number of New patients	331	284	222	252	123
Total Number of Male patients	219	192	180	118	114
Total Number of Female patients	375	351	244	226	192

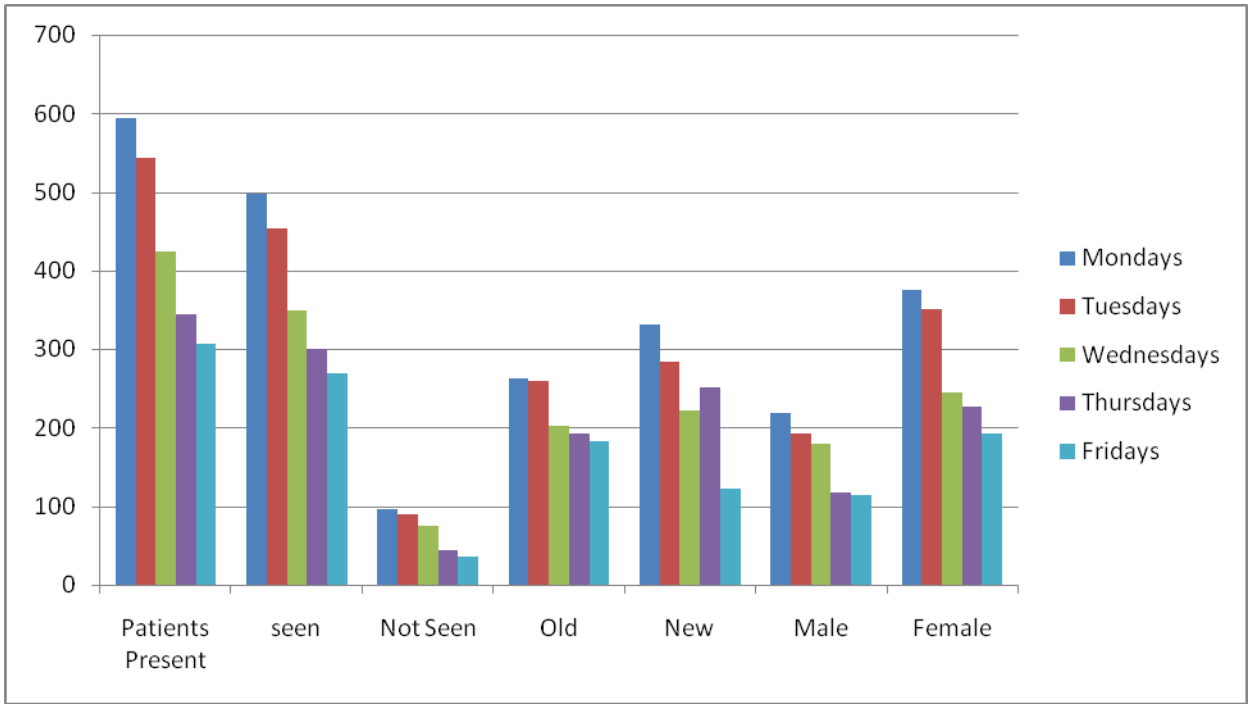

Figure 2: Patients Daily Statistics in the General Outpatient Department

In Table 1 above, a detailed one month statistics of patients visiting the outpatient department showing the total number of patients present, seen, not seen, old and new patients, male and female patients. This comprehensive statistics will help us to implement the proposed system for the hospital.

In order to determine the need of a new queuing system in the hospital, possible conflicting requirements of the management, staff and

patients must be put into consideration. The new system uses an appointment system which assigns an appointment time slot to patients in the hospitals thus reduces patients waiting time and evaluates the quality of services offered in the hospitals.

4. Algorithm

The algorithm for the queuing system is as specified below :

Step 1: Create an empty queue
{(void enqueue(String Name_of_Patient) }
Step 2: Insert a new string onto queue String
{ dequeue() }
Step 3: Remove and return the string least recently added
Step 4: Is the queue empty?
{ boolean isEmpty() }
Step 5: Repeat 1 to 4 till done
Step 6: Stop

Assuming that each patient is represented using a Name; which is a String. A simple representation of the algorithm using java syntax is illustrated below:

```
Public Class QueueOfPatients
{
   private Node first, last;
private class Node {
   String Name_of_Patient;
   Node next;
}
public boolean isEmpty() {
    return first == null;
}
public void enqueue(String
       Name_of_Patient) {
   Node oldlast = last;
   last = new Node();
   last.Name_of_Patient =
          Name_of_Patient;
   last.next = null;
  if (isEmpty())
     first = last;
  else
     oldlast.next = last;
}
public String dequeue() {
    String Name_of_Patient = first.
Name_of_Patient;
    first = first.next;
  if (isEmpty()) last = null;
  return Name_of_Patient;
  }
}
```

The algorithm can be used in the implementation of the system using any programming language or tool.

5 Model Development

We assume that the calling population (patients') arrives in a Poisson process to the hospital with an average of 10 patients per minutes. The system is modeled as a Poisson process [11] showing the average inter-arrival time and probability of having more than 15 patients.

Given an average rate as:

$\tau = 1/E\{r\} = \lambda$ (1)

Thus, the parameter of distribution λ can be translated as the average rate of patients' arrivals.

$$\tau = \frac{1}{\lambda} \quad (2)$$

$$= \frac{1}{10/60} = 6(\text{sec.})$$

Probability of having more than 15 patients per minutes

$P_r = \{Y>15\} = P_r\{Y=16\} + P_r\{Y=17\} + P_r\{Y=18\} + \ldots\ldots$ (3)

Using the equation:

$$P(n,t) = \frac{(\lambda t)^n e^{-(\lambda t)}}{n!} \quad (4)$$

Substituting the values numerically, we have:

$$P_r\{Y>15\} = \frac{1 - \sum_{k=0}^{15} (10.1)\, e^{-(10)}}{n!}$$

$$= 0.0487$$

6. Result and Discussion

The health system design is a conflicting issue due to the increase in the calling population (patients). These patients' just walk-in and expects to get the needed treatment in little or no time with or without queue with different health problems that are mutually related. These correlated health services has led to difficulty in classifying services based on different approaches for designing multi-channel specialty service facilities. From flow chart in figure 1, our statistical calculations of the data collected from the patients record book at the general outpatient department shows that for a period of one month, the following database analysis holds; there are a total number of 2211 patients present, 1,870 (84.58%) patients seen, 341 (15.42%) patients not seen, 999 (45.18%) old(review) patients, 1,212 (54.82%) new patients, 823 (37.22%) male patients and 1,388 (62.78%) female patients. These patients have different health challenges that require prompt medical attention.

The appointment system shows the relationship among the different tables.

i. Reserves: The reserve page is used to book for appointment by the counter personnel who is in-charge of assigning patients for consultation.
ii. Calendar: The calendar shows year, month, week and day available for appointment.
iii. Login: The login section provides a secure access to information by only registered users.
iv. Patients: Outpatients can always login to view their appointment date and time.
v. Staff: this section provides doctors, nurses, counter personnel and administrators' access to patients appointment date and medical history.

6.1 Experimental Setup

This section describes the software packages and tools we used in development, implementation, testing and documentation of our software application. These are important and indispensible software packages and tools used in setting up our experiment:

i. XAMPP Server
ii. AJAX
iii. Adobe Dreamweaver CS5
iv. Calendar

In our experiment for testing the application, our developed UPTH Outpatient Appointment System application was used to secure an appointment slot for consultation and some of the outputs generated from the appointment testing were: Patients records were entered into the input parameters; patients appointments were booked and a monthly, weekly and daily view of appointments were shown respectively. The hospital card personnel page is where consultation time slots are being assigned, registration of patients are being carried out and also patients medical history stored in the database can be accessed.

7. Summary and Conclusion

The Appointment system designed is used to reduce patient waiting time, work efficiency and other hospital management tool thereby implementing an efficient queuing system for work efficiency and patients' satisfaction. Queuing model seems difficult to implement due to the increase in the calling population. In essence, queuing system is used to achieve better utilization of resources and it reduces patient waiting times in hospital using an appointment system. This research has adopted several hospital activities and all other

associated means by which a healthcare appointment queuing system could be developed and implemented due to the need to improve patients satisfaction and to improve the development of the hospital services.

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