

**OPTIMISING PATIENTS FLOW AND RESOURCES UTILISATION IN
THE OUT-PATIENT DEPARTMENT OF A PUBLIC HOSPITAL A
CASE STUDY OF YUSUF DANTSOHO MEMORIAL HOPITAL
KADUNA**

BY

USMAN, KANDI MOHAMMED

P14EGME8054

**A PROJECT REPORT SUBMITTED TO THE SCHOOL OF POST
GRADUATE STUDIES AHMADU BELLO UNIVERSITY ZARIA, IN
PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE
AWARD OF A MASTER'S DEGREE IN ENGINEERING
MANAGEMENT**

**DEPARTMENT OF MECHANICAL ENGINEERING,
FACULTY OF ENGINEERING,
AHMADU BELLO UNIVERSITY, ZARIA**

DECEMBER, 2016

DECLARATION

I declare that the work in this project report **Optimising Patients Flow and Resources Utilisation in The Out-Patient Department of a Public Hospital a Case Study of Yusuf Dantsoho Memorial Hospital Kaduna**, has been carried out by me in the department of mechanical engineering. The information derived from the literature has been duly acknowledge in the text and a list of references provided. No part of this project report was previously presented for another degree or diploma at this or any other institution.

Name of Student

Signature

Date

CERTIFICATION

This project report **OPTIMISING PATIENTS FLOW AND RESOURCES UTILISATION IN THE OUT-PATIENT DEPARTMENT OF A PUBLIC HOSPITAL A CASE STUDY OF YUSUF DANSTOHO MEMORIAL HOPITAL KADUNA** by Usman Kandi MOHAMMED meets the regulations governing the award of the degree of master of engineering management of Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

_____ Chairman, Supervisory Committee	_____ Signature	_____ Date
_____ Member, Supervisory Committee	_____ Signature	_____ Date
_____ Member, Supervisory Committee	_____ Signature	_____ Date
_____ Head of Department	_____ Signature	_____ Date
_____ Dean, School of Postgraduate Studies	_____ Signature	_____ Date

DEDICATION

To the memory of my late father Dr M.U. KANDI and to my family.

ACKNOWLEDGEMENT

In the course of this project, contacts with numerous people were made to ensure the success of the assignment, therefore it is impossible to enlist the names of all contributors here, but I must express my profound gratitude to those who assisted me directly and indirectly to make this project a success.

First to my project supervisor in the person of Dr D.M. Kulla for his too numerous to mention understanding and support. Then my mother, my siblings, my friends and course mates for their guidance and support.

Also my special thanks goes to all lecturers in the Department of Mechanical Engineering, Ahmadu Bello University, Zaria for their friendly advice and good working relationship without which this study could not have been successful.

ABSTRACT

Queuing theory as a tool for optimising patients flow and resources utilisation in the female section of the OPD at Yusuf Dantsoho memorial hospital Kaduna, the study was conducted for a period of 5 days. Simple queuing theory calculations were done using the data collected in the evaluation of the performance characteristics of the system, i.e. the average utilisation of the servers, the probability that the system would be idle, the average number of patients in the queue and the average time a patient spends in the system. These parameters are used by hospital managers in making better decisions as it relates to the management of queues, long wait times thus resulting in overcrowding at the OPD of most public hospitals, from the study it was established that the average arrival rate equal 34.4998 patients/hour which is greater than the mean service rate (μ) = 18.0867 patients/hour at the records section and 14.5226 patients/hour at the consultation unit, this accounted for the high utilisation at the servers thus leading long queues and subsequently long wait times at the OPD. QM software for windows was used to model 5 cases using a server capacity of 3, 4, 5, 6 and 7 doctors at post in the female section of the OPD and it was established that for optimum performance 5 doctors need to be available for service at the OPD at a time as compared to an average of 3 doctors which is presently obtainable at the female section of the OPD during the study.

TABLE OF CONTENT

Content

Cover page	Error! Bookmark not defined.
DECLARATION	ii
CERTIFICATION	iii
DEDICATION	iv
ACKNOWLEDGEMENT	v
ABSTRACT	vi
Contents	vii
CHAPTER ONE	1
INTRODUCTION	1
1.1 BACKGROUND OF THE STUDY	1
1.2 STATEMENT OF PROBLEM	4
1.3 RESEARCH QUESTIONS	4
1.4 AIM/OBJECTIVES	5
1.5 JUSTIFICATION OF STUDY	5
1.6 SCOPE OF THE STUDY	6
1.7 LIMITATION OF THE STUDY	6
1.8 STRUCTURE OF WORK	7
CHAPTER TWO	8
LITERATURE REVIEW	8
2.1 INTRODUCTION	8
2.2 RELATED PAST WORKS	9
2.3 THE QUEUING SYSTEM	13
2.4 BASIC OF QUEUING THEORY	14
2.4.1 THE INPUT AND OUTPUT PROCESSES	14
2.5 CHARACTERISTIC OF A QUEUING SYSTEM	15
2.6 EXIT/ DEPARTURE	18
2.7 TYPES OF QUEUING SYSTEM	18
2.8 PROPERTIES OF SOME SPECIFIC WAITING LINE MODELS	21
2.9 NOTATIONS FOR EQUATIONS	22
2.9.1 Infinite queuing model	22

2.9.2 Finite queuing model	22
2.9.3 Important assumptions for a queuing model	23
2.9.4 Suggestions for managing queues	24
CHAPTER THREE	25
RESEARCH METHODOLOGY	25
3.1 Introduction	25
3.2 Methods of Data Collection	25
3.2.1 Primary Data	25
3.2.2 Secondary Data	26
3.3 Data Collection Process.....	26
3.3.1 Yusuf Dantsoho Memorial Hospital.....	26
3.4 Method of Data Analysis.....	26
3.4.1 Mathematical/Analytic waiting line analysis.	27
3.4.2 The mean arrival rate	27
3.4.3 The mean service rate.....	27
3.4.4 Little`s Formula	27
3.4.5 Operating Characteristics of the Multiple Server Model with Infinite Population.....	29
CHAPTER FOUR	31
4.1 DATA PRESENTATION AND ANALYSIS	31
4.1.1 Presentation of data collected at the female section of the out-patient department of Yusuf Dantsoho Memorial Hospital from Monday (23 rd –May-2016) to Friday (27 th –May-2016).	
32	
4.2 The operating characteristics at the two sections in the Female unit at the OPD of Yusuf Dantsoho Memorial Hospital from Monday to Friday.....	50
4.3 Data Collection and Presentation for Questionnaires Administered to Patients.....	59
4.4 USING QUEUING MODEL (QM) FOR WINDOWS SOFTWARE TO MODEL CASES	62
CHAPTER FIVE	65
SUMMARY, CONCLUSION and RECOMENDATION.....	65
5.1 Summary	65
5.2 Conclusion.....	66
5.3 Recommendations	67
REFERENCES.....	69
APPENDIX.....	73
QUESTIONNAIRE	73

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND OF THE STUDY

Out-patient department (OPD) services are one of the most critical aspects of hospital administration. The OPD reflects the performance of the hospital as the first point of contact between the patient and the hospital staff, therefore ensuring high standard for medical treatment as well as other service will be essential in improving upon the efficacy of the current first line treatment for patients who visit various OPD centres in Nigerian hospitals. Many out-patient department (OPD) centres in Nigeria are confronted with long waiting times, delays and queues of patients.

Typical questions challenging hospital managers include: How should they optimally allocate their limited resources? How much exam rooms do they need? How much physicians and supporting staff do they need? If they increase or decrease the amount of exam rooms and/or staff, how would this affect patient waiting time, the length of a medical treatment and the total time spent in clinic by patient?

The amount of time a patient waits to be seen is one factor which affects the utilisation of health care services; patients perceive long

waiting times as barrier to actually obtaining services (kurata et al 1992). The degree to which health consumers visit OPD centres are satisfied with the services rendered is strongly related to the quality of waiting experience, therefore effectively managing patient flow in an out-patient unit is a key to achieving operational excellence as well as ensuring clinical quality.

Waiting time can be defined as the time a patient waits in the out-patient department (OPD) unit before being attended to by a physician. Healthcare is riddled with delays. Almost all of us have waited for days or weeks to get an appointment with a physician or schedule a procedure, and upon arrival we wait some more until being seen. In hospitals, it is not unusual to find patients waiting for beds in hallways, and delays for surgery or diagnostic tests are common. Delays are the result of a disparity between demand for a service and the capacity available to meet that demand. Usually this mismatch is temporary and due to natural variability in the timing of demands and in the duration of time needed to provide service. A simple example would be a healthcare clinic where patients walk in without appointments in an unpredictable fashion and require anything from treatment of malaria to the setting of a broken limb. This variability and the interaction between the arrival and service processes make the dynamics of service systems very complex. Consequently, it's impossible to predict levels of congestion or to

determine how much capacity is needed to achieve some desired level of performance without the help of a queuing model.

In view of these many challenges confronting the health care sector in a developing country such as Nigeria, the out-patient department/unit is not immune and has its own fair share of challenges, over the years investment have been made by government in improving upon existing hospital facilities and the construction of new ones, but the challenge of overcrowding in out-patient units of most government hospitals still persist and still a source of concern to both hospital management, government and other stake holders.

The health care delivery system in private hospitals are perceived to be better than that of public hospitals, but majority of Nigerians rely on government hospitals for health care service which is as a result of the higher cost in accessing private health care facilities due to low income levels of many Nigerians, therefore a large number of patients patronise public hospitals which results in overcrowding and longer waiting times.

1.2 STATEMENT OF PROBLEM

Queues and overcrowding in public hospitals in Nigeria has been a challenge to both government and hospital administrators on one hand and patients on the other hand. Several factors have been identified as been responsible for this trend, these factors includes the relatively low cost of service in public hospital as compared to private hospitals, inadequate infrastructure, shortage of health care personnel and the inability of hospital administrators to deploy effective operations management techniques in the management of queues .

1.3 RESEARCH QUESTIONS

This study intends to answer the under-listed question and proffer necessary solutions.

- How to optimally allocate available resources i.e. examination rooms, physicians, and supporting staff which are limited
- Suggest a system to reduce patient wait time in public hospitals.
- Improve access to healthcare in public hospitals.

1.4 AIM/OBJECTIVES

The main aim of this study is to optimise the female section of the out-patient department (OPD) of Yusuf Dantsoho memorial hospital (public hospital);

- (i) To examine using waiting line model patients flow in the out-patient department of Yusuf Dantsoho memorial hospital.
- (ii) To determine the performance measures of the OPD.
- (iii) To examine the effect of varying these parameters on the system.

1.5 JUSTIFICATION OF STUDY

- 1 This study will be of immense benefit to hospital administrators in making decisions on how resources can be optimally allocated.
- 2 This study will go a long way in assisting government in proper policy formulation.
- 3 The study will have positive impact on the economy, where hitherto time spent on queues can be engaged in productive activities.
- 4 The study will help in saving lives.

1.6 SCOPE OF THE STUDY

This study covers the female section of the out-patient department of Yusuf Dantsoho memorial hospital Kaduna, Kaduna state, Nigeria the choice of the female section of the OPD is as a result of long queues and long waiting times experienced by patients before getting service. The scope of this study is limited to obtaining both primary and secondary data. The primary data was sourced by the researcher by monitoring patient (folders) at various sections of the OPD and the secondary data was sourced from the records section, the data collected was for a period of 5 days from Monday 23rd-05-2016 to Friday 27th-05-2016 between the hours of 6.00 am to 12 noon

1.7 LIMITATION OF THE STUDY

The study was confined to the female section of the out-patient department of Yusuf Dantsoho memorial hospital Kaduna, this implies that results may be peculiar to the chosen case study and may be of limited generalization except for health care institutions with similar characteristics in terms of patients flow and resources.

1.8 STRUCTURE OF WORK

The thesis consists of five chapters in which chapter one presents the introduction to the background of the study, objectives of the study, justification of the study, scope and the limitation of the study. Chapter Two consist of the literature on queuing system, types of queuing model and queuing performance parameters. The third chapter concentrates on research methodology. This addresses the issues on the description of case problem, research design, data collection process, instruments and steps adopted for investigation. The data presentation and analysis of primary and secondary data are presented in chapter four which using queuing theory. The last chapter centres on discussion of the result (specific and general results), conclusion, recommendations and suggestion for further studies.

CHAPTER TWO

LITERATURE REVIEW

2.1 INTRODUCTION

Understanding waiting lines or queues and learning how to manage them is one of the most important areas in operations management. It is basic to creating schedules, job design, and inventory levels and so on. In our service economy we wait in line every day from driving to work, to checking out at the super market. We also encounter waiting lines at factories, jobs waiting lines to be worked on at different machines and machines themselves wait their turn to be over hauled. Every waiting line situation is a trade-off decision. The manager must weigh the added cost of providing more rapid service (more traffic lines, additional landing strips etc.) against the inherent cost of waiting i.e. hospital administration want queues that are short enough so that patient don't become unhappy and either leave "without buying or buy but not return". However managers are willing to allow some waiting if a significant saving in service balances waiting costs.

(Adedayo et al 2006). To achieve this manager need to optimise available resources (doctors, nurses etc.), waiting time and other queuing parameters within a complex system such as hospitals using tools like mathematical modelling, linear programming, queuing theory and

simulation. These instruments can be used for optimizing the performance of system.

2.2 RELATED PAST WORKS

Queuing theory was developed by A.K Erlang in 1904 to help determine the capacity requirement of the Danish telephone system (Brockmeyer et al. 1948). It has since been applied to a large range of service industries including banks, airlines and telephone call centres (Brewton 1989, Stern and Hersh 1980, Halloran and Bryne 1986, Brusco et al, 1995 and brigand et al 1994), as well as emergency systems such as police patrol, fire and ambulances (Chelst and Barlach 1981, Green and Kolesar 2001, Taylor and Huney 1989). Umar I, et al (2011), identified that the amount of time a patient waits to be seen is one factor which affects the utilisation of health care services. Patient satisfaction has emerged as an increasingly important parameter in the assessment of quality of health care; hence, healthcare facility performance can be best assessed by measuring the level of patient's satisfaction. This was a cross-sectional descriptive study carried out at the out patients' departments of the Usmanu Danfodiyo University, Sokoto. A total of 384 new patients were randomly selected into the study. A set of pretested questionnaires was used to extract information from the respondents; descriptive statistics was used for analysis. A total of 118 (31%) of the patients waited for less than an hour in the waiting room, while 371 (96.6%) spent less than 30 min with the doctor. More than half, 211 (55%) of the respondents were satisfied with the service delivery in the

hospital, while only 63 (16%) of the respondents admitted to being given health talks while waiting to be seen by the doctor. Although majority of the patients waited for more than 1 h before being attended to, more than half of them were however satisfied with the services rendered to them. There is the need for health care institutions and providers to put in place measures aimed at reducing waiting time and ensuring patient satisfaction.

Nilesh Sheath and Dr. Prashant Makwanna (2016), highlighted the role of providing appropriate medical care to patients within time limits as an important factor for healthcare organization to increase patient satisfaction. Patients are generally dissatisfied with long waiting times and it leaves negative effects on patients. Furthermore, queuing theory and modelling is an effective tool that can be provided to make decisions on requirements of staffing for good performance with regards to queuing challenges in hospitals. This analysis should be useful in other hospitals in India and other countries regarding on the usefulness of queuing theory and modelling as a tool for improved decision making with regard to the queuing challenges that are faced by hospitals. From the study server utilisation was 120.83% in case 1 with 3 doctors and 90.63% in case 2 with 4 doctors i.e. patients had spent less time in the queue and system utilization is good. Same when compared with case 3 server utilisation is very good as case 2. Also, from the results analysed the waiting time in queue also decreased. From the case 2 waiting time is $W_q = 0.038$ hour and in case 3, $W_q = 0.010$. It was observed from the results of the study that the number of

servers necessary to better serve is 5. This is the appropriate number of servers that can serve the customers without waiting long in queue.

The Institute of Medicine (IOM) recommends that, at least 90% of patients should be seen within 30 min of their scheduled appointment time (O'Malley MS et al 1983). This is, however, not the case in most developing countries, as several studies have shown that patients spend 2-4 h in the outpatient departments before seeing the doctor (Singh H et al 1999, Ofilli AN and Ofowve CE 2005). A source of dissatisfaction with health care reported by patients is having to wait a long period of time in the clinic, and several studies have documented the negative association between increased waiting time and patient satisfaction with primary care (Huang XM 1994). The duration of waiting time varies from country to country, and even within country it varies from centre to centre. Long waiting times have been reported in both developed and developing countries. In the USA, an average waiting time of about 60 min was found in Atlanta (Dos Santos LM et al 1994) and an average of 188 min in Michigan. In Nigeria, an average waiting time of about 173 min was found in Benin (Dansky KH and Miles J 1997), while in University College Hospital Ibadan, a mean waiting time of 1 h 13 min was observed (Bamgboye EO et al 1994). Time spent waiting is a resource investment by the patient for the desired goal of being seen by the physician and therefore may be moderated by the outcome.

Nidhi Malik and O.K Belwal (2016) studied the application of queuing theory to patient satisfaction and it was observed On the average the total number of minutes a patient spends in the queue before seeing a doctor are as follows; 4.888 minutes on Monday, 2.341 minutes on Tuesday, 5.543 minutes on Wednesday, 1.385 minutes on Thursday, 1.238 minutes on Friday and 1.608 minutes on Saturday. Again, the average number of minutes a patient spent in the entire system are as follows; 8.317 minutes on Monday, 5.268 on Tuesday, 9.216 minutes on Wednesday, 4.242 minutes on Thursday , 3.986 minutes on Friday and 4.399 minutes on Saturday. In total, it was found out that patients had to wait for long in the queues of the OPD section of the hospital which is resulting to the higher congestion in the hospital. In another study, Obamiro (2003) also applied the queuing theory in a study to determine the optimum number of nurses required in an antenatal clinic to reduce the time spent by pregnant women in the queue and the system. Queuing theory and modelling can thus be said to be useful modern tools for decision making on issues of capacity and resourcing. Singh (2006) looked into minimising total cost incurred and also minimising the waiting costs by comparing the outputs for two nurses, three nurses and four nurses by evaluating the performance measures for each of the cases. In that study, it was found that case of 3 nurses was the optimal solution with optimum trade-off between the two types of cost involved in queuing models.

In healthcare queuing models can be very useful in identifying appropriate levels of staff, equipment, and beds as well as in making decisions about resource allocation and the design of new services. Unlike simulation methodologies, queuing models require very little data and result in relatively simple formulae for predicting various performance measures such as mean delay or probability of waiting more than the given amount before being served. This means that they are easier and cheaper to develop and use, In addition. Since they are extremely fast to run they provide a simple way to perform “what If” analyses identify trade-offs and find attractive solution rather than just estimating performance for a given scenario.

2.3 THE QUEUING SYSTEM

The queuing system consist essentially of three major components,

- (i.) The source population and the way the customers arrive at the system
- (ii.) The servicing system and
- (iii.) The condition of the customer existing the system (back to source population or not).

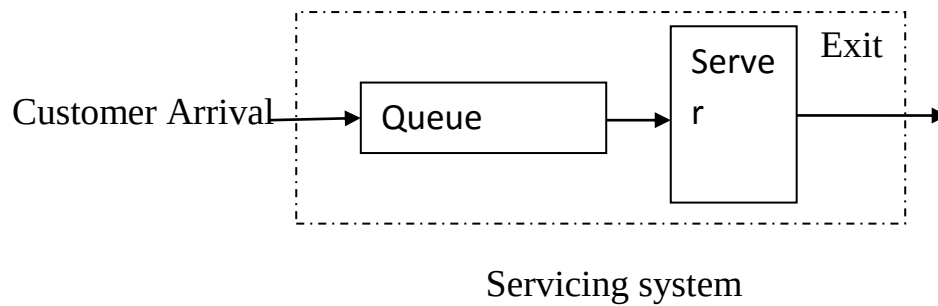


Fig 2.1 shows the components of queuing system

2.4 BASIC OF QUEUING THEORY

The simplest form of queuing models is the single-server single queue model as illustrated in fig 2.1. Single server model has a single line of customers (Krasewski and Ritzman, 1998). The structure of a queuing model comprises of the input and output queuing system i.e. a queue that must obey a queuing rule and service mechanics (Hillier and Lieberman, 2005)

2.4.1 THE INPUT AND OUTPUT PROCESSES

In applying queuing model to any situation the input and output processes need to be understood. Input processes also known as customer / patient arrival are generated one time by an input source randomly from a finite or infinite population. These patients/customers enter the queuing system and join a waiting line to be served. In hospital setting, the group of individuals from the arrivals come is referred to as the call-in population. At all times, a patient on the queue is selected for service by some rules known as the queue discipline. The required service is then performed for the customer by the server after which the customer leaves the servicing

system. The provision of services using certain rule and departure of patients/ customers is referred to as outputs process

	Settings	Input	Output
(1)	Hospital	Arrival of patients at the records units	Assessment, triage provision of services, discharged
(2)	(2) call center	Customers calls the customer care line	Attended to by an online agent. Afterwards the call is ended

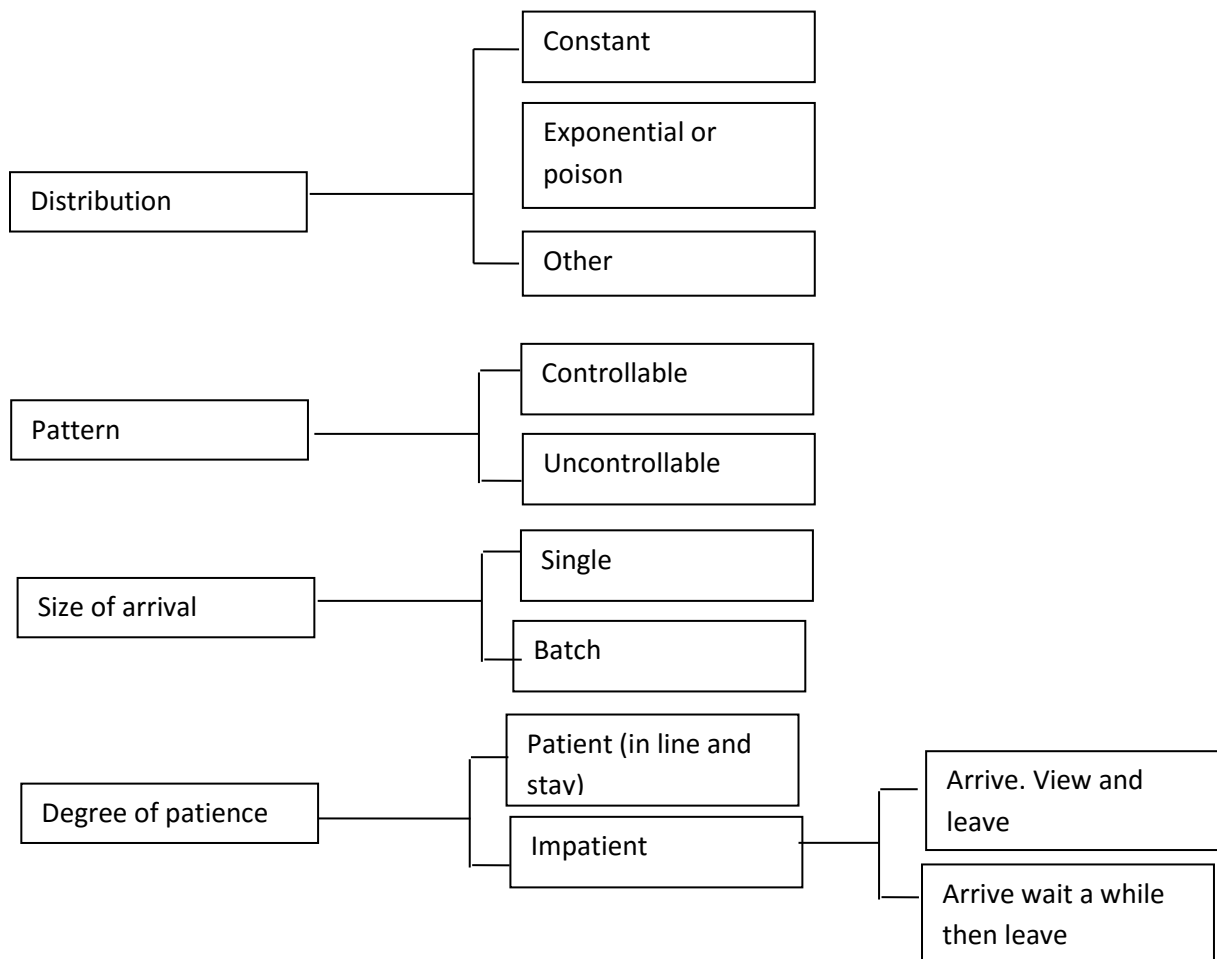
Table 2.1 shows a typical example of an input and output process

2.5 CHARACTERISTIC OF A QUEUEING SYSTEM

Some basic features of a queueing system includes

- (i) Arrival: (ii) queue length (iii) service channels (iv) queue discipline; (vi) service mechanism (vi) capacity of the system: (vii) exit or departure
- (i) Customer arrival: This describes the behaviour or pattern by which customers arrives queueing system drawn from a finite an infinite population
 - Finite population refers to the limited size customer pool that will use the service and, at time form a line.
 - Infinite population is a large enough in relation to the service system so that the population size caused by subtractions or additions to the population does not significantly affect the system probabilities.

Fig 2.2 Arrival characteristics in queue



- (ii) Queue length: this is the average number of customers in the queue
- (iii) waiting to get service, large queues many indicate poor sever performance while small queues may mean too much saver capacity
- (iv) Service pattern: This is the distribution of time taken to complete a service. The reciprocal of the mean service time is referred to as the service rate this pattern is commonly described by exponential distribution. The assumption is that departures occur one by one, and not in batches.
- (v) Number of severs: - A number of servers may work in parallel, and an arriving unit can choose randomly between any of the free

servers. If all servers are busy, the patient joins a common queue to all the servers.

- (vi) System capacity: - A system may have an infinite capacity i.e. the queue in front of the server (s) may grow to any length. Furthermore, there may be limitation of space and so when the space is filled to capacity, an arrival will not be able to join the system and will be lost to the system.
- (vii) Queue discipline: - This is a priority rule or set of rules for determining the order of service to customers in a waiting line. The rules selected can have a dramatic effect on the system's overall performance i.e. the number of customer in line, the average waiting line the range of variability in waiting time and the efficiency of the service facility. The most common priority rule is the first come, first served (FCFS). This rule states that customer in line are served on the basis of their chronological arrival. This is popularly accepted as the fairest rule although in practice it discriminates against the arrival requiring a short service. Other common queue disciplines are first in first out (FIFO) last come – first serve (LCFS) and priority where customer in queue are rendered service on priority basis. Thus customers may be called according to some identifiable characteristic i.e. highest profit customer first, largest order, best customer first etc.

2.6 EXIT/ DEPARTURE

Once a customer is served, two exit fates are possible, the customer may return the source to population and immediately become a competing candidate for service again or there may be a low probability of re-service. In hospitals, departure means home discharge, admission or death (Smith and Mayhew 2008).

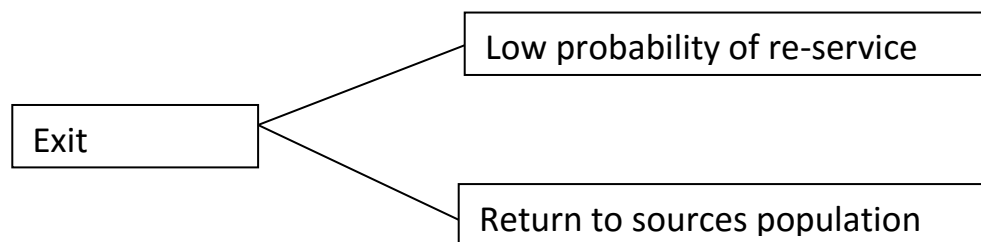


Fig 2.3

2.7 TYPES OF QUEUEING SYSTEM

The flow of customers of items to be serviced may go through a single line, multiple lines, or a mixture of the two. The choice of format depends partly on the volume of customers served and partly in the restrictions imposed by segmental requirements governing the order in which service must be performed

- (1) Single server, single queue: This is the simplest type of waiting line structure, and straight forward formulas are available to solve the problem for standard distribution patterns on arrival and service.

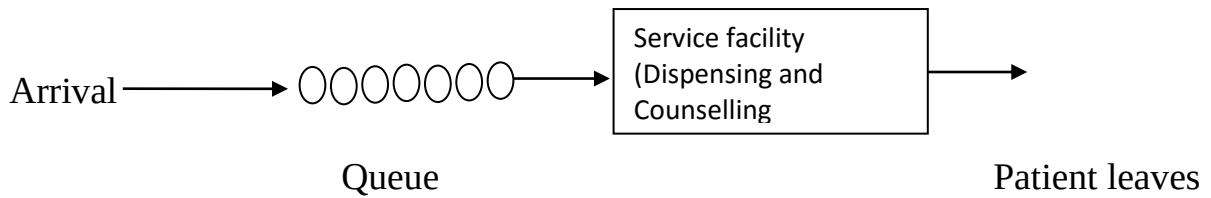
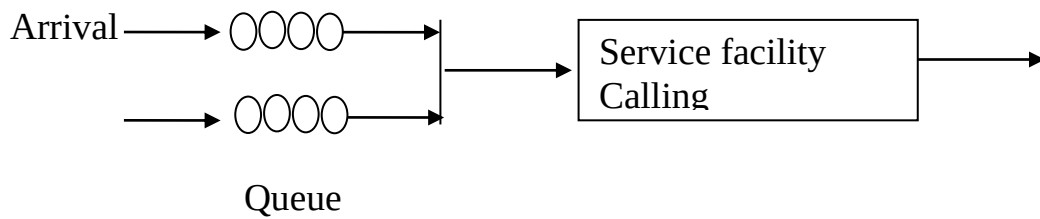


Fig 2.4 single server single queue model

(2) Single – multiple queue:



2.5 Single server multiple queue model

(3) Multiple (parallel) servers – single queue model

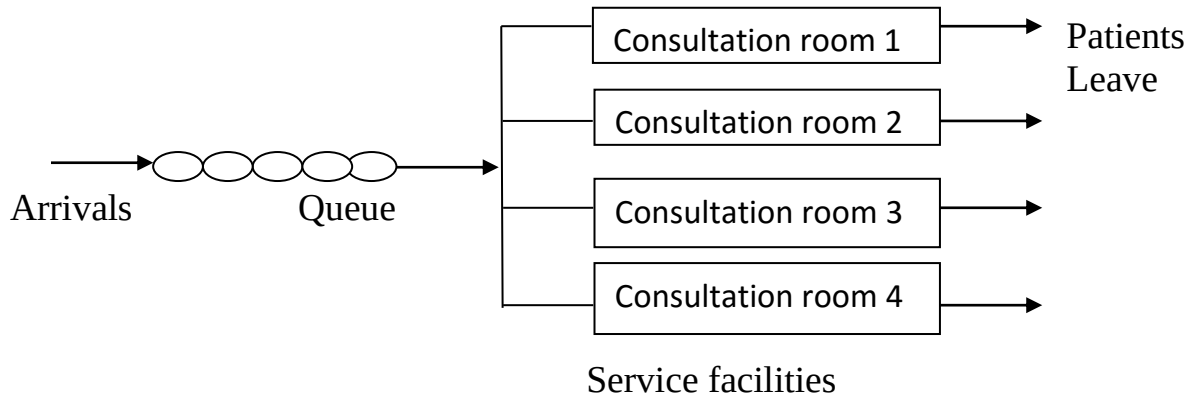
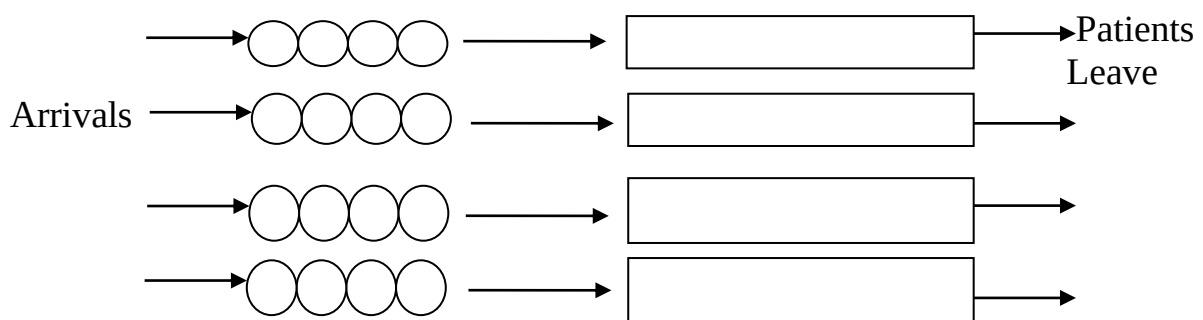


Fig 2.6 multiple (parallel) servers single queue model

(4) Multiple (parallel) server- multiple queue models



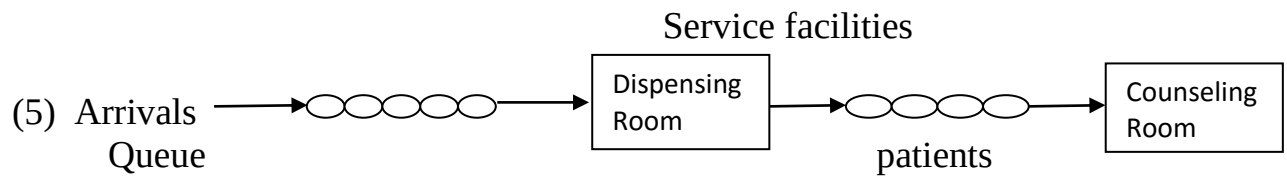
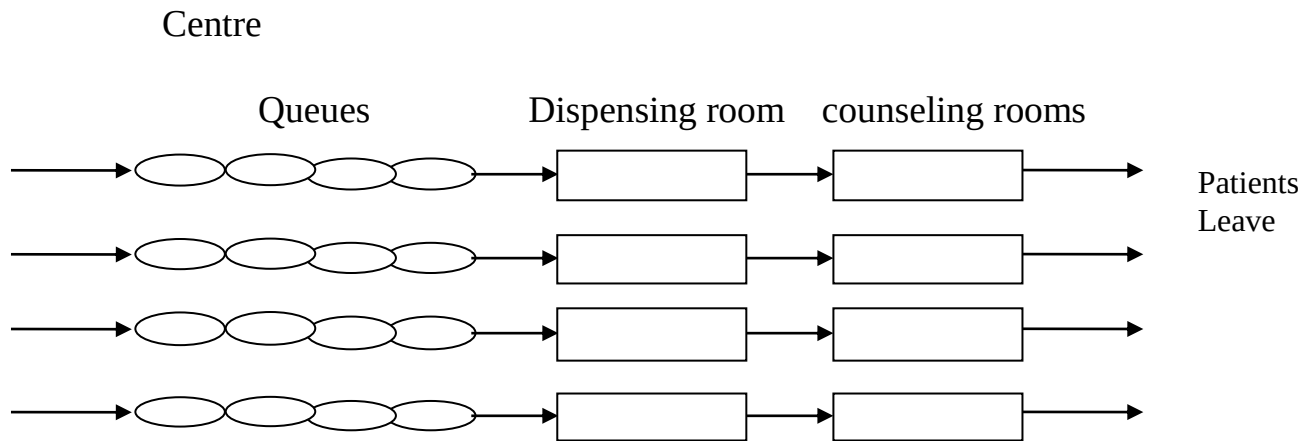


Fig 2.7 multiple servers in series to meet specialized needs (e.g.) HIV/AIDS



Arrivals

Fig (2.8) multiple servers in parallel to meet specialized needs and cases

(E.g. in a DOTs Centre for Tuberculosis)

2.8 PROPERTIES OF SOME SPECIFIC WAITING LINE MODELS

Model	Layout	Service phase	Source population	Arrival patient	Queue discipline	Service patient	Permissible Queue length	Typical example
1	Single channel	Single	INFINITE	POISSON	FCFS	EXPONENTIAL	UNLIMITED	Drive in teller at a bank.
2	Single channel	Single	INFINITE		FCFS			Roller coaster rides
3	Multiple channel	Single	INFINITE	POISSON	FCFS	EXPONENTIAL	UNLIMITED	Parts counter in auto agency
4	Single channel	Single	INFINITE	POISSON	FCFS	EXPONENTIAL	UNLIMITED	Machine breakdown and repair in a factory
Table 2.2 properties of some specific waiting line models								

2.9 NOTATIONS FOR EQUATIONS

2.9.1 Infinite queuing model

λ = Arrival rate

μ = Service rate

$\frac{1}{\mu}$ = Average service time

$\frac{1}{\lambda}$

$\frac{1}{\lambda}$ = Average time between arrivals

ρ

ρ = Ratio of total arrival rate to service for a single

$\frac{\lambda}{M\mu}$

L_q = average number waiting inline

L_s = Average number in system (including any being served)

W_q = Average time waiting inline

W_s = Average total time in system (including time to be served)

N = Number of units in the system

S = Number of identical service channels

P_n = Probability of exactly units in system

P_w = Probability of waiting in line

2.9.2 Finite queuing model

D = Probability that an arrival must wait in line

F = Efficiency factor, a measure of the effect of having to wait in line

H = Average number of units being serviced

J = population sources less these in queuing system ($N - n$)

L = Average number of units in line

S = Number of service channels

N = Average number of units in queuing system (including the one being served)

N = Number of units in population sources

P_n = Probability of exactly n units in evening system

T = Average time to perform the service.

U = Average time between customer service requirement

W = Average waiting time in line

X = Service factor or proportion of service time required

2.9.3 Important assumptions for a queuing model

- (i) Each source has a well define arrival pattern over time i.e. inter – arrival or interval times are constant or randomly spaced over times with known inter arrival time probability distribution (Poison distribution)
- (ii) The service time at each channel (server) may be constant random with a known service distribution (negative exponential distribution)
- (iii) The potential arrivals may balk if the length of waiting line becomes excessive and decide not to join the waiting line the waiting line and subsequently renege i.e. become impatient and leave before being served. They are lost by the system.

- (iv) In a steady state, the average rate of departure is equal to average rate of arrivals

2.9.4 Suggestions for managing queues

The following are some lawful suggestions for managing queues that go beyond quantitative waiting line models

1. Determine an acceptable waiting time for your customers
2. Try to divert your customer's attention when waiting
3. Inform your customer of what to expect
4. Keep employee not serving out of sight
5. Segment customers
6. Training your servers to be friendly
7. Encourage customers to come during slack periods

CHAPTER THREE

RESEARCH METHODOLOGY

The basis for research usually comes up as a result of enquiries in finding answers to the various questions surrounding man. Research has been used over time to find answers to problems seeking resolutions. Therefore, research is a problem induced activity; research is simply the process of arriving at a dependable solution to problems through the planned and systematic collection, analysis and interpretation of data.

3.1 Introduction

The method used is the conceptual framework which the whole research is based, for this research work; data was sourced predominantly from primary data for Yusuf Dantsoho Memorial Hospital.

The out-patient department of the hospital consist of basically two sections, the records and the consultation area where nurses take the vitals as the patients are waiting in line for their turn to see the doctor for consultation.

3.2 Methods of Data Collection

3.2.1 Primary Data

A form of data collection process was designed to gather valid, reliable or expert in formation through responses or interviews to a planned sequence of enquiries. Advantages of primary data.

- a) It's flexibility due to the fact that questions could be reframed to enhance ability to respondents.

- b) It saves time, since it is a direct way of data collection.
- c) Personal contacts help ease interviewees when answering questions, thereby providing reliable information.

3.2.2 Secondary Data

Secondary data can be defined as information from other sources for another purpose. This information is normally published for public and administrative use.

3.3 Data Collection Process

3.3.1 Yusuf Dantsoho Memorial Hospital

Letter of introduction was collected from the Department of Mechanical Engineering Ahmadu Bello University Zaria. The researcher personally waited at the out-patient department of Yusuf Dantsoho Hospital where he was introduced to the head of records who took him round the various sections of the out-patient department. The researcher at various sections of the OPD i.e. records and consultation monitored the movement of patients (folders) and recorded the data, by the use of stop watches, interview with some patients and staff using a questionnaire was conducted. Data was collected for Monday (23rd 05-2016) to Friday (27th -05-2016) between the hours of 6.00am to 12.00am. The number of arrivals was taken for the said period.

3.4 Method of Data Analysis

Data collected were analysed by mathematical/analytic waiting line formulas.

3.4.1 Mathematical/Analytic waiting line analysis.

Waiting line analysis is dependent on the accurate measurement of three variables i.e. arrival rate (λ), service rate (μ) and the number of servers in the system (S or K). (McManus et al, 2004). These three major parameters are necessary in the determination of other useful queuing model performance parameters.

3.4.2 The mean arrival rate

Let λ be the mean arrival rate and n the number of patients that entered the system between 6am – 12noon for Yusuf Dantsoho Memorial Hospital.

$$\lambda = \frac{n}{h} \text{ Arrival/hour} \quad 3.1$$

3.4.3 The mean service rate

$$\mu = \frac{1}{n} \sum_{i=1}^n S_i \text{ Arrival/hour} \quad 3.2$$

μ = mean service rate

S_i = service times

n = number of patients that entered the system.

3.4.4 Little`s Formula

Given by

$$L = \lambda w \quad 3.3$$

This would be used in determining the amount of time that a patient would spend in the system.

From (3.3) above

L = average number of patients present in the queue.

λ = mean arrival rate

W = expected time a patient spends in the system.

From equation (3.3) above (little second flow equation) used for both single and multiple – channel waiting line models.

$$W_q = \frac{L_s}{\lambda} \quad 3.4$$

W = average time in the waiting line

W_q = average service time

For a system with a mean service rate of (μ) , the mean service time is $\frac{1}{\mu}$.

Hence we have the following general relationship

$$W = W_q + \frac{1}{\mu} \quad 3.5$$

$$L = \lambda W \quad 3.6$$

$$L_q = \lambda W_q \quad 3.7$$

$$L_s = \lambda W_s \quad 3.8$$

Where equations (3.7) and (3.8) represents the average number of patients in queue and the average number of patients in the system respectively.

3.4.5 Operating Characteristics of the Multiple Server Model with Infinite Population

λ = average rate of arrival

K = number of servers

λK = mean combined rate of all the servers

$$P = \frac{\lambda}{K\mu} \quad 3.9$$

P = Utilisation factor of the entire system

$$P_0 = \left[\sum_{i=0}^{k-1} \frac{\left(\frac{\lambda}{\mu}\right)^i}{i!} + \frac{\left(\frac{\lambda}{\mu}\right)^k}{k! (1-p)} \right]^{-1} \quad 3.10$$

P_0 = Probability that the system would be idle

$$L_q = \frac{\left[\frac{\lambda}{\mu} \right]^k P}{k! (1-p)^2} \quad (P.) \quad 3.11$$

L_q = expected number of patients waiting in the queue

$$L_s = L_q + \frac{\lambda}{\mu} \quad 3.12$$

L_s = expected number of patients waiting in the system

$$W_q = L_q / \lambda \quad 3.13$$

W_q = expected waiting time in the queue

$$W_s = W_q + \frac{1}{\lambda} \quad 3.14$$

W_s = the expected time a customer spends in the system.

CHAPTER FOUR

4.1 DATA PRESENTATION AND ANALYSIS

The data for this study will be presented in this chapter. This chapter would seek to prove the importance of queuing theory in the optimisation of system parameters i.e. (waiting time, service time, system idle time etc.) in the outpatient department of public hospitals. The data collected from the records and the consultation unit of the female section at the out-patient department of Yusuf Dantsoho Memorial Hospital from Monday (23rd of May 2016) to Friday (27th 05-2016) was analysed.

The mean arrival rates (λ) and the mean service rates (μ) would be calculated from the data collected and their results used in measuring the performance of the entire system.

4.1.1 Presentation of data collected at the female section of the out-patient department of Yusuf Dantsoho Memorial Hospital from Monday (23rd –May-2016) to Friday (27th –May-2016).

From equation (3.1), mean arrival rate= $\Sigma n/h$

Table 4.1: Service times for patients at the record section (female) of the out-patient department of Yusuf Dantsoho Memorial Hospital on Monday.

K=2

	Number of patients (folders)	Service times (minutes) departure
	15	90
	20	80
	20	85
	30	100
	18	95
	15	75
	17	90
	20	95

$$\lambda = \frac{155}{6} = 25.8333 \text{ patients/hour}$$

$$\mu = \frac{155}{11.8333} = 13.0986 \text{ patients/hour}$$

(1) The utilization factor of the system is;

$$P = \frac{25.8333}{2(13.0986)} = \frac{25.8333}{26.1972} = 0.9543$$

(2) The probability that the system would be idle;

$$P_0 = \left[\sum_{i=0}^1 \frac{\left(\frac{25.8337}{13.0986}\right)^i}{i!} + \frac{\left(\frac{25.8333}{13.0986}\right)^2}{2!(1 - 0.9543)} \right]^{-1}$$

$$= [1 + 1.9722 + 42.5555]^{-1} = 0.02196$$

(3) Expected number of patients waiting in line;

$$L_q = \frac{\left(\frac{25.8333}{13.0986}\right)^2 \times 0.9543}{2!(1 - 0.9543)^2} \times 0.02196$$

(4) Expected number of patients waiting in the system;

$$L_s = 19.5145 + 1.9722$$

$$= 21.4868 \text{ patients}$$

(5) Expected waiting time of a patient in the queue;

$$W_q = \frac{19.5145}{25.8333} = 0.7554 \text{ hours} = 45.3241 \text{ min}$$

(6) Expected time a patient spends in the system;

$$W_s = 0.7554 + \frac{1}{13.0986} = 0.8317 \text{ hours} = 49.946 \text{ min}$$

Table 4.2 Service times for patients at the consultation unit (female) at the out-patient department of Yusuf Dantsoho Memorial Hospital on Monday.

K = 2

Number of patients (folders)	Service times (minutes)
15	60
20	80
20	50
30	105
18	50
15	110
17	80
20	90

$$\lambda = \frac{155}{6} = 25.8333 \text{ patients/hour}$$

$$\mu = \frac{155}{10.4167} = 14.8800 \text{ patients/hour}$$

(1) The utilization factor of the system

$$P = \frac{25.8333}{2 (14.8800)} = 0.8681$$

(2) The probability that the system would be idle

$$P_0 = \left[\sum_{i=0}^{\infty} \frac{\left(\frac{25.8333}{14.8800}\right)^i}{i!} + \frac{\left(\frac{25.8333}{14.8800}\right)^2}{2!(1-0.8681)} \right]^{-1}$$

$$= [1 + 1.7361 + 11.4256]^{-1} = 0.0706$$

(3) Expected number of patients waiting in line;

$$L_q = \frac{\left(\frac{25.8333}{14.8800}\right)^2 \times 0.8681}{2!(1-0.8681)^2} \times 0.0706$$

$$= 5.3089 \text{ patients}$$

(4) Expected number of patients waiting in the systems;

$$L_s = 5.3089 + 1.7361 = 7.0451 \text{ patients}$$

(5) Expected waiting time of patient in the queue;

$$W_q = \frac{5.30895}{25.8333} = 0.2055 = 12.3305 \text{ minutes}$$

(6) Expected time a patient spends in the system;

$$W_s = 0.2055 + \frac{1}{14.8800} = 0.2727 \text{ hours} = 16.3623 \text{ minutes}$$

Table 4.3: Service times for patients at the record section (female) of the out-patient department of Yusuf Dantsoho Memorial Hospital on Tuesday.

K = 3

Number of patients (folders)	Service times (minutes)
30	65
35	60
35	90
17	40
15	40
16	35
25	60
11	60
15	45
10	70
31	70
20	65

$$\lambda = \frac{260}{6} = 43.4444 \text{ patients/hour}$$

$$\mu = \frac{260}{14.75} = 17.6271 \text{ patients/hour}$$

(1) The utilisation factor of the system;

$$P = \frac{43.3333}{3(17.6271)} = 0.8194$$

(2) The probability that the system would be idle;

$$P_0 = \left[\sum_{i=0}^2 \frac{\left(\frac{43.3333}{17.6271}\right)^i}{i!} + \frac{\left(\frac{43.3333}{17.6271}\right)^3}{3!(1 - 0.8194)} \right]^{-1}$$

$$= [1 + 2.4583 + 3.0216 + 13.7099]^{-1} = 0.0495$$

(3) Expected number of patients waiting in line;

$$L_q = \frac{\left(\frac{43.3333}{17.6271}\right)^3 \times 0.8194}{3! (1 - 0.8194)^2} \times 0.0495 = 3.0791 \text{ patients}$$

(4) Expected number of patients waiting in the system;

$$L_s = 3.0791 + \frac{43.3333}{17.6271} = 5.5374 \text{ patients}$$

(5) Expected waiting time of a patient in the queue;

$$W_q = \frac{3.0791}{43.3333} = 0.0711 \text{ hours} = 4.2634 \text{ minutes}$$

(6) Expected time a patient spends in the system;

$$W_s = 0.0711 + \frac{1}{17.3271} = 0.1278 \text{ hours} = 7.6698 \text{ minutes}$$

Table 4.4: Service times of patients in the female consultation unit of the out-patient department at Yusuf Danstoho Memorial Hospital on Tuesday.

K = 3

Number of patients (folders)	Service times (minutes)
30	115
35	110
35	105
17	75
15	100
16	70
25	100
11	65
15	75
10	75
31	95
20	65

$$\lambda = \frac{260}{6} = 43.3333 \text{ patients/hour}$$

$$\mu = \frac{260}{17.5} = 14.8571 \text{ patients/hour}$$

(1) Utilisation factor of the system;

$$P = \frac{43.3333}{3(14.8571)} = 0.9722$$

(2) The probability that the system would be idle

$$P_0 = \left[\sum_{i=0}^2 \frac{\left(\frac{43.3333}{14.8571}\right)^i}{i!} + \frac{\left(\frac{43.3333}{14.8571}\right)^3}{3!(1 - 0.9722)} \right]^{-1}$$

$$= [1 + 2.9167 + 4.2536 + 148.7576]^{-1} = 0.0064$$

(3) Expected number of patients waiting in line;

$$L_q = \frac{\left(\frac{43.3333}{14.8571}\right)^3 \times 0.9722}{3!(1 - 0.9722)^2} \times 0.0064 = 33.2943 \text{ patients}$$

(4) Expected number of patients waiting in the system;

$$L_s = 33.2943 + 2.9167 = 36.2110 \text{ patients}$$

(5) Expected waiting time of patients in the queue;

$$W_q = \frac{33.2943}{43.3333} = 0.7683 \text{ hours} = 46.0998 \text{ minutes}$$

(6) Expected waiting time a patient trends in the system;

$$W_s = 0.7683 + \frac{1}{14.8571} = 0.8356 \text{ hours} = 50.165 \text{ minutes}$$

Table 4.5: Service times of patients at the female records section of the OPD of Yusuf Dantsoho Memorial Hospital on Wednesday.

Numbers of patients (folders)	Service times (minutes)
15	60
18	50
12	40
20	70
8	35
9	35
7	30
7	35

Table 4.6: Service times of patients at the female consultation unit of the OPD of Yusuf Dantsoho Memorial Hospital on Wednesday.

K = 2

Numbers of patients (folders)	Service times (minutes)
15	90
18	100
12	80
20	110
8	45
9	50
7	35
7	40

$$\lambda = \frac{96}{6} = 16 \text{ patients/hour}$$

$$\mu = \frac{96}{9.1667} = 10.4727 \text{ patients/hour}$$

(1) Utilisation factor of the system;

$$P = \frac{16}{2(10.4727)} = 0.7639$$

(2) The probability that the system would be idle

$$P_0 = \left[\sum_{i=0}^1 \frac{\left(\frac{16}{10.4727} \right)^i}{i!} + \frac{\left(\frac{16}{10.4727} \right)^2}{2! (1 - 0.7639)} \right]^{-1}$$

$$= [1 + 1.5278 + 4.9432]^{-1} = 0.1344$$

(3) Expected number of patients waiting in line;

$$L_q = \frac{\left(\frac{16}{10.4272}\right)^2 \times 0.7639}{2! (1 - 0.7639)^2} \times 0.1344 = 2.1495 \text{ patients}$$

(4) Expected number of patients waiting in the system;

$$L_s = 2.1495 + 1.5278 = 3.6773 \text{ patients}$$

(5) Expected waiting time of patients in the queue;

$$W_q = \frac{2.1495}{16} = 0.1343 \text{ hours} = 8.0606 \text{ minutes}$$

(6) Expected waiting time a patient trends in the system;

$$W_s = 0.1343 + \frac{1}{10.4727} = 0.2298 \text{ hours} = 13.7872 \text{ minutes}$$

Table 4.7: Service times of patients at the female records section of the OPD of Yusuf Dantsoho Memorial Hospital on Thursday.

K = 3

Numbers of patients (folders)	Service times (minutes)
35	90
28	70
30	100
25	75
25	65
32	105
35	120
20	70
26	65
18	50
25	80

$$\lambda = \frac{299}{6} = 49.8333 \text{ patients/hour}$$

$$\mu = \frac{299}{15} = 19.9333 \text{ patients/hour}$$

(1) Utilisation factor of the system;

$$P = \frac{49.8333}{3(19.9333)} = 0.8333$$

(2) The probability that the system would be idle

$$P_0 = \left[\sum_{i=0}^2 \frac{\left(\frac{49.8333}{19.9333}\right)^i}{i!} + \frac{\left(\frac{49.8333}{19.9333}\right)^3}{3!(1-0.8333)} \right]^{-1}$$

$$= [1 + 2.5000 + 3.1250 + 15.6219]^{-1}$$

(3) Expected number of patients waiting in line;

$$L_q = \frac{\left(\frac{49.8333}{19.9333}\right)^3 \times 0.8333}{3!(1-0.8333)^2} \times 0.04495 = 3.5102 \text{ patients}$$

(4) Expected number of patients waiting in the system;

$$L_s = 3.5102 + 2.5000 = 6.0102 \text{ patients}$$

(5) Expected waiting time of patients in the queue;

$$W_q = \frac{3.5102}{49.8333} = 0.0704 \text{ hours} = 4.2263 \text{ minutes}$$

(6) Expected waiting time a patient trends in the system;

$$W_s = 0.0704 + \frac{1}{19.9333} = 0.1206 \text{ hours} = 7.2340 \text{ minutes}$$

Table 4.8: Service times of patients in the female consultation section of the OPD at Yusuf Dantsoho Memorial Hospital on Thursday.

K = 3

Numbers of patients (folders)	Service times (minutes)
35	120
28	100
30	105
25	80
25	110
32	120
35	130
20	80
26	90
18	80
25	90

$$\lambda = \frac{299}{6} = 49.8333 \text{ patients/hour}$$

$$\mu = \frac{299}{8.4167} = 16.2353 \text{ patients/hour}$$

(1) Utilisation factor of the system;

$$P = \frac{299}{3(18.4167)} = 0.90196$$

(2) The probability that the system would be idle

$$P_0 = \left[\sum_{i=0}^2 \frac{\left(\frac{49.8333}{18.4167}\right)^i}{i!} + \frac{\left(\frac{49.8333}{18.4167}\right)^3}{3!(1-0.90196)} \right]^{-1}$$

$$= [1 + 3.0695 + 4.7109 + 49.1641]^{-1} = 0.0173$$

(3) Expected number of patients waiting in line;

$$L_q = \frac{\left(\frac{49.8333}{18.4167}\right)^3 \times 0.90196}{3!(1-0.90196)^2} \times 0.0173 = 7.8249 \text{ patients}$$

(4) Expected number of patients waiting in the system;

$$L_s = 7.8249 + 3.0695 = 10.8944 \text{ patients}$$

(5) Expected waiting time of patients in the queue;

$$W_q = \frac{7.8249}{49.8333} = 0.1570 \text{ hours} = 9.4213 \text{ minutes}$$

(6) Expected waiting time a patient trends in the system;

$$W_s = 0.1570 + \frac{1}{18.4167} = 0.2113 \text{ hours} = 12.6779 \text{ minutes}$$

Table 4.9: Service times of patients at the female records section of the OPD of Yusuf Dantsoho Memorial Hospital on Friday.

K = 3

Numbers of folders (patients)	Service times (minutes)
25	50
20	45
25	60
10	50
24	65
28	65
30	80
20	50
18	50
10	45
15	50

$$\lambda = \frac{225}{6} = 37.5 \text{ patients/hour}$$

$$\mu = \frac{225}{10.3333} = 21.7743 \text{ patients/hour}$$

(1) Utilisation factor of the system;

$$P = \frac{37.5}{2(21.7743)} = 0.8611$$

(2) The probability that the system would be idle

$$P_0 = \left[\sum_{i=0}^1 \frac{\left(\frac{37.5}{21.7743}\right)^i}{i!} + \frac{\left(\frac{37.5}{21.7743}\right)^2}{2!(1-0.8611)} \right]^{-1}$$

$$= [1 + 0.7222 + 1.4830 + 0.4119]^{-1} = 0.3191$$

(3) Expected number of patients waiting in line;

$$L_q = \frac{\left(\frac{37.5}{21.7743}\right)^2 \times 0.8611}{2!(1-0.8611)^2} \times 0.3191 = 21.1209 \text{ patients}$$

(4) Expected number of patients waiting in the system;

$$L_s = 21.1209 + 1.7222 = 22.8431 \text{ patients}$$

(5) Expected waiting time of patients in the queue;

$$W_q = \frac{21.1209}{37.5} = 0.5632 \text{ hours} = 33.7934 \text{ minutes}$$

(6) Expected waiting time a patient trends in the system;

$$W_s = 0.5632 + \frac{1}{21.7743} = 0.6091 \text{ hours} = 36.5475 \text{ minutes}$$

Table 4.10: Service times of patients at the female consultation section of the OPD of Yusuf Dantsoho Memorial Hospital on Friday.

K = 3

Numbers of folders (patients)	Service times (minutes)
25	100
20	70
25	110
10	60
24	70
28	105
30	120
18	90
10	50
15	60
225	835

$$\lambda = \frac{225}{6} = 37.5 \text{ patients/hour}$$

$$\mu = \frac{225}{13.9167} = 16.1677 \text{ patients/hour}$$

(1) Utilisation factor of the system;

$$P = \frac{37.5}{3 (16.1677)} = 0.7454$$

(2) The probability that the system would be idle

$$P_0 = \left[\sum_{i=0}^2 \frac{\left(\frac{37.5}{16.1677}\right)^i}{i!} + \frac{\left(\frac{37.5}{16.1677}\right)^3}{3!(1-0.7454)} \right]^{-1}$$

$$= [1 + 2.3194 + 2.6898 + 8.1680]^{-1} = [14.1772]^{-1} = 0.0705$$

(3) Expected number of patients waiting in line;

$$L_q = \frac{\left(\frac{37.5}{16.1677}\right)^3}{3!(1-0.7454)^2} \times 0.7457 = 0.0705 \text{ patients}$$

(4) Expected number of patients waiting in the system;

$$L_s = 1.6859 + 2.3194 = 4.0053 \text{ patients}$$

(5) Expected waiting time of patients in the queue;

$$W_q = \frac{1.6859}{37.5} = 0.0446 \text{ hours} = 2.6974 \text{ minutes}$$

(6) Expected waiting time a patient trends in the system;

$$W_s = 0.0446 + \frac{1}{16.1677} = 0.1065 \text{ hours} = 6.3871 \text{ minutes}$$

4.2 The operating characteristics at the two sections in the Female unit at the OPD of Yusuf Dantsoho Memorial Hospital from Monday to Friday.

Table 4.11: The Operating Characteristics for Monday

Operating Characteristics	Records	Consultation Unit
The mean arrival rate (λ) (patients/hr)	25.8333	25.8333
The mean service rate (μ) (patients/hr)	13.0986	14.8800
The utilisation factor of the system (p) in %	95.4300	86.8100
The probability that the system would be idle (P_0) in %	2.1960	7.0600
The expected number of patients in the queue (L_q)	19.5145	5.3089
The expected number of patients in the system (L_s)	21.4868	7.0451
The average time a patient spends in the queue (W_q) in minutes	45.3241	12.3305
The average time a patient spends in the system (W_s) in minutes	49.9460	16.3623

From table 4.11, the busier of the two sections is the records with a utilisation factor of 95.43%, whereas the consultation unit has a utilisation factor of 86.81%. The records section also has the highest number of patients waiting in the queue compared to the consultation unit, on an average a patient spends 49.9460 minutes in the entire system of the records section and 16.3623 minutes at the consultation unit.

Table 4.12: The Operating Characteristics for Tuesday

Operating Characteristics	Records	Consultation Unit
The mean arrival rate (λ) (patients/hr)	43.3333	43.3333
The mean service rate (μ) (patients/hr)	17.6271	14.8571
The utilisation factor of the system (p) in %	81.9400	97.2200
The probability that the system would be idle (P_0) in %	4.9500	0.6400
The expected number of patients in the queue (L_q)	3.0791	33.2943
The expected number of patients in the system (L_s)	5.5374	36.2110
The average time a patient spends in the queue (W_q) in minutes	4.2634	4.60998
The average time a patient spends in the system (W_s) in minutes	7.6698	50.1650

From table 4.12, the busier of the two sections is the consultation unit with a utilisation factor of 97.22%, as compared to the 81.94% at the records sections. The consultation unit has the highest number of patients waiting in line compared to the records section an average time a patient spends in the entire system of the consultation unit is 50.1650 minutes and 7.6698 minutes at the records section.

Table 4.13: The Operating Characteristics for Wednesday

Operating Characteristics	Records	Consultation Unit
The mean arrival rate (λ) (patients/hr)	16.0000	16.0000
The mean service rate (μ) (patients/hr)	18.0000	10.4727
The utilisation factor of the system (p) in %	44.4400	76.3900
The probability that the system would be idle (P_0) in %	38.4600	13.4400
The expected number of patients in the queue (L_q)	0.2187	2.1495
The expected number of patients in the system (L_s)	1.1076	3.6773
The average time a patient spends in the queue (W_q) in minutes	0.8201	8.0606
The average time a patient spends in the system (W_s) in minutes	4.1553	13.7872

From table 4.13, the busier of the two sections is the consultation unit with a utilisation factor of 76.39%, as compared to the 44.44% utilisation at the records sections. The consultation unit also has the highest number of patients waiting in line compared to the records section a patients spends an average of 13.7872 minutes at the consultation unit and 4.1553 minutes at the records section.

Table 4.14: The Operating Characteristics for Thursday

Operating Characteristics	Records	Consultation Unit
The mean arrival rate (λ) (patients/hr)	49.8333	49.8333
The mean service rate (μ) (patients/hr)	19.9333	16.2353
The utilisation factor of the system (p) in %	83.3300	90.1960
The probability that the system would be idle (P_0) in %	0.4495	1.7300
The expected number of patients in the queue (L_q)	3.5102	7.8249
The expected number of patients in the system (L_s)	6.0102	10.8944
The average time a patient spends in the queue (W_q) in minutes	4.2263	9.4213
The average time a patient spends in the system (W_s) in minutes	7.2340	12.6779

From table 4.14, the busier of the two sections of the female OPD is the consultation unit with a utilisation factor of 90.1960% as compared to the 83.33% utilisation at the records section. The consultation unit also has the highest number patients waiting in line, a patient spends an average of 122.6779 minutes at the consultation unit and 7.2348 minutes at the records section.

Table 4.15: The Operating Characteristics for Friday

Operating Characteristics	Records	Consultation Unit
The mean arrival rate (λ) (patients/hr)	37.5000	37.5000
The mean service rate (μ) (patients/hr)	21.7743	16.1677
The utilisation factor of the system (p) in %	86.1100	74.5400
The probability that the system would be idle (P_0) in %	15.95	7.0500
The expected number of patients in the queue (L_q)	21.1209	1.6859
The expected number of patients in the system (L_s)	22.8431	4.0053
The average time a patient spends in the queue (W_q) in minutes	33.7934	2.6974
The average time a patient spends in the system (W_s) in minutes	36.5475	6.3871

From table 4.15, the busier of the two sections of the female OPD is the records section with a utilisation factor of 86.11% as compared to the 74.54% utilisation at the records section. The record section has the highest number of patients waiting in line, a patient spends an average of 36.5475 minutes at the records section and 6.3871 minutes at the consultation unit.

Table 4.16: The mean arrival rates at the female section of the OPD from Monday to Friday.

Days	(Yusuf Dantsoho Hospital) Mean arrival rate
Monday	25.8333
Tuesday	43.3333
Wednesday	16.0000
Thursday	49.8333
Friday	37.5000

From table 4.16, the female section of the OPD recorded the highest number of arrivals per hour on Thursday and the least arrival per hour was noticed on Wednesday.

Table 4.17: The mean service rates of servers at both sections of the hospital, from Monday to Friday:

Mean service rate (patients / hr) [Yusuf Dantsoho Hospital]	Monday	Tuesday	Wednesday	Thursday	Friday
Records	13.0986	17.6271	18.0000	19.9333	21.7743
Consultation unit	14.8800	14.8571	10.4727	16.2353	16.1677

From table 4.17, the server at the record section of Yusuf Dantsoho memorial hospital on Friday served more number of patients per hour (21.7743) patients on an average.

Table 4.18: The utilisation factor at both sections of the hospital, from Monday to Friday

Utilisation factor (%) Yusuf Dantsoho Hospital	Monday	Tuesday	Wednesday	Thursday	Friday
Records	95.4300	81.9400	44.4400	83.3300	86.1100
Consultation unit	86.8100	97.2200	76.3900	90.1960	74.5400

From Table 4.18, the busier of the two section of the OPD for Yusuf Dantsoho memorial hospital is the consultation unit with an average utilisation of 85.0312.

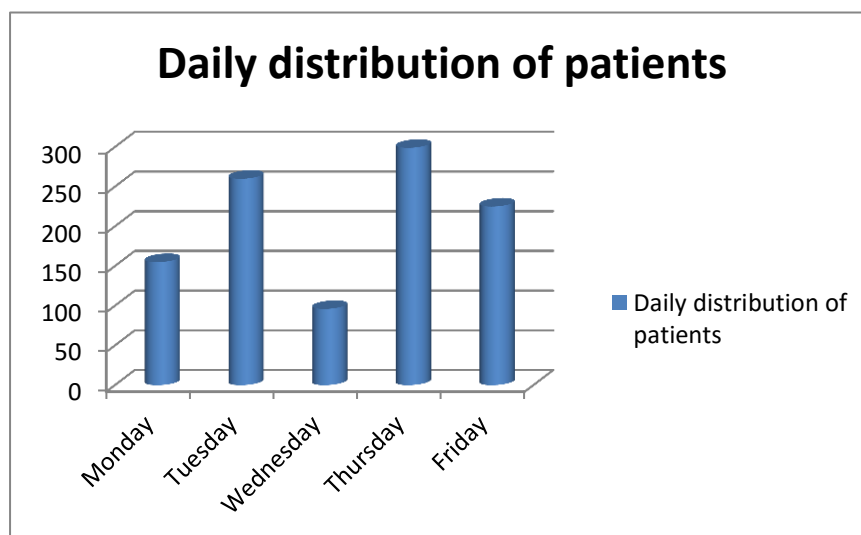


Fig 4.3 above shows the daily distribution of patients at the female section of the OPD for the period understudy, the chart shows that Tuesday and Thursday had the highest number of arrivals with 255 and 299 patients respectively, 225 patients visited the OPD on Friday, 155 patients on Monday and the least number of patients was recorded on Wednesday with 96 patients visiting the OPD.

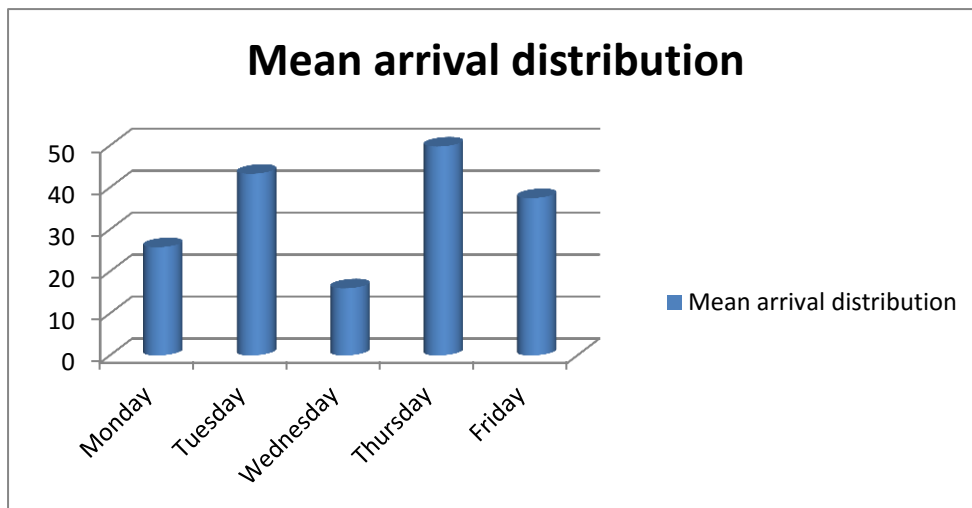


Fig 4.4 above shows the daily arrival distribution of patients at the OPD (female) of Yusuf Dantsoho Memorial Hospital for the period understudy Thursday had the highest arrival rate of 49 patients /hour with the least arrival of 16 patients/hour recorded of Wednesday, the average mean arrival at this section of the OPD for the period of study is 34 patients/hour.

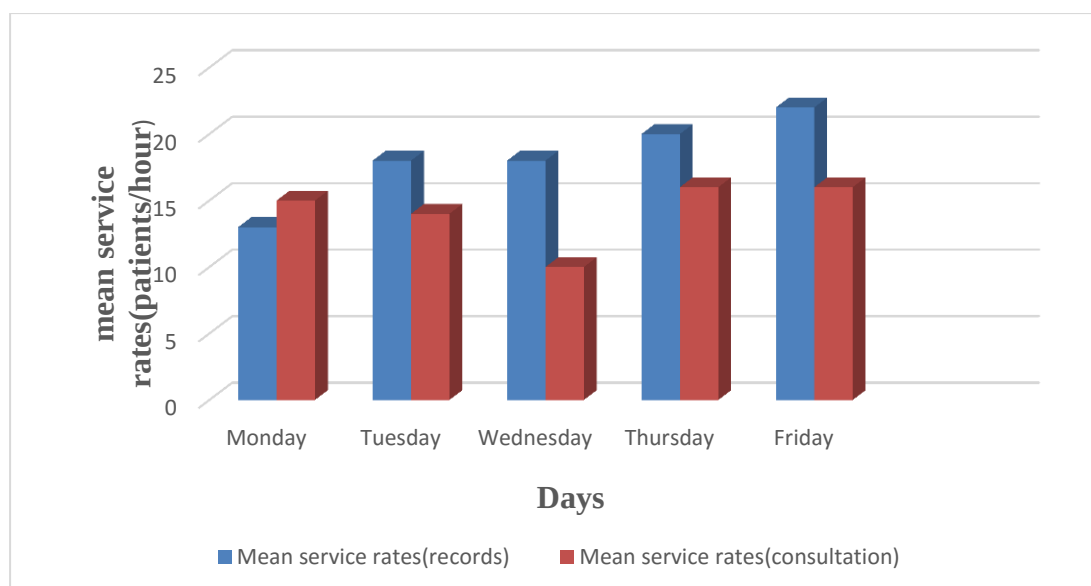


Fig 4.1 Mean service rates distribution

Fig 4.1 above shows the mean service rates distribution at the female section of the OPD with an average service rate of 17.92 patients/hour at the records and an average of 14.48 patients/hour at the consultation unit.

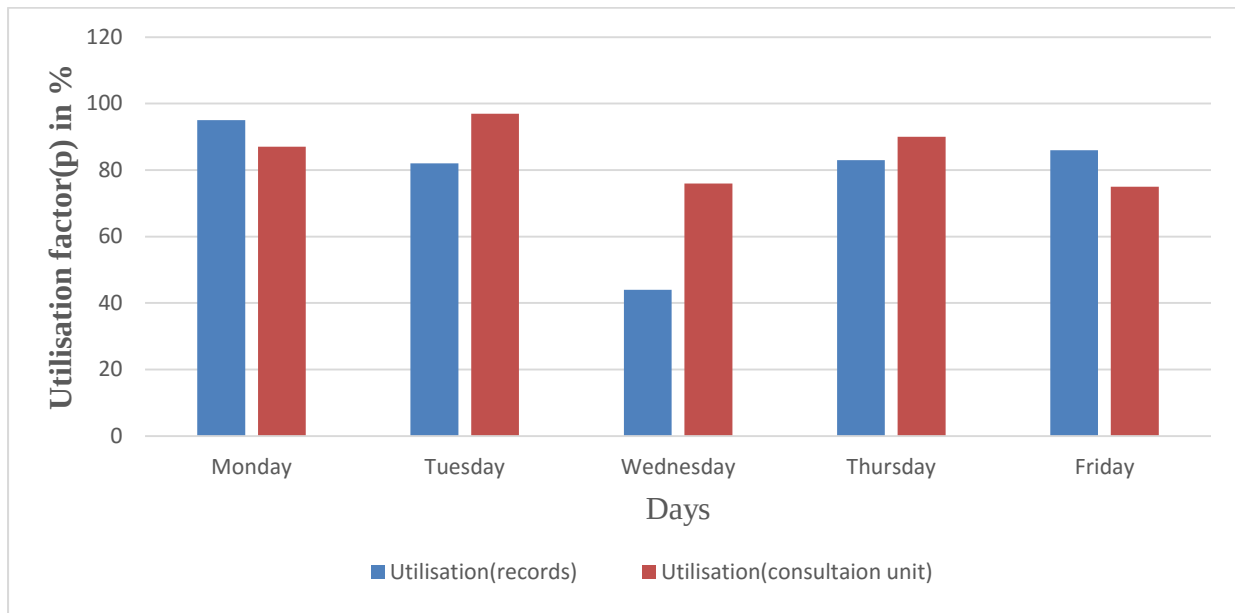


Fig 4.2 shows the utilisation factor (p) at both sections of the OPD

Fig 4.2 above shows the daily utilisation of service at both sections of the OPD of Yusuf Dantsoho memorial from Monday to Friday and it was observed that the consultation unit was the busier of the sections with an average utilisation of 85.0312% as compared with an average utilisation of 78.25% at the records.

4.3 Data Collection and Presentation for Questionnaires Administered to Patients

A total number of 400 questionnaires were randomly administered to patients over the period of the study, out of which 345 responses were successfully captured and the data was analysed. This data was used in to capturing patient's behaviour on the queue and also to get the view of patients on how to effectively manage patients flow in the female section at OPD of Yusuf Dantsoho Memorial hospital, Kaduna.

Table 4.19: Results for Patients' Behaviours on the Queue?

Patients behaviour	Number	Percentage (%)
Wait for turn	211	61.1594%
Jump queue	49	14.2029
Patients not seen in order	57	16.5217
Join and leave queue	8	2.3188
Others	20	5.7971

It was observed that 211 (61.1594%) of patients waited patiently in the queue, 49 (14.2029%) jumped queue, 57 (16.5217%) not seen in order, 20 (5.7971%) was combination of any of the above 8 (2.3188%) joined and left the queue.

Table 4.20: Total time spent of the record section

Time spent of the record section	Number	Percentage (%)
<15 min	55	15.9420
15 – 30 min	140	40.5787
30 – 45 min	50	14.4928
>45 min	100	28.9855
Total	345	100

It was observed that 55 (15.9420%) of patients spent less than 15 minutes at the records section, 140 (40.5787%) spent between 15 -30 minutes at the record section, 50 (14.4928%) spent 30-45 minutes and 100 (28.9855%) of patients spent above 45 minutes.

Table 4.21: Total Time Spent at the Consultation Unit?

Total time spent at the consultation unit	Number	Percentage (%)
< 15 minutes	90	26.0864
25-50 minutes	25	7.2413
50 – 75 minutes	160	46.3768
75 -95 minutes	40	11.5942
> 95 minutes	30	8.6957
Total	345	100

90 (26.0864%) of patients spent less than 25 minutes at the consultation unit, 25 (7.2413%) spent between 25 -50 minutes, 160 (46.3768%) spent 55 -75 minutes, 40 (11.5942%) spent 75 -95 minutes and 30 (8.6957%) spent above 95 minutes.

Table 4.22: Total Time Spent by the Patient in the OPD?

Total time spent at OPD	Number	Percentage (%)
<30 minutes	45	13.0435
20 – 60 minutes	80	23.1984
1hr-1hr 30 minutes	110	31.8841
1hour 30 minutes – 2hour	95	27.5362
>2hours	15	4.3478
Total	345	

45 (13.0435%) of patients spent less than 30 minutes at the OPD, 80 (23.1984%) spent 30-60 minutes, 110 patients (32.8841%) spent 1hour 30 minutes, 95 (27.5362%) spent between 1hour 30 minutes – 2hours and 15 patients (4.3478%) spent above 2hours.

Table 4.23: Suggestions on how to Reduce Patients Wait Time?

Suggestions	Number	Percentage (%)
Doctors should come on time	105	30.4378
More nurses required at the consultation area	60	17.3913
FCFS rule should strictly be applied	100	28.9855
Proper sitting arrangement in the waiting area	40	11.5942
Total	345	100

From the responses it has observed that 104 patients (30.4378%) suggested that doctors resume on time, 60 (30.4378%) were of the opinion that more nurses are required at the consultation area of the OPD, 40 (11.5942%) were satisfied with the service, 100 (28.9855%) wants the FCFS rule strictly followed and 40 (11.5942%) recommended a modification in the sitting arrangement at the waiting area of the consultation unit so as to prevent jockeying.

In view of these suggestions by patients and also from the collected data analysed for the period of the study it has therefore established that waiting in line is a problem of concern at the female section of the OPD at Yusuf Dantsoho memorial hospital, as is the case in several other public hospitals in

the country. There is therefore a need to take steps to improve the queuing situation at the hospital. One such way is by application of queuing theory and modelling to rectify the queuing situation, as has been done in other places discussed in the literature review, a model of five scenarios of server capacity at the hospital applying the queuing theory to establish whether this can inform an optimal scenario setting that will reduce the queuing burden.

4.4 USING QUEUING MODEL (QM) FOR WINDOWS SOFTWARE TO MODEL CASES

Five cases of server capacity was considered, comparing capacity utilisation, average number in the queue, average number in the system, average waiting time in the queue and average time in the system by patients using Software: QM for Windows . Based on the input data below, sensitivity analysis was carried out and the results are presented in Table 4.48.

Table 4.24: Input Parameters for QM for Windows models

Parameter M/M/1 (exponential service times)	Value
Arrival rate (λ)	43 patients per hour
Service rate (μ)	15 patients per hour
Number of servers (doctors)	3, 4, 5, 6 and 7 depending on case

Table 4.25: Sensitivity Analysis of 5 Model cases

Cases	Avg. Service Utilisation	Expected number of patients in the queue (Lq)	Expected number of patients in the system (Ls)	Average time a patient spends in the queue (Wq) in minutes	Average time a patient spends in the system (Ws) in minutes
Case 1 (3 doctors)	0.96	19.72	22.59	27.60	31.80
Case 2 (4 doctors)	0.72	1.15	4.02	1.80	5.40
Case 3 (5 doctors)	0.57	0.27	3.14	0.60	4.20
Case 4 (6 doctors)	0.48	0.08	2.94	0.00	4.20
Case 5 (7 doctors)	0.41	0.02	2.89	0.00	4.20

SENSITIVITY ANALYSIS

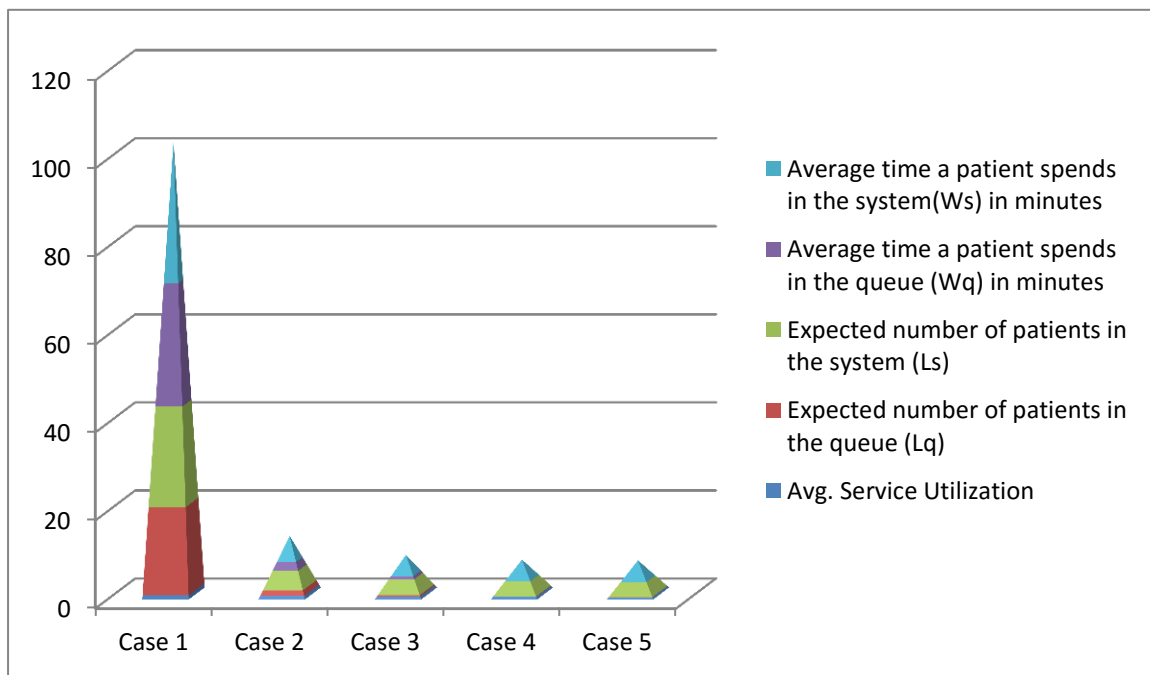


Fig 4.5 Graphical Plot of Results of Sensitivity Analysis

From the results of the sensitivity analysis for the modelling using QM software for windows, case 1 with an average three doctors working produced a less efficient performance in comparison to the others with expected number of patients in the queue (L_q) 19.72, expected number of patients in the system (L_s) 22.59, average time in queue (W_q) 27.60, and average time in the system (W_s) being 31.80. Case 3 (5 doctors) provides optimal performance of the system with expected number of patients in the system (L_s) being 3.14, average time a patient spends in queue (W_q) 0.60, average number of patient in the queue (L_q) 0.27 , and average time a patient spends in the system (W_s) being 4.20. The drop in time spent in the queue from 3 doctors (case 1) to 5 doctors at post (Case 3) is very significant. The average number in the queue (L_q) drops from 19.72 with 3 doctors to 0.27 with 5 doctors. Similarly, average time in the queue (W_q) drops from 27.60 to 0.60 respectively.

CHAPTER FIVE

SUMMARY, CONCLUSION and RECOMENDATION

5.1 Summary

This study seeks to prove queuing theory as a tool for optimising patient's flow and resources utilisation in the female section of the outpatient department of Yusuf Dantsoho Memorial hospital Kaduna as a case study. The study consists of five chapters. The first was the general introduction of the subject matter i.e general problem of the topic, research questions, aims and objectives scope and the limitations of the study. The second chapter presents the relevant literature review of the using queuing theory as a tool for optimising patients flow and resources utilization in the OPD of clinics. The third chapter dealt with the methodology of the research. The fourth chapter is the presentation of results and discussion; finally the last chapter highlighted the findings, implications and potential recommendations.

The study has established that at the OPD department (female section) of Yusuf Dantsoho memorial hospital has an average of 3 doctors working at a time, considering their effective working time. The average daily arrival rate is approximately 43 patients per hour and the service rate averages 15 patients per hour. Data analysed from questionnaires administered to patients determined that average waiting time before seeing a doctor of about 60% of patients to be between 1-2 hours which is in the same range with similar studies conducted within and outside the country (e.g. Bamgboye EO et al 1994, Dansky KH and

Miles J 1997 and Dos Santos LM et al 1994). Using the queuing model for windows software, five scenarios modelled (for 3, 4, 5, 6 and 7doctors), established that optimum system performance will be achieved with five doctors effectively working for the number of hours the study was conducted in contrast to the prevailing situation that has an average 3 doctors at post working for the same number of hours.

5.2 Conclusion

In conclusion, an attempt has been made through this study to optimise patients flow and resources utilisation at female section of the OPD in Yusuf Dantsoho Memorial hospital, Kaduna for a period of 5 days, Monday (23rd -05-2016) to Friday (27th -05-2016), has proven that queuing theory is a very useful tool for evaluating the performance parameters of the various sections of the OPD which allows for easy trade-offs between utilisation and wait time and allows for better decisions relating to staffing and potential waiting times for patients. The parameters computed in this project are mean arrival rate, mean service rate. The utilisation factor of the system and average time a patient spends in the system.

It was observed that patients had to wait longer than necessary at both sections of the OPD in Yusuf Dantsoho Memorial hospital especially on appointment day's i.e. Monday, Tuesday and Thursday. In general long queues were

observed over the period of the study which resulted in overcrowding and congestion in the hospital.

5.3 Recommendations

Based on the findings and conclusions drawn above, one may wish to offer the following, recommendations that will assist management of public hospital and specifically management of Yusuf Dantsoho memorial hospital optimise patients flow and reduce congestion in the OPD.

- (1) The hospital should put in place system such that 5 doctors effectively consult in the female section of the OPD during peak hours (6am to 12noon) for optimal performance instead of an average of 3 doctors which is presently the case.
- (2) Improving the efficiency of the servers at both sections of the OPD so as to reduce waiting and congestion as well as minimise patient's length of stay.
- (3) The priority rule (FCFS) should strictly be adhered to, as it was observed in the course of the study about 28.9855% complained that some hospital staffs ignored this rule, thereby impacting negatively on the performance of the system by increasing the average wait time of the patients which becomes a hindrance to the free flow of traffic in the OPD.
- (4) Health information management system should be introduced in the records section of the OPD this will go a long way in reducing the wait

time in the records by easing the retrieval of patient's information and subsequently leads to a decrease in the overall wait time of patients in the OPD.

In view of the these recommendations I believe if followed will go a long way in assisting hospital managers in effectively utilising resources (staffs) in other to reduce congestion experienced in the OPD of public hospitals.

REFERENCES

Adedayo A.O Ojo and Obamiro J.K (2006) Operatons Research in decision analysis and Production Management, Lagos Pumark Nigeria Limited.

Bamgboye EO, Erinoso HO, Ogunlesi AO. The waiting time at the children's emergency room, University College Hospital, Ibadan. Nig J Pediatr. 1994; 19:9–14.

Brewton, J.P 1989, Teller staffing models financial manager's statement July-August: 22-24

Bringandi, A.J, Dargon, D.R, Sheehan, M.J and Spencer 1994 AT AND T's call processing simulator (CAPS) operational design for inbound call centers interfaces, 24: 6-28

Brockmeyer, E., Halstrom, H.L and Jensen, A. 1948, The life and works of A.K Erlang, Transactions of the Danish academy of technical science 2.

Brusco, M.J., Jacobs, L.W., Bongiorno, R.J., Lyons, D.V. and Tang, B., 1995, Improving personnel scheduling at airline stations, Operations Research, 43: 741-751.

Chelst, K. and Barlach, Z., 1981, Multiple unit dispatches in emergency services, Management Science, 27: 1390-1409

Dansky KH, Miles J. Patient satisfaction with ambulatory healthcare services: Waiting time and filling time. Hosp Health Serv Adm. 1997;42:165–77. .

Dos Santos LM, Stewart G, Rosenberg NM. Pediatric emergency department walk-outs. Pediatric Emergency Care. 1994;10:76–8.

Green, L.V., Kolesar, P.J., Svoronos, A., 2001, Improving the SIPP approach for staffing service systems that have cyclic demands, Operations Research, 49: 549-564.

Gross D, and C.M Harris Fundamentals of queuing theory. New York: Witey 1997

Hiller, S.F and Lieberman, J.G (2005) Introduction to operations research, Boston: McGraw Hill Seventh Edition.

Holloran, T. J. and Byrne, J.E., 1986, United Airlines station manpower planning system, Interfaces, 16: 39-50.

. Huang XM. Patient attitude towards waiting in an outpatient clinic and its applications. Health Serv Manage Res. 1994;7:2–8.

k. Katz, B.M. Larson and R.C Larson “Prescription of waiting line blues” Sloan management review, winter 1991

Kurata J, Nogawa A, Philips D, Hoffman S, Werblum M (1992). Patient and Provider satisfaction with medical care. J. Fam. Prac., 35: 176179. Labonte

Kleinrock, I and R, Gail Queuing systems: problems and solutions New York: Wiley, 1996

Krasjewski, L.J and Ritzman, L. (1998) Operations management: Strategy and analysis, New York: Addison Wesley Longman publishers 5th Edition

Mackey TA, Cole FL (1997). Patient Waiting Time in Nursing Managed Clinic. The Int. J. Adv. Nur. Practice, 1 p. 1.

Nilesh Sheath and Dr. Prashant Makwanna Application of Queuing Model on Hospital OPD. IJSRD - International Journal for Scientific Research & Development| Vol. 3, Issue 11, 2016 | ISSN (online): 2321-0613

O’,Malley MS, Fletcher SW, Fletcher RH, Earp JA. Measuring patient waiting time in a practice setting: A comparison of methods. J Ambul Care Manage. 1983; 6:20–7.

Obamiro, J. (2003). Application of Queing Model in Determining the Optimum number of Service Facility in Nigerian Hospitals, M Sc. Project submitted to Department of Business Administration, University of Ilorin.

Ofilli AN, Ofowve CE. Patient's assessment of efficiency of services at a teaching hospital in a developing country. *Ann Afr Med*. 2005; 4:150–3.

Singh H, Haqq ED, Mustapha N. Patients' perception and satisfaction with health care professionals at primary care facilities in Trinidad and Tobago. *Bull World Health Organ*. 1999; 77:356–60.

Singh, V. (2006). Use of Queuing Models in Health Care Decision Analysis. Department of Health Policy and Management, University of Arkansas for Medical Science

Smith, D. and Mayhew, I. (2008) using queuing theory to analyze Government completion time target in accident and emergency department, *Healthcare management science II*: 11-21

Stern, H.I. and Hersh, M., 1980, Scheduling aircraft cleaning crews, *Transportation Science*, 14: 277-291.

Taylor, P.E. and Huxley, S.J., 1989, a break from tradition for the San Francisco police: patrol officer scheduling using an optimization-based decision support system, *Interfaces*, 19: 4-24.

Torres, J.E and Guo K.L (2004): Quality improvement techniques to improve patient satisfaction. *International journal of health care quality assurance* 17(6) 334 - 338

Umar I., Oche M. O.* and Umar A. S, *Journal of Public Health and Epidemiology* Vol. 3(2), pp. 78-82, February 2011 Available online at

APPENDIX

QUESTIONNAIRE

Dear Respondents,

I am **MOHAMMED USMAN KANDI** a master's student of engineering management, department of Mechanical Engineering Ahmadu Bello University Zaria, Kaduna State Nigeria, as part of my curriculum; I am to undertake a research on the project topic “**OPTIMIZING PATIENTS FLOW AND RESOURCE UTILIZATION IN OUT-PATIENT DEPARTMENT (OPD) A CASE STUDY OF YUSUF DANSTOHO MEMORIAL HOSPITAL KADUNA FEMALE SECTION**”. To assist in carrying out the study I request for your fair views, insight and perspective which are important for my research work.

Policy on confidentiality: Respondents should feel free to give honest responses, as the confidentiality of the information provided by the respondent is completely assured.

Name:

Age:

Sex:

Address:

Occupation

PATIENTS

(1) Time of arrival at the out-patient department?

(2) Time spent at the records section?

- (a) >15 min
- (b) 15-30 min
- (c) 20-30 min
- (d) >30 min

(3) Time spent with the doctor?

- (a) < 10 min
- (b) 10-20 min
- (c) 20-30 min
- (d) 30-40 min
- (e) > 40 min

(4) Total time spent in the OPD?

- (a) < 30 min
- (b) 30-60 min
- (c) 1-1hr 30 min
- (d) 1hr 30min-2hrs
- (e) > 2 hrs.

(5) Does the OPD start on time?

- (a) Yes
- (b) No

(8) Patients view on time spent on the queue before seeing the doctor?

- (a) Time is long

- (b) Time is short
- (c) Ok with time spent
- (d) Can't say

(9) Patients behaviour in the queue?

- (a) Wait for turn
- (b) Jump queue
- (c) Join and then leave the queue
- (d) Patients not seen on FCFS basis
- (e) Other lapses

(10) Suggestions from patients on how to reduce waiting time?

- (a) Doctors should come on time
- (b) More doctors required
- (c) FCFS should strictly be applied
- (d) Waiting area should have proper sitting arrangement
- (e) Satisfied with service