Healthcare Service Improvement at a Government Managed Clinic

By

Kamogelo Puoane
26413982

Study Leader:
Landi van Deventer

Submitted in partial fulfillment of the requirements for
The degree of

BACHELORS OF INDUSTRIAL ENGINEERING

In the

FACULTY OF ENGINEERING, BUILT ENVIRONMENT
AND INFORMATION TECHNOLOGY

UNIVERSITY OF PRETORIA

October 2010

Universiteit van Pretoria
University of Pretoria

EXECUTIVE SUMMARY

This project proposal is focused on the topic for the improvement of the healthcare service at a government managed clinic in Olifantsfontein under management Ekurhuleni Metropolitan Council. It is centrally situated in Olifantsfontein for easy access of the community.

Currently the service turnaround time is so long that some patients have to go back home without being attended to and on the surface its indicative of primarily the shortage of resources. As one looks deeper into the situation it actually reveals other additional aspects like deficiencies in the operational processes and the inefficiency of staff members that cause such extreme delays with the service delivery and inevitably the quality of healthcare service gets compromised.

The report suggests improving the identified problem by using industrial engineering techniques and methodologies such as application of the queuing theory; process analysis; quality assurance; and facility planning.

As the industrial engineering techniques have been applied to the problem, conclusions about the clinics system could be drawn. To name a few: resources are poorly utilised, the current system design can accommodate the service demand; and staff management crops up as the main source of poor service delivery.

Recommendations made are those to improve system components such as the facility layout, the operation processes, and better utilization of available resources for the queuing model. Ad hoc industrial engineering tool, System of Profound Knowledge, was recommended to improve the system holistically.

Table of content

List of Figures

List of Tables

Chapter 1: Project Proposal

1. Introduction and Background

Olifantsfontein community clinic is managed by Ekurhuleni Metropolitan Municipality. Ekurhuleni is one of six metropolitans in South Africa. Over the years Ekurhuleni, then known as the east rand, attracted many low and semi skilled job seekers. This is due to the fact that the east rand is historically known as the heartland of manufacturing of South Africa and the sector's employment has grown, particularly recently between 1996 and 2001.

Majority if not all the job seekers ended up residing in informal settlements. Since these people receive low income, if any at all, medical services are a luxury to them. To solve the problem local government provides communities with hospitals and clinics for all people to have access to medical care. The people who cannot afford to use private medical services use those facilities provided by the government.

Olifantsfontein clinic is one of the many healthcare facilities provided by the local government. It caters for communities in and around Olifantsfontein such as Ivory Park and Tembisa. The clinic deals with primary health services such as: immunization, family planning, tuberculosis, sexually transmitted diseases, and mental health. The services are offered Monday to Friday during office hours, which is from 08h00 to 17h00, at no cost to the outpatients. If the outpatients require advanced medical attention they are referred to Tembisa Hospital.

The development of local clinics has also mitigated the overcrowding of hospitals. Previously the local clinics were designed to render preventative, promotional, and rehabilitative care. Currently clinics are decentralized and they offer curative services at level one.

2. Problem Statement

Patients using the government clinics receive substandard healthcare services compared to private clinics. Aggravating queues and long waiting times are experienced by the patients and the resources at the clinics are not fully utilized. The appropriate attitude of the staff towards the patients requires major improvement.

3. Research Questions

The following research questions were asked:

- Why it is that only patients who arrive early morning receive medical service?

- What factors contribute to the unnecessarily long queuing times?
- Can the attitude towards patients by the staff improve if the pressure on the staff is alleviated?
- What are the suggestions for improving healthcare service at governmental clinics?

4. Project Aim

The aim of the project is to integrate both system components and subsystems to function at the highest level of optimization. Since the system is complex the highest optimization will be a local optimization and not global optimization meaning not everything can made to run optimally for the system to run optimally..

4.1. Objectives:

- To investigate and illustrate the perception of stakeholders in regards to the functioning of the clinic;
- To explore the system process and why they are performed in that manner
- To identify limitations in the optimal functioning of the clinic;
- And to formulate strategies that when implemented cause the clinic to run efficiently.

5. Project Scope

The project covers the daily activities of the clinic that are directly linked with a customer/patient entering into the system. That takes account of the queuing; administration of the patient; resources used on the patients; the flow of the patient within the system; and the facility layout.
The project excludes any costs incurred in the operating of the clinic but rather focused on improving the service to the patients who have no option but to utilize the healthcare provided by the government.

6. Project Deliverables

6.1. Process analysis that will create an opportunity to realize the system glitches that can be fixed or improved;
6.2. A new facility layout plan that will improve the accommodation of the patient's psychological and physical needs and expectations.
6.3. Evaluation and reconstruction of the queuing methods that will potentially improve the overall system
6.4. Finally an improved health care system made available to the community.

7. Project Limitations

The medical industry works with strict rules and sensitive information. This limits the scope of the project in that some information cannot be accessible for research purposes. Another limitation is time. There's inadequate time for proper data collection and perfect model formulation and improvement thereof.

8. Project Plan

8.1. Research Method

8.1.1. Data collection will be done, using time study to collect data such as:

- the number of patients entering the system at any given time;
- the duration that patients wait before they are serviced;
- the number un-serviced patients;
- the workflow of the medical staff;
- And administration of patients.

8.1.2. Data manipulation will be performed using industrial engineering techniques that will allow for the presentation of the data into insightful information. These techniques include:

8.1.2.1. Process Analysis:

- Processes flowcharting;
- Investigate different stages in a process and determine what effect they have on the process as a whole.
- Study processes in detail..

8.1.2.2. Facility Layout

- Revise the current facility layout;

8.1.2.3. Queuing

- After the study of customer arrivals, distribution of arrivals, queuing system factors, and exiting the queuing system a better queuing system can be formulated

8.2. Project Budget

An estimated R1250 will be required to accomplish the project successfully.

Table 1 Project Budget

Expenses	Amount
Travelling	R 500-00
Research	R 500-00
Printing	R 50-00
Stationary	R 50-00
Telephone	R 100-00

Total	R 1250-00

8.3. Project resources

The following resources will be required in order to complete the project successfully:

- Co-operation from the clinic staff members
- Access to project leader
- Internet
- Stationery
- Money
- Assistance from people to perform time study
- Car
- Laptop
- Electricity

9. Conclusion

The improvement of one clinic will mean the improvement of all the other clinics. The research will open doors to a good healthcare service no matter what socio-economic standards of the people using the service all persons have the right to basic healthcare and just because the people cannot afford a medical aid does not justify the substandard service that they receive.

Chapter 2: Literature Study

1. Purpose of Literature Study

Literature review is the summary of reports of primary or original scholarship of a chosen field of study where the reports are evaluated, clarified, and/or integrated. The literature review on itself does not report new findings. Types of scholarships available could be methodological, empirical, theoretical, or analytical.

When one conducts a project one of the first critical steps is to perform a literature study where information from various sources is gathered regarding the topic at hand. These sources include the library, internet, discussions/interviews, and observations. The analysis of the information guides the researcher about what has already been done, how it has been done; and what errors have been made. This knowledge allows for the researcher to have a starting point with the project and to have an idea for a solution to the proposed problem.

When the researcher conducts a literature study besides attaining insight on the topic the aim is to find a similar problems as the one at hand and investigate how it's been solved. Errors that are picked up from the reports will assist the researcher in what has to be avoided when formulating a solution for problem. In this way the avoidance of pitfalls will save both time and effort

2. Research Methods

During clinic visitations it has been obvious that there exists a problem with the system processes because of extensive waiting times of the patients in the clinic. Hence it was identified that the application of operations research is ideal. In exact queuing theory is ideal for the problem statement. Hence a literature study on queuing theory is conducted through resources such as the library, internet, and interviews.

3. Literature On Queuing System

3.1. Introduction to Queuing Theory

A.K. Erlang was the first to observe, in the environment of telephones facilities, waiting lines or queuing theory. Further development on Erlang's observations formed the "Queuing Theory." Queuing theory falls under the purview of decision science. It is extensively used in industrial setting and service industry under operations research.

3.2. Basic Principles of Queuing System

When creating a queuing model the first step to take is describe the "input process" and the "output process". A brief description of the both processes can be seen in figure 1.

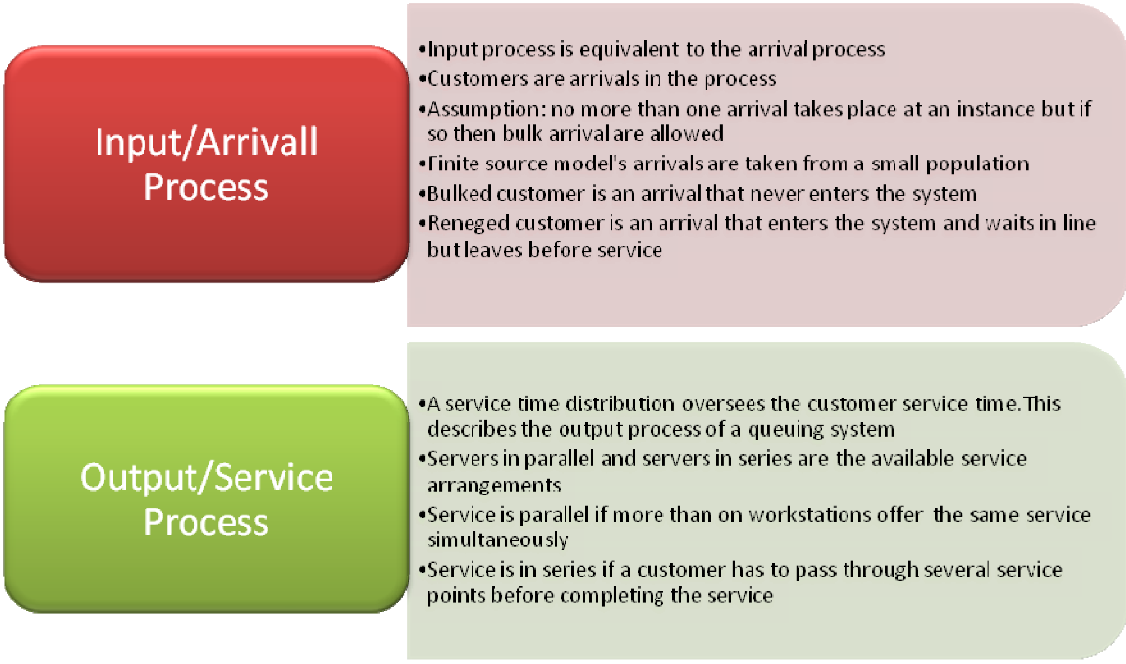


Figure 1 Arrival Process and Service Process

An important fact to mention is that the queuing model uses averages. "It takes the average of the random numbers of patients arriving randomly, of the same service times, arrival interval, etc."Singh V (2006)

3.3. Characteristics of Queuing System

The characteristics of queuing theory are summarized in the diagrams below:

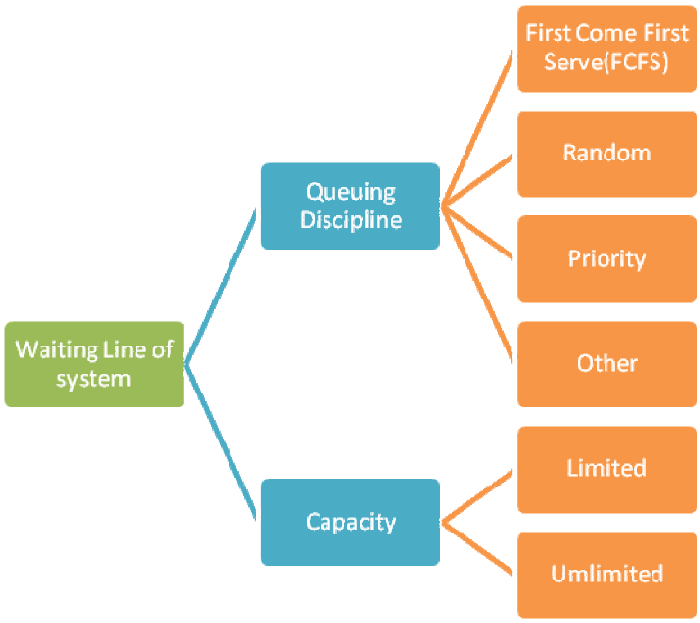


Figure 2 Waiting Line Characteristics

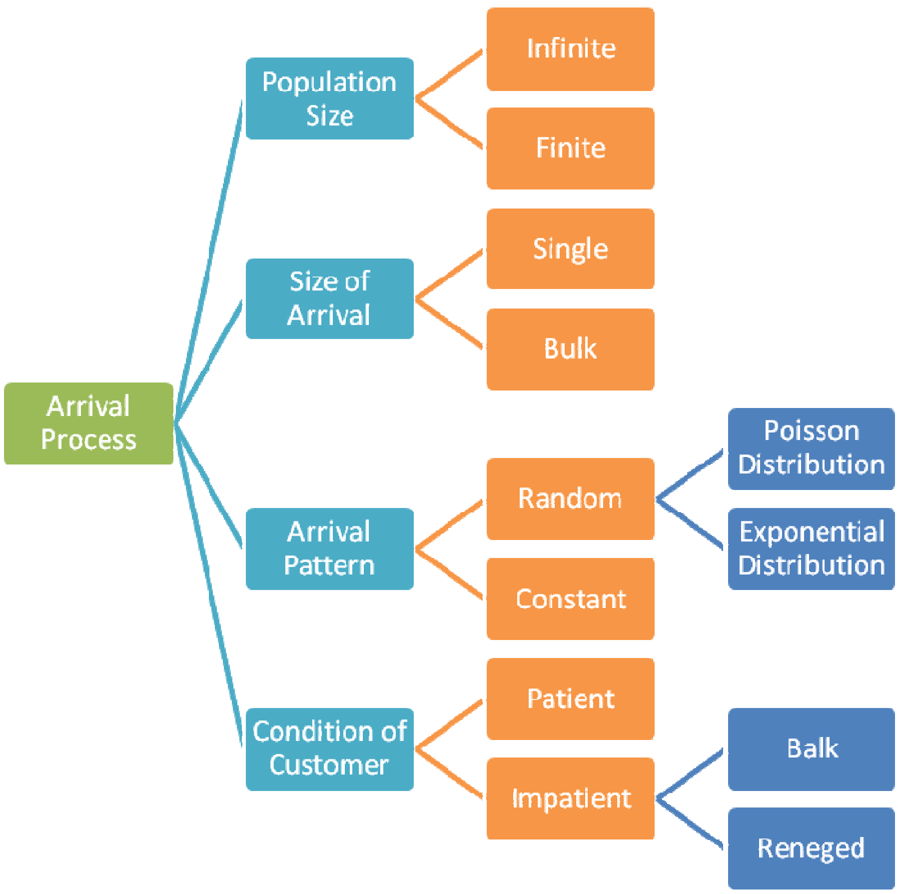


Figure 3 Arrival Process Characteristics

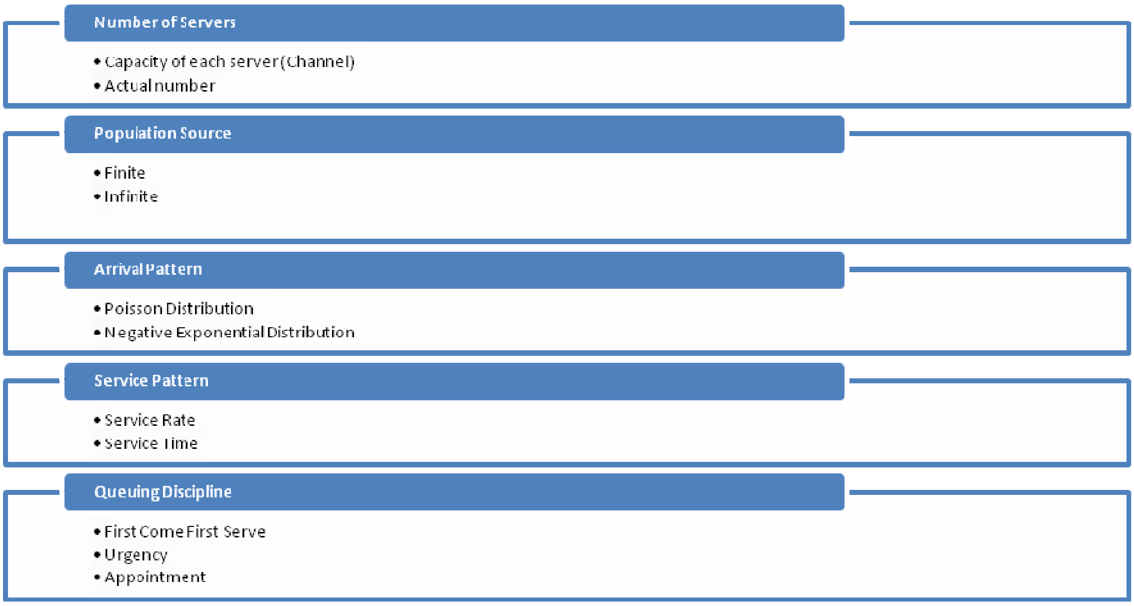


Figure 4 Queuing System Characteristics

3.4. Queuing System Notations

A few notations are used in queuing theory equations. Notations are enumerated in table 2.

Table 2 Notations for Queuing Theory Equations

Notation	Description
λ	Arrival Rate
μ	Service Rate
Lq	Average number of customers waiting for service
L	Average number of customers in the system (waiting or being served)
Wq	Average time customers wait in line
W	Average time customers spend in the system
ρ	System Utilization
1/μ	Service Time
Po	Probability of zero units in the system
Pn	Probability of n units in the system

Source: Singh, V., Use of Queuing Models in Health Care

In addition when describing a queuing system a certain notation is used. That is 1/2/3/4/5 where: 1 describes the arrival distribution; 2 describe the service distribution; 3 describe the number of servers; 4 describe the system capacity; and lastly 5 describe the queuing discipline.

3.5. Types of Queuing Systems

Four basic line structures that a queuing system can be are described below. These include single channel-single phase; single channel-multiphase; multichannel- single phase and; multichannel-multiphase.

Single channel, single phase. This is when there exists a single queue. The customers in the queue wait for the service offered by a single server. A one-person barbershop is an example of a single channel-single phase

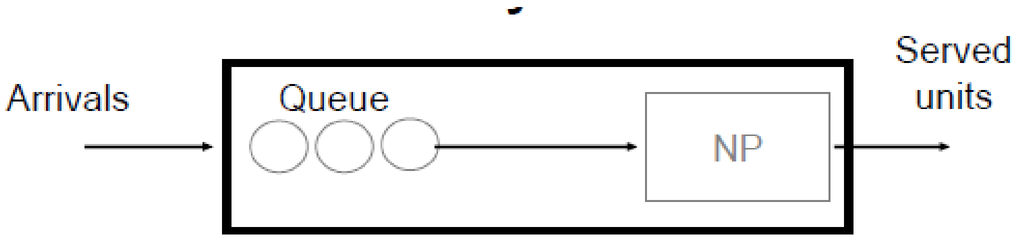


Figure 5: Single channel-Single phase

Single channel, multiple phases. This is when there exists a single queue. The customers in the queue wait for services that are in phases. An example of a single channel-multiple phase is a car wash. A customer waits in line to wash a car. The car is washed then the next queue is entered to vacuum the car and so on it goes.

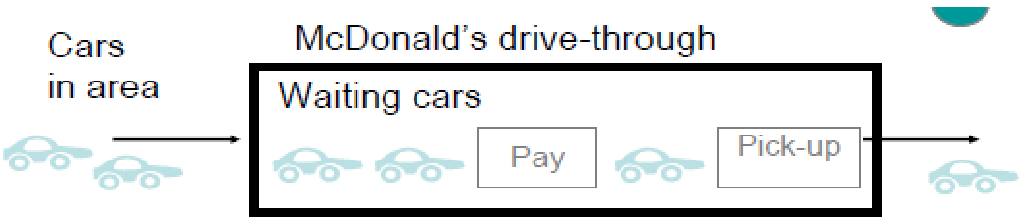


Figure 6 : Single channel, multiple phases

Multichannel, single phase. This is when multiple queues can be formed by customers and the same service is offered at a few stations. Line shifting is allowed. Paying for groceries at a super market is an example of a multichannel-single phase.

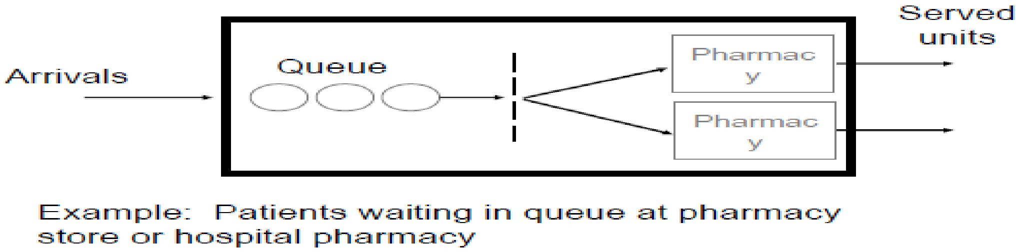


Figure 7 : Multichannel, single phase

Multichannel, multiphase. This is when there are multiple queues and a complicated network of services given simultaneously. An example of this line structure can be found at hospitals where many queues for various services exist but service is attained at a sequence of steps. At the hospital first the patient has an admission at the clerk's desk; forms are filled; identification tag is collected; room is assigned; etc

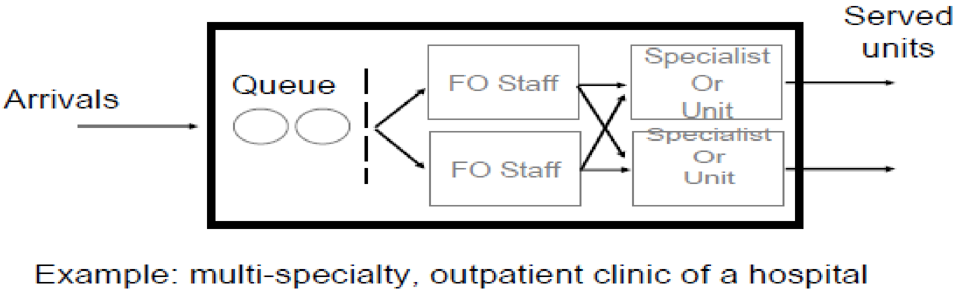


Figure 8 : Multichannel, Multiphase

3.6. Measures of Performance of a Queuing System

Queuing system measures the performance of a system through:

- Average waiting time;
- Average number of customers in the system;
- Capacity utilization;
- Cost of service provision;
- Probability of customer arriving and waiting.

This measure will allow for model adjustments to reach targeted operating levels.

3.7. Limitations of Queuing Theory

Enumerated below are some of the limitations of queuing theory:

- Assumption that the system is in a steady state;
- Service rate of the system is known;
- The service rate has to be greater than the arrival rate;
- Based on the averages of variables;
- The service time are not dependant on one another;
- Service times follow a negative exponential distribution; and
- First come first serve queuing discipline.

3.8. Design of Queuing Model

A typical queuing system problem is enumerated below.

Problem

American Vending Inc. (AVI) supplies vended food to a large university. Because students often kick the machines out of anger and frustration, management has constant repair problem. The machines breakdown on average of three per hour, and the breakdowns are distributed in a poison manner. Downtown costs the company 25 dollars per hour per machine, and each maintenance worker gets 4 dollars per hour. On worker can service machines at an average of five per hour, distributed exponentially, two workers working together can service 7 per hour, distributed exponentially, and a team of three workers can do eight per hour, distributed exponentially.

What is the optimal maintenance crew size for servicing the machines?

Solution

Case 1-One worker

$\lambda = 3 \text{ per hour}$

$\mu = 5 \text{ per hour}$

There are an average number of machines in the system of

$$Ls = \frac{\lambda}{\mu - \lambda} = \frac{3}{5-3} = 1\frac{1}{2}$$

machines

Downtime cost is $25× 1.5=$37.50 per hour, repair cost is $4.00 per hour; and total cost per hour for 1 worker is $37.50+ $4.00= $41.50

Downtime (1.5 × $25) = $37.50

Labor (1 worker × $4.00) = $ 4.00

$ 41.50

Case2-two workers

$\lambda = 3, \mu = 7$

$$Ls = \frac{\lambda}{\mu - \lambda} = \frac{3}{7-3} = 0.75 \text{ machines}$$

Downtime (0.75 × $25) = $18.75

Labor (2workers × \$4.00) = \$ 8.00

\$ 26.75

Case 3-three workers

$\lambda = 3, \mu = 8$

$$Ls = \frac{\lambda}{\mu - \lambda} = \frac{3}{8-3} = 0.6\ machines$$

Downtime (0.6 × \$25) = \$15.00

Labor (3workers × \$4.00) = \$12.00

\$ 27.00

Comparing the costs for one, two, or three workers, we see that case 2 with two workers is the optimal decision

Source: Jacobs, F.R.,Chase, R.B.,Aquilano, N.J.,Operations & Supply Management

3.9. Conclusion

Queuing models facilitate the determination of capacity levels needed to act in response to demands in a timely fashion.

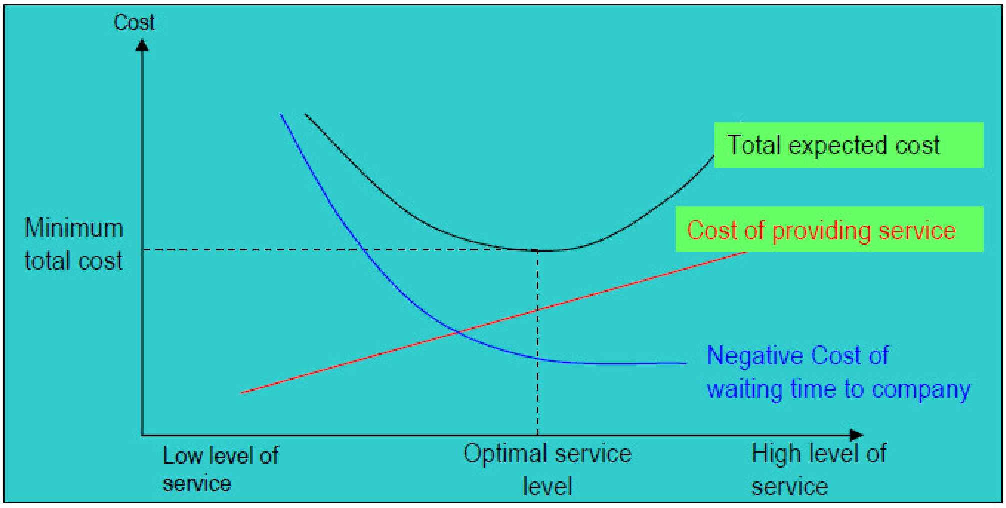
4. Literature on Queuing Models in Healthcare

4.1. Introduction

It is only recently that operations research is utilized in the healthcare industry. As mentioned above queuing theory is used extensively in the service industry and industrial setting. On the other hand the use of queuing theory in the healthcare industry is relatively small. This is mainly due to the unique key attributes that the healthcare industry presents which makes it complex to solve queuing problems.

4.2. Why Use Queuing System

There are two interlinked reasons why queuing theory should be used. Firstly it matches the demand for service and supply of available capacity. Secondly it minimizes the total cost of the system. The system has two types of cost: capacity cost (the cost of providing the service) and customers waiting in line costs. Figure 2 shows a graph of what queuing modeling does to a system. Analyzing the graph, if there is an increase in service provision then the capacity costs increases. Alternatively: if the service capacity is limited then the waiting costs increase. The whole aim of queuing theory is to a strike a balance between the two costs.



Source: Yasar A. Ozcan, Quantitative Methods in Health Care Management

Figure 9 : Cost Comparison

4.3. Limiting Healthcare Key Features

There are two key features which make the healthcare area particularly challenging to solve using the queuing theory and they are pooled capacity and performance measurement.

Internal delay and external delay are the key points of performance measurement. Internal delay refers to the time a patient is in the clinic before they are serviced. External delay refers to the occurrence of a waiting list. In manufacturing systems unexpected results can be absorbed by finished goods inventory or in the service industry time buffers and capacity buffers are available. Another performance measurement is utilization level of resources. Government and other institutional agents prefer average utilization levels of resources as a performance measurement. This also implies that higher utilization levels would be ideal but this also means an increase in delays. The consequence is a conflict of objectives to decrease delay or utilize resources to a maximum.

Pooling capacity refers to the occurrence of sharing among a variety of demands the available resource capacity. In a retail store for example when a product is finished on the shelf stock can be taken from the available inventory. In contrast in healthcare pooling is absent. Specific patient types are dedicated resources. One department in the hospital cannot use the beds from another department. There is no flexibility with resources.

Other distinctive features of healthcare system that causes difficulty to form queuing models:

- Capacity related issues,
- Modeling of interruptions, disturbances and absences,
- Re-entry of patients and stochastic routing, and
- Service session and for consultation and surgery.

4.4. Application of Queuing Theory in Healthcare

4.4.1. Emergency Room Arrival

Generally the emergency room(ER) is where queuing theory is used the most. Long waiting times in the ER have raised a need for a better facilitating healthcare service in the ER. To attend to the problem the arrival pattern of patient's needs assessment and from the results the suitable facilities and staffing decisions can be made.

4.4.2. Outpatient Clinics/Surgeries in Hospital

Analysis of the patient arrival flow; the arrangement of the system; manpower distinctiveness; and the scheduling structure are essential for the application of queuing model. The model improves some features that include the decline of patients in the system; a boost in customer service; a decline in operating cost; and better use of available resources. Modeling in this scenario is complex and significantly demanding to administer.

4.4.3. Hospital Pharmacy and pharmacy stores

Queuing theory application is generally few in pharmacy. Big systems with considerable case loads usually use Automated Queuing Technology (AQT). As with some big hospitals, they use AQT system. Pharmacy stores use queuing theory which asses' factors such as prescription fill time; patient counseling time; patient waiting time; and staffing levels. Application is useful in pharmacies with significant outpatient workload and/or pharmacies that provide many points of service.

4.4.4. Inventory Control

The application of queuing theory in pharmacy is similar as in inventory control. Aspects of inventory such as the consumption trend of supplies, it peculiarities, etc are incorporated to the ordering system. Since some inventory control models are based on similar principles as queuing theory, their application are sometimes thought of as a variation of queuing theory.

4.4.5. Healthcare Disaster Management

Queuing models are used together with simulation models to create a what-if analysis. The analysis allows for the planning, organization, and preparation for disasters at which immediate medical services are required.

4.4.6. Public Health

In the case of public health the application of queuing theory can help determine facility and resource planning. This allow for the smooth running of the system.

5. Conclusion

Generally the healthcare systems are different intrinsically from manufacturing systems. In the healthcare system demand for resources is significantly unscheduled and the resulting effect is a lasting mismatch between demand for healthcare service and available capacity. The choice to use queuing model will match demand and supply of a system. Utilizing queuing system analysis can at best improve medical performance, patient satisfaction, and cost efficiency of healthcare

Chapter 3: Solution Approach

1. Identify Queuing System Requirements

Modeling both the arrival and service process ; determining the type of queuing discipline; identifying the service capacity and the number of system servers is information required to proceed with queuing model . All the gathered information will equip in formulating the queuing notation.

1. Modeling Arrival Process and Service process
   The arrival process is determined through the monitoring of the arrival of patients into the clinic. An excel sheet would be used to analyze the data. For queuing theory it is assumed that no more than one arrival can take occur at a time, *t*. where t_i is the time at which patient *i* enters the system. The data collected, t_i's must form a Poisson distribution graph according to the assumptions of queuing theory. Poisson distribution can be recognized by a mean and variance that share the same value. Below is an example of a Poisson distribution graph.

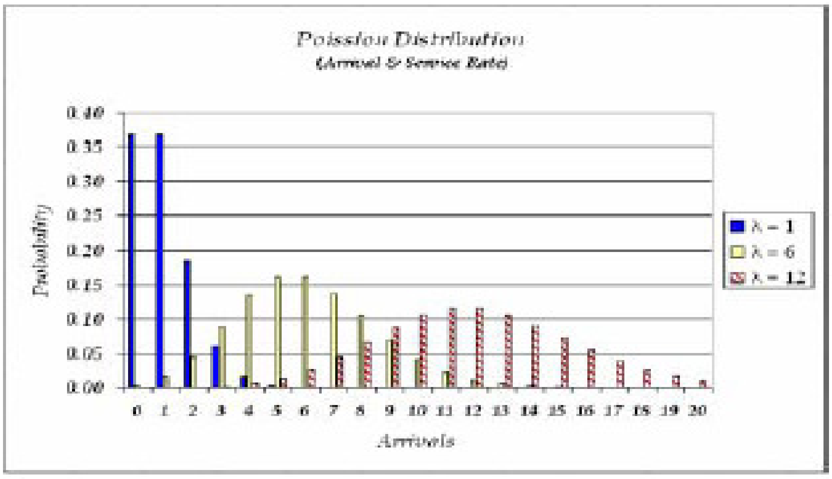


Figure 10 Example of Poisson distribution

Another assumption of queuing theory is that the inter-arrival time,

$$T_i = t_{i+1} - t_i \text{ where } i > 0$$

must follow an exponential distribution. Inter-arrival time is the time between two arrivals. Ideally if the arrival follows a Poisson distribution then the inter-arrival times will form an exponential distribution

Service arrival is determined in a similar way as the arrival process. The difference is the type of data collected which are the service times. Enumerated below is a display of the exponential distribution.

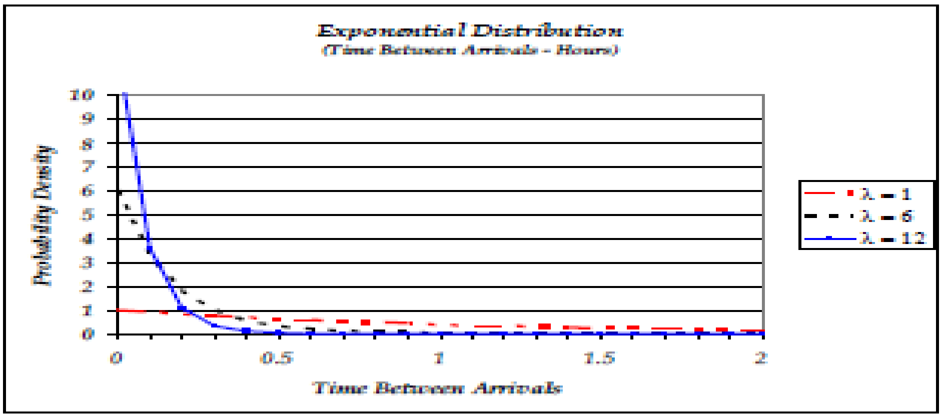


Figure 11 Example of exponential Distribution

2. Identifying the system servers
   The number of service points in each phase need to be identified. This can be done by observation and through interviews with the clinic staff members

3. Identifying system capacity
   System capacity refers to the amount of arrivals that the system can facilitate. It can be observed to be infinite or finite. Information can be accessed through interview with the relevant staff members.

4. Identify queue discipline
   The system has to be analyzed for the number of queues available and for what service they are available for. In addition the number of phases in the system should be recognized.

2. Identify Existing Procedures

A study performed by researchers at the Sloan School of Management (MIT) will be illustrated below. It's a real life situation at the MIT University Health Service(UHS). The problem statement included the naming of the description of the process flow;

make use of the queuing model to examine the utilization and waiting of staffing; develop staffing model recommendations; and sources variability.

1. The first step the researchers took was to understand the flow process. Figure 12 is the process flow diagram for UHS.
2. Second step was the identification of sources of variability. Enumerated in figure 13 is a list of sources of variation in the healthcare system.
3. What follows is the study of patient arrival rates for healthcare service. The peak hour arrival rate is detached from the normal arrival rate for accurate calculations.

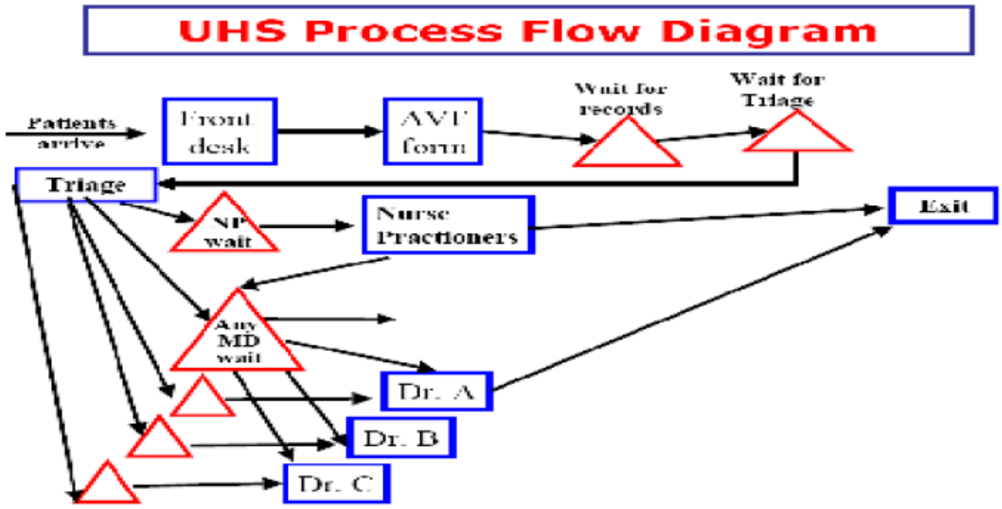


Figure 12 : Process Flow Diagram of UHS

sources of variability

Patients arrival rates by hour, day, week and season.
- Number of MD's on duty - by time of day, day of week.
- Number of NP's on duty - by time of day, day of week.
- MD service rates by Doctor and patient ailment
- NP service rate by nurse and patient ailment.
- Triage service rate.
- Triage coordinator allocation to MD - NPs.

Others
- # of patients wanting to see a special NP or MD,
- by hour, day, week.
- Speed of filling out AVF forms.

Figure 13 : List of UHS Sources of Variability

Patient Arrival Rates

The clinic is opened to patients from 8:00AM to 5:30PM, a total of 9.5 hrs. Staff are asked to stay until 6:00 PM, So the clinic serves patients 10 hours per day. For simplification, we will assume that patients arrive over the 10 hrs.

Patient average arrival rate =
λ =(143 pat/day)/10 hrs/day = 14.3 pat/hr

8 - 9:00 AM on Monday mornings is a peak hour.

Patient peak arrival rate = λ =
14.3 [average rate] X (163/143)[the Monday factor]
X (18.2/14.3)[the 8-9 AM factor] = 20.7 patients/hr

Figure 14 : Patient Arrival Rate at UHS

4. The forth step the researchers took was to identify the systems assumptions. These assumptions are:
    - Exponentially distributed service times and Poisson distributed arrival times
    - Constant number of system servers
    - FIFO service
    - Single queue to medical practitioner
    - Infinite queuing capacity
    - No special priority requests and/or emergencies

5. Depicted below are the arrival rates of the two different servers of the system. The percentages refer to the percentage that an arrival is sent to a particular server.

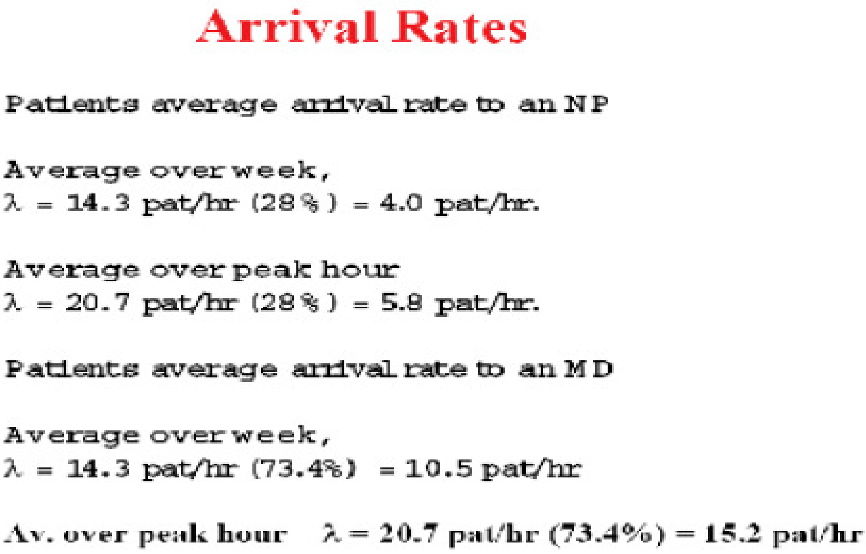


Figure 15: Arrival Rate Input

6. The information referring to the system servers is described below.
   Weekly
   Average number of nurse practitioners = 3.15
   Average number of medical doctors = 2.9
   Monday peak hour
   Average number of nurse practitioners = 2
   Average number of medical doctors = 2

7. The findings of the research are listed below.

   Nurse practitioner calculations-average for the week

   M = 0.57 hrs/patient

   S = 3.15

   $\lambda = 4\frac{patients}{hr}$

   $\rho = {\lambda M}/{S} = {4\,(0.547)}/{3.15} = 0.695$

   L = 1.15 (Calculated in the researchers report)

   $W = L\lambda = {1.15}/{4} = 0.29hrs = 17min$

   Nurse practitioner calculations-average for the peak hour

   M = 0.54 hrs/patient

   S = 2

   $\lambda = \frac{5.8patients}{hr}$

$\rho = {}^{\lambda M}/_{S} = {}^{5.8\,(0.547)}/_{2} = 1.58$

Similar calculations are computed for the medical practitioner.

3. IDENTIFY ADDITIONAL PROCEDURES

Additional industrial engineering tools and techniques that are necessary for obtaining a solution are discussed below. This paper focuses on queuing theory and the topics listed below will compliment the modeling thereof

Figure 16 Industrial Engineering Tools and Techniques

3.1. FACILITY LAYOUT

The current layout of the facility will be obtained through observations and interviews with staff members. Muther's Systematic Layout Planning (SLP) will be used as a tool to formulate a better facility layout. Figure 10 enumerates the steps followed when using the SLP.

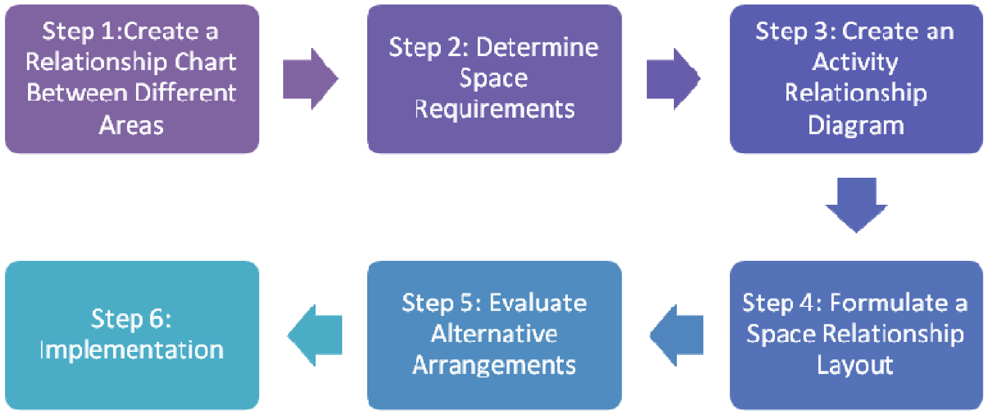


Figure 17 Muther's Systematic Layout Planning Steps

3.2. PROCESS ANALYSIS

To better understand the process a process flow chart and a flow diagram can be drawn up. These diagrams offer a visual representation of process steps. Moreover these charts will help to identify the queuing discipline of the system.

3.3. EXTRA INDUSTRIAL ENGINEERING TECHNIQUES

As the project commences it might become necessary to use other industrial engineering techniques to complete the project successfully. This also gives the advantage of not being limited in regards to alternative solutions to the identified problem.

4. CONCLUSION

The UHS example can be altered to suit the problem environment of the project at question. The example illustrates the application of queuing theory to a healthcare problem. Supplementing queuing theory will be other industrial engineering tool and techniques. The purpose of the supplements is to improve the actual process flow and thereafter model a queuing system for the clinic. Consequently the queuing model will be based on an optimal running process flow.

Chapter 4: Data and Information gathering

1. Process

The clinic has many patients who enter the system for various reasons like for HIV testing and to refill their prescription. These patients will not all follow the same steps in the clinic. The focus of the project will be on the majority of patients who enter the clinic and will be consulting a nurse. Figure 15 shows a generic diagram of the service process, the steps that are observed in project. Shown in figures 16-19 are the flow charts of the process stages in detail.

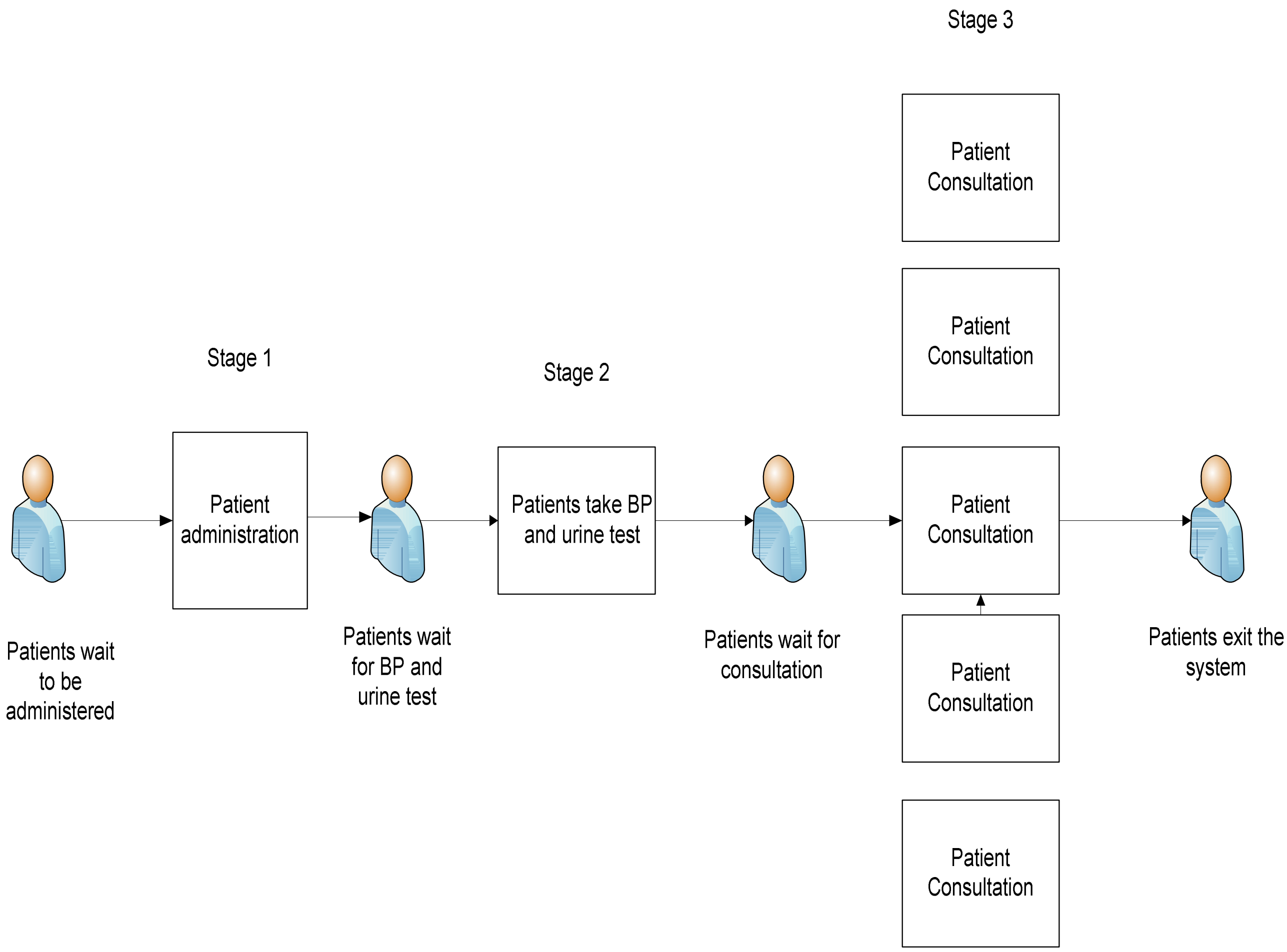


Figure 15 : Service Process

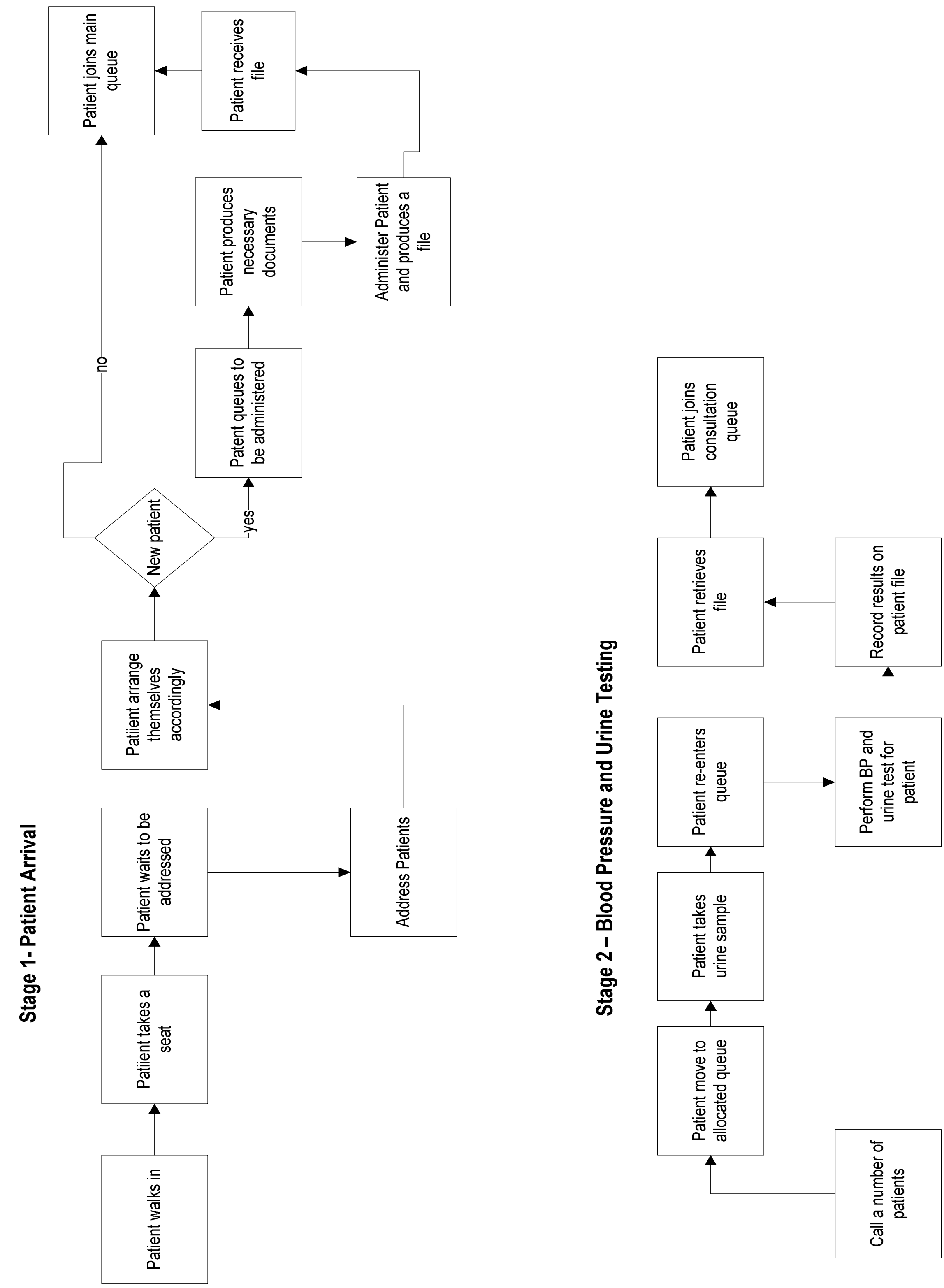


Figure 16 : Stage 1 and Stage 2 Processes

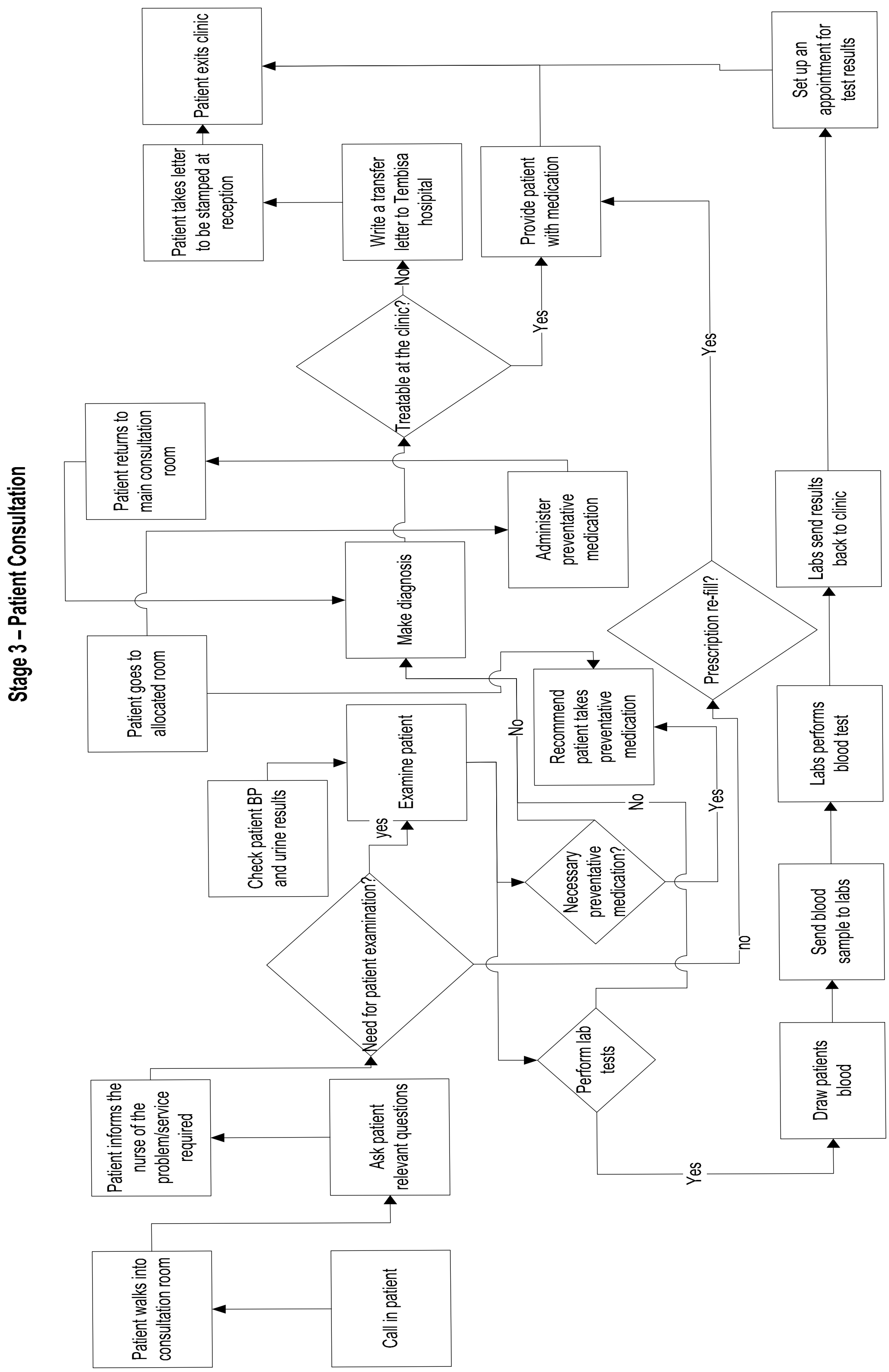


Figure 17 : Stage 3 Process

2. Queuing

Data on the patient arrival rate; the services rate; system servers; and system capacity was gathered manually through time studies and through observation.

2.1. Arrival rate distribution

The arrival rate of the patients into the clinic follows a poison distribution with the inter arrival times following an exponential distribution. It is assumed that since the arrival of patients into the clinic follows a Poisson distribution then all queues in the system will follow suit. The arrival times can be found in Appendix C. Enumerated in figure 17 is the exponentially distributed inter arrival times.

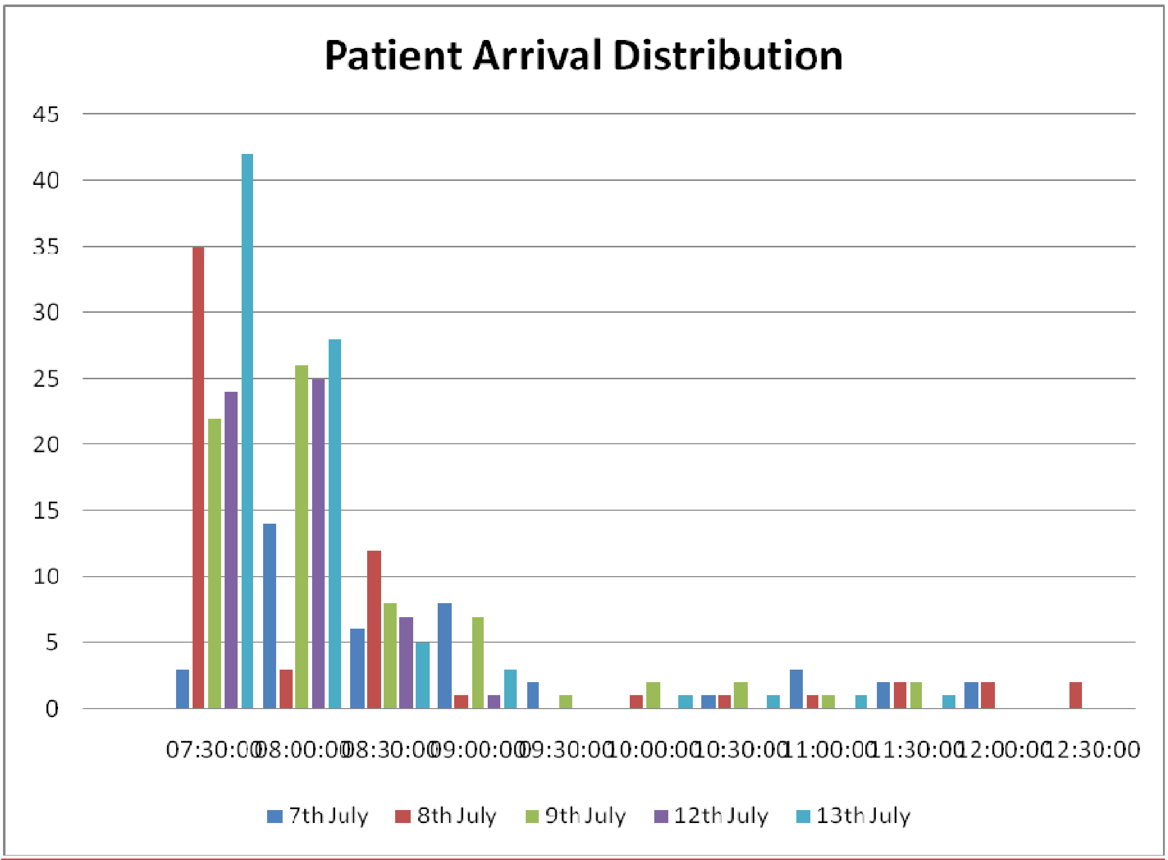


Figure 18 : Patient Arrival Distribution

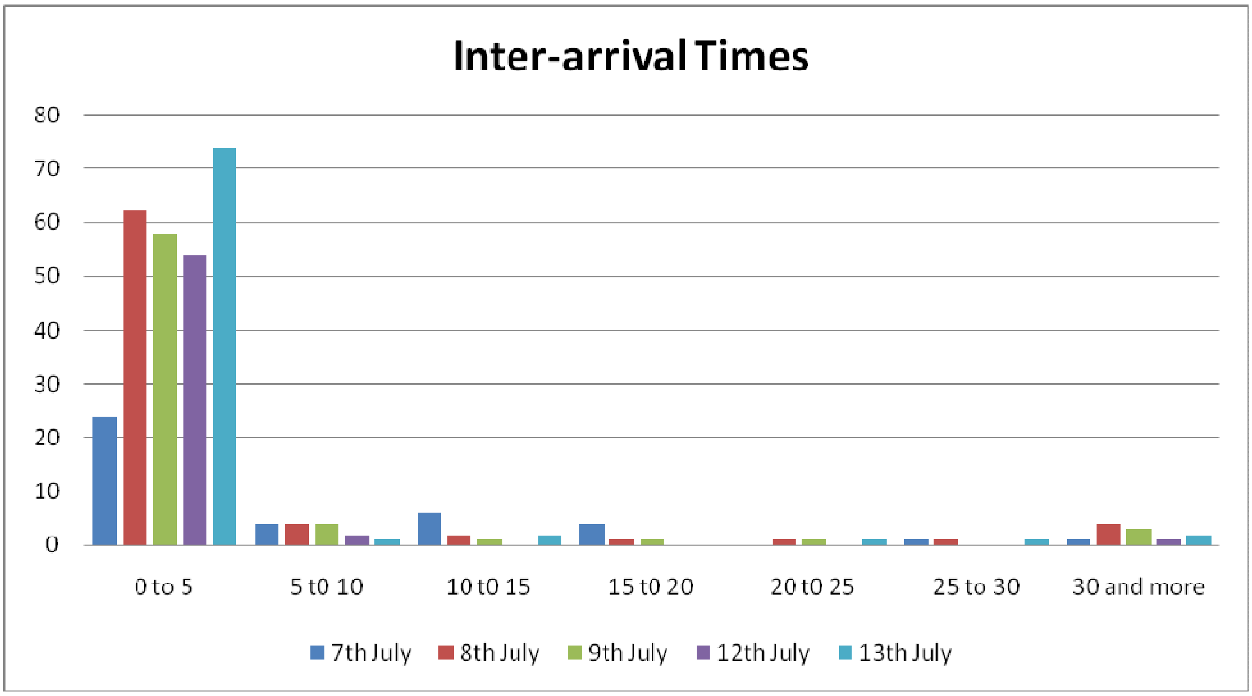


Figure 19 : Patient Inter-Arrival Times

2.2. Service times distribution

Since the system has three queues that one has to pass through before being done with being serviced, the service rates of the three stages were observed.

The first queue that people enter is that of administration, but not all the patients entering the system require administration services. To capture as much of the current system as possible the queuing stage is considered. Shown on figure 18 is the distribution of service duration, data was captured over five days. From the graph it can be estimated that on average it takes three minutes for each customer to be serviced which means 20 customers can be serviced in one hour

The next queue to enter is that of blood pressure and urine testing. Interviewing the nurses in charge provided an estimation of how long it takes to attend to the patients. The nurses estimated that they see roughly eight patients in an hour. This estimation is from a reliable source and it will be used in the document

The service rate for the last queue was also obtained in a similar fashion. The majority of nurses who perform the consulting estimated that they usually attend four patients in an hour each. This estimation will be used in the document.

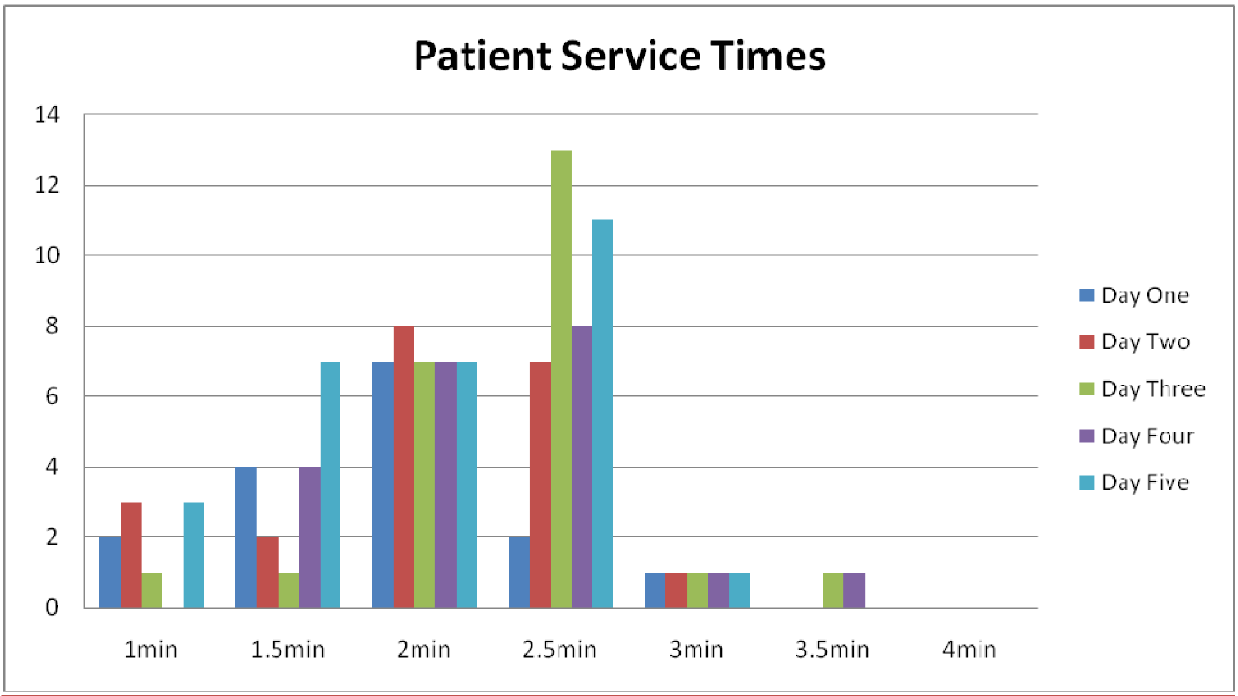


Figure 20 : Patient Service Times

2.3. System servers

The three stage system servers, refer to figure 15, are:

- one administrator;
- one blood pressure and urine testing nurse; and;
- five consultation rooms with outnumbering nurses

2.4. System capacity

The system can facilitate for a finite number of people. The queuing areas in total can accommodate 150 patients. No certain amount of space is provided for a certain queue.

2.5. Queuing discipline

The type of setup at the clinic can be recognized as a 3-staged tandem queuing system where the following theorem must be applicable:

'if(1) interarrival times for a series queuing system are exponential with rate λ, (2) service times or each stage I server are exponential, and (3) each stage has an infinite-capacity waiting room, then interarrival times for arrivals to each stage of the queuing system are exponential.'(Winston, 2004)

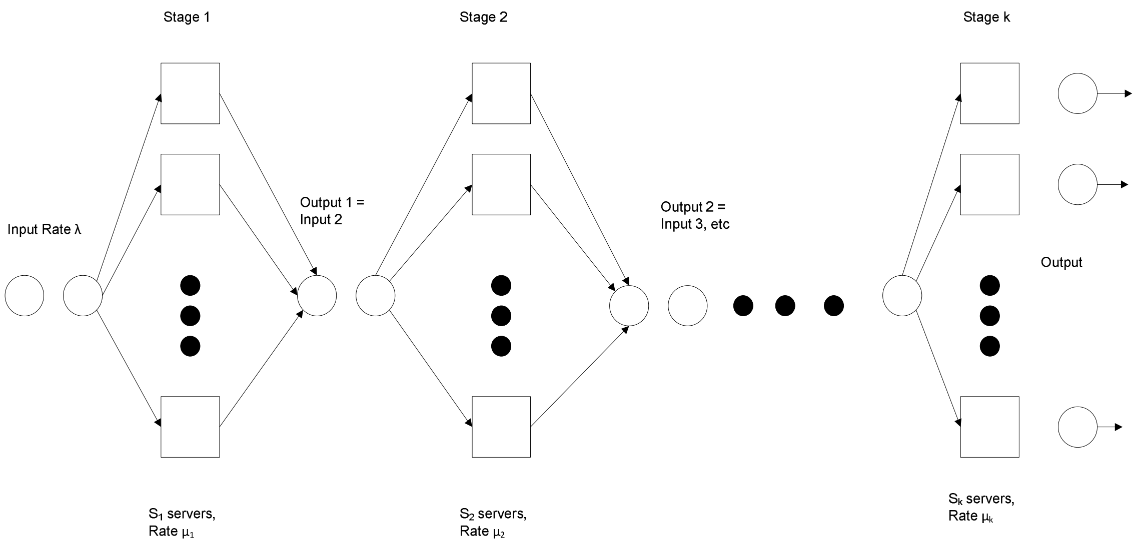


Figure 21 : k-Stage Series Queuing System (Winston, 2004)

.

3. Facility Planning

The layout of a facility is essential in helping any company to execute its purpose. The current clinic layout can be found in Appendix B. This layout also shows the patient flow in the clinic.

Two tables are essential for the commencement of the facility design. Table three provides code for the possible reasons why a certain rating is allocated between two rooms in the clinic. Table four on the other hand is a Systematic Layout Planning relationships ratings chart. These are the standard ratings required to create a relationship chart.

Shown in figure 21 is a from-to chart /relationship chart which is built based on tables three and four and the observed relation between the various rooms. The chart is then used as reference in sketching the activity relationship diagram, figure 20. The diagram shows a visual picture of what has been populated in the relationship chart.

Table 3 : Rating Reasons

Code	Reason
1	Type of patient
2	Ease of supervision
3	Contact necessary
4	Security
5	Privacy

Table 4 : SLP Relationship Ratings

Value	Closeness	Line Code	Numerical Weights
A	Absolutely necessary	(red quadruple line)	4
E	Especially important	(orange triple line)	3
I	Important	(green double line)	2
O	Ordinary closeness	(blue single line)	1
U	Unimportant		0
X	Undesirable	(zigzag line)	-1

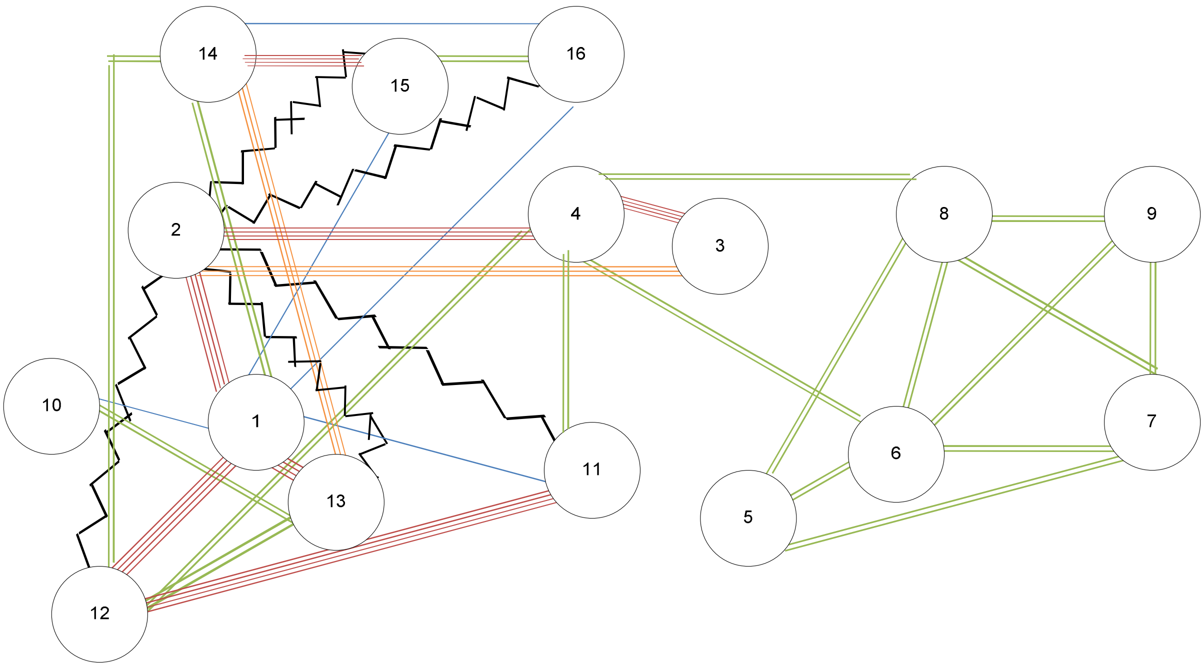


Figure 22 : Activity Relationship Diagram

From	To														
	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1. Reception	A	O	U	U	U	U	U	U	O	O	A	A	I	O	O
	2	5	_	_	_	_	_	_	5,2	4	4,5	4,5	3	5	5
2. Waiting area		E	A	A	A	A	A	A	A	X	X	X	U	X	X
		1	1,3	1,3	1,3	1,3	1,3	1,3	1,3	4	4	4	_	5	5
3. Toilets			A	U	U	U	U	U	U	U	U	U	U	U	U
			1,3	_	_	_	_	_	_	_	_	_	_	_	_
4. Consultation Room 0				I	I	I	I	I	U	I	I	U	U	U	U
				3	3	3	3	3	_	1	1	_	_	_	_
5. Consultation Room 1					I	I	I	I	I	I	U	U	U	U	U
					1	1	1	1	1	1,3	_	_	_	_	_
6. Consultation Room 2						I	I	I	I	I	U	U	U	U	U
						1	1	1	1	1,3	_	_	_	_	_
7. Consultation Room 3							I	I	I	I	U	U	U	U	U
							1	1	1	1,3	_	_	_	_	_
8. Consultation Room 4								I	I	I	U	U	U	U	U
								1	1	1,3	_	_	_	_	_
9. Consultation Room 5									I	I	U	U	U	U	U
									1	1,3	_	_	_	_	_
10. HIV Counseling Room										U	U	I	U	U	U
										_	_	1	_	_	_
11. Dispensary											A	U	U	U	U
											3,4	_	_	_	_
12. Storage Room												I	I	U	U
												1	1	_	_
13.File Room													E	U	U
													1,3,4	_	_
14. Office														A	O
														1,3,5	5
15. Staff Toilets															I
															1,3,5
16. Kitchen															

Letter	Closeness Rating
Number	Reason for Rating

Figure 23 : From-to Chart and Relationship Chart

Chapter 5: Problem and Design Solving

1. Process

The observed operation processes at the clinic have been drawn up as service blueprints. The reasoning was to emphasize the significance of the process design. The service blueprint consists of a line of visibility which distinguishes between high customer contact and activities that the customer doesn't see. Another addition to the process flow chart is poka-yokes. Poka-yokes are fail safe procedures or devices such as warning methods, and physical or visual contact methods. Another poka-yoke method, particularly for the service industry, is named the *Three T's- the* Task to be done, the Treatment accorded to the customer, and the Tangible or environmental features of the service. Service poka-yokes fail-safe the actions of both the service worker and the customer. figures 24-26 show the service blueprints.

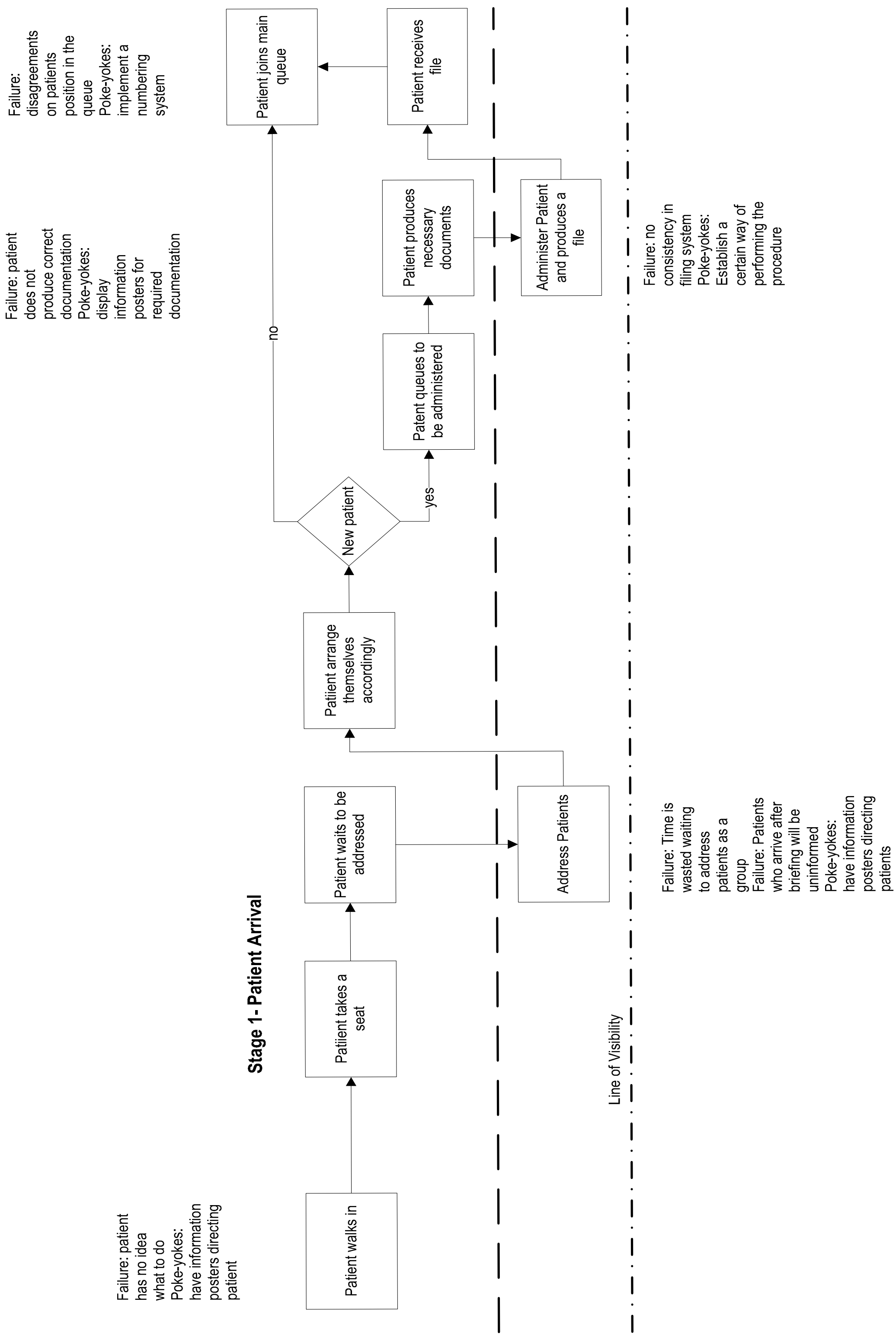


Figure 24 : Stage 1 Fail Safing

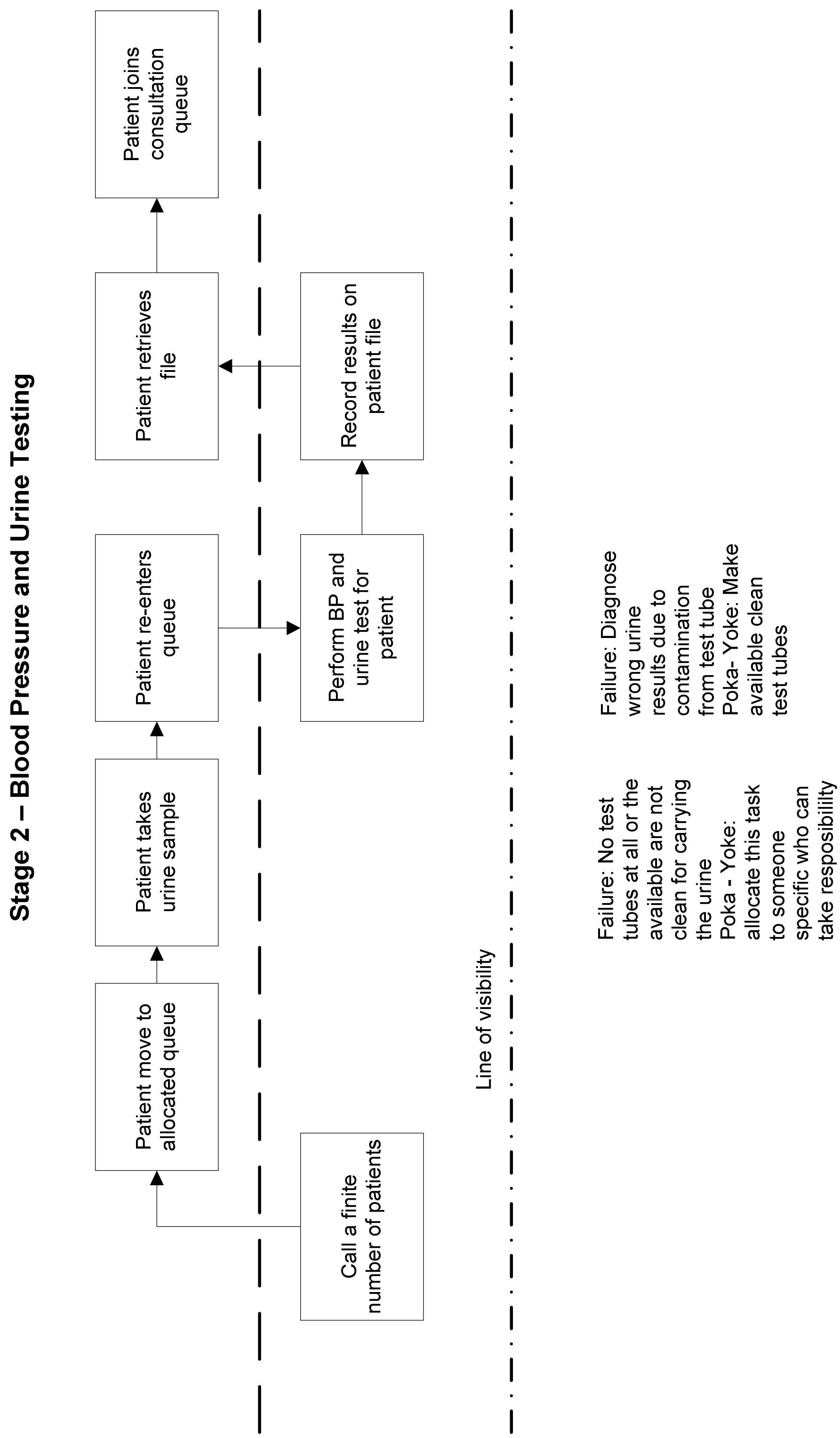


Figure 25 : Stage 2 Fail Safing

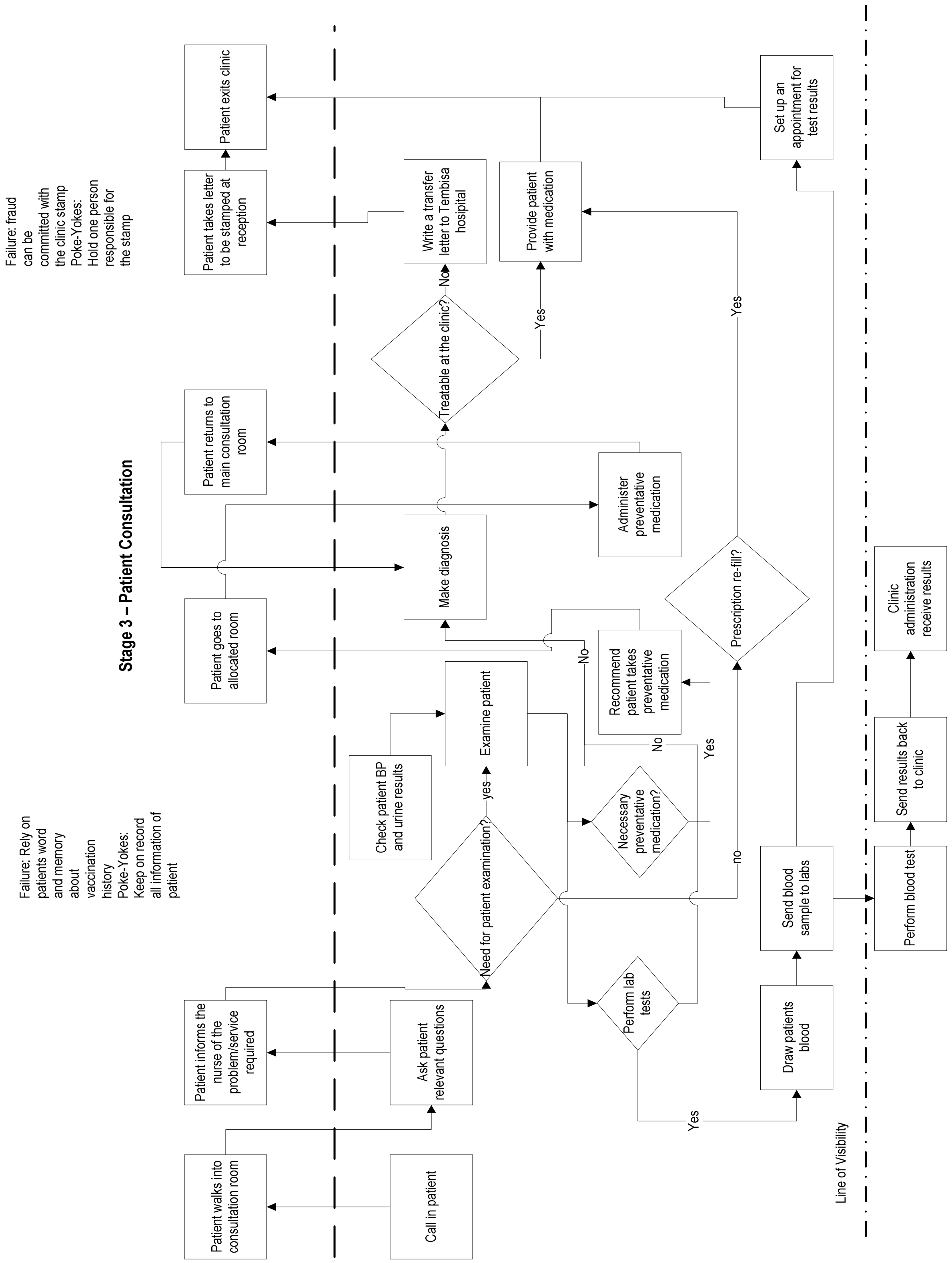


Figure 26 : Stage 3 Fail Safing

2. FACILITY LAYOUT

The suggested facility layout plan alternatives are shown below in figures 22 and 24.For the current evaluation the plan only considers the relationships of the rooms and not the building constraints.

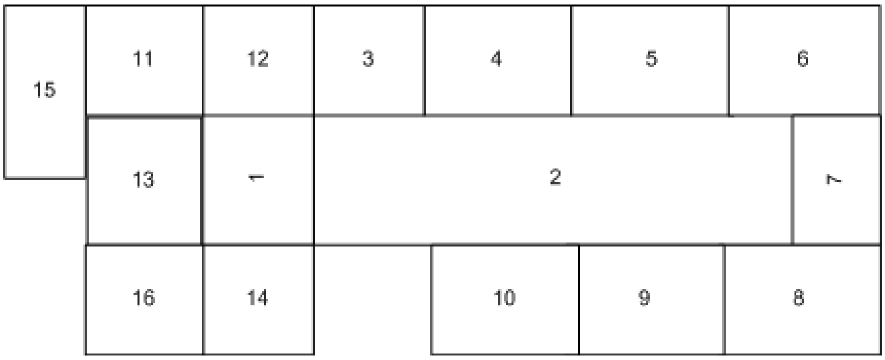


Figure 27 : Facility Layout Alternative 1

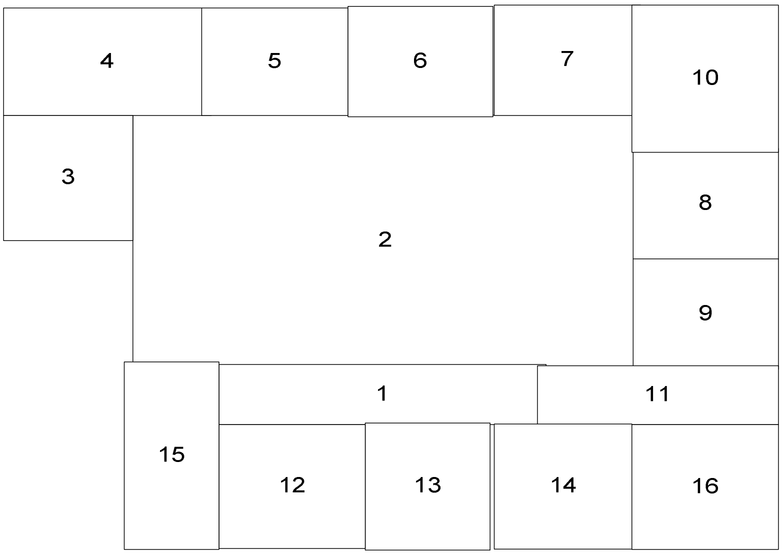


Figure 28 : Facility Layout Alternative 2.

Since there are alternatives to consider an evaluation form was populated in order to determine the best alternative. Factors and considerations important to the facility layout were listed and given ratings from 1 to 4, ranging from acceptable to excellent. enumerated below is the evaluation form and it can be concluded from the form that alternative 1 ranks higher than its competitor therefore the layout of alternative 1 would be better to use.

Company: Olifantsfontein Clinic	Alternatives	A		B		C		D		E	
Project: Service improvement		Alternative 1		Alternative 2							
Date: 03/08											
Analyst: KWE Puoane											
		Ratings and Weighted Ratings									
Factor/ Consideration	Wt.	A		B		C		D		E	
Security	8	2	16	1	8						
Privacy	4	3	12	1	4						
Ease of Control	6	4	24	3	18						
Efficiency	6	3	18	2	12						
Logical	8	4	32	3	24						
Ease of Movement	8	3	24	4	32						
Flexibility	4	2	8	3	12						
Totals		134		110							

Figure 29 :Facility Layout Alternatives Evaluation

3. Queuing Model

In the previous chapter it was concluded that the clinic runs in a series queuing system where:

- λ= 6 customers per hour,
- s1= 1
- µ1= 20 customers per hour
- s2= 1
- µ2= 8 customers per hour
- s3= 5
- µ3= 4 customers per hour

Stage 1 calculations

λ	6	customers per hour
µ	20	customers per hour
ρ	0.3	
Lq	0.128571	patients
Wq	0.021429	hours

Figure 30: Stage 1 Calculations

Stage 2 Calculations

λ	6	customers per hour
μ	8	customers per hour
ρ	0.75	
Lq	2.25	patients
Wq	0.375	hours

Figure 31 : Stage 2 Calculations

Stage 3 calculations

λ	6	customers per hour
μ	4	customers per hour
S3	5	servers
ρ	0.3	
P(j≥5)	0.2	
Lq	0.085714	patients
Wq	0.014286	hours

Figure 32: Stage 3 Calculations

Thus from the calculations the total waiting time in the clinic is 0.014286+0.375+0.021429 = 0.4107 hours. When observing the situation at the clinic the calculations are fully off track because people wait for hours before they are fully serviced. A good queuing system is available for the clinic so now the question is why do people wait hours, why is there a blow-up in the system?

Further investigation into the problem showed the problem to be an outcome of bad staff scheduling, bad staff management, and no job standardization. This takes us to a whole different project scope where staffing issues need to be addressed. What was observed of the staff members was that they work in an environment with many disturbances ranging from municipality demands to extended tea breaks. This has reflected in the queue waiting times. In figure 28 the calculations for stage 1 are recalculated using a lower service rate in order to move closer to the actual queue waiting times.

Stage 1 re-calculations

λ	6	6	6	6	6	6	6	customers per hour
μ	18	16	14	12	10	8	7	customers per hour
ρ	0.333	0.375	0.429	0.5	0.6	0.75	0.857	servers
Lq	0.167	0.225	0.321	0.5	0.9	2.25	5.143	patients
Wq	0.028	0.038	0.054	0.083	0.15	0.38	0.857	hours

Figure 33 : Stage 1 re-calculation

The lowest service rate gives the closest waiting time as to what happens in the clinic. The only ambiguous calculation is that of ρ=85.7% which means that the administrator is used at that percentage. It remains that it takes 3 min to service each customer but due to daily disturbances and no work measurement the service rate is low.

Stage 2 is the most consistent stage where the service rate mentioned is the actual rate hence the calculations in figure 22 still remain.

Stage 3 re-calculations

λ	6	6	6	6	customers per hour
μ	4	4	4	4	customers per hour
S_3	5	4	3	2	servers
ρ	0.3	0.375	0.5	0.75	
P(j≥5)	0.2	0.7	0.24	0.64	
Lq	0.086	0.42	0.24	1.92	patients
Wq	0.014	0.07	0.04	0.32	hours

Figure 34 : Stage 3 recalculations

Referring to figure 29 the variable that changes is the system servers and the service rate remains constant. As the number of servers decreases, naturally, the queue waiting times increases. A higher queue waiting time is closer to real life as possible where only two nurses are working consistently. Thus the total waiting time in the clinic will be, when using the recalculation, 0.32+0.857+0.375=1.552 hours. That is almost four times longer than what the designed system can perform.

In conclusion a new revised queuing model will not solve the identified problem. An “error of the third kind” has occurred where the wrong problem is being solved. Instead of the cause being treated the symptom is treated. The identified problem is only the surface of the real problem. A new queuing model won’t be sufficient to solve the problem.

Chapter 6: Recommendations

Evaluation of data collected at Olifantsfontien community clinic showed that the problem identified was not the core problem but rather a symptom of a bigger problem. The facility is not dismally short of resources, that is unable to service its clients in appropriate time but in my opinion, it shows a lack of proper and efficient management of resources particularly the human resources. In the previous chapter under the queuing model section it was proven that appropriate resources are allocated to service the patients but the times are still grimly long.

Recommendations are that:

- The system processes be fail-safe guided by the suggested poke-yokes shown in figures 24-26 in the previous chapter;
- The facility layout be improved to assist in the efficient running of the clinic. possible layouts can be found in the previous chapter with the evaluation of the best suggested layout; and
- The allocated resources should be fully utilized in order to cater for the number of patients who enter the clinic,

The listed recommendations will cure the symptom of long queuing times. The recommendation that will follow is a suggested solution for the core problem of the clinic. There are several management theories available but for the purpose of this project Deming's System of Profound Knowledge will be used due to exposure to the theory in quality assurance. The management theory can be considered as an industrial engineering tool.

W. Edwards Deming's System of Profound Knowledge

Deming, born in Sioux City, Iowa, October 14 1900, developed a theory of management named System of Profound Knowledge. Through gaining of process knowledge acquired from experience and correspondence by theory "joy in work" is promoted by Deming's theory. Deming's theory is said to be applicable in any culture perceptibly with focus to uniqueness of the culture. Joy in work by the clinic's staff members might be the best solution to target the root problem at Olifantsfontien clinic.

The purpose of Deming's theory is the promotion of joy in work for an organization's stakeholders. "Deming believed that joy in work will unleash the power of human resource contained in intrinsic motivation. Intrinsic motivation is the motivation an individual experiences from the sheer joy of an endeavor."(Oppenheim, 2005). Improved intrinsic motivation of the clinic staff members would have a positive effect on the functioning of the clinic. The "machines" are there ready to be functioning at full capacity the challenge faced here is to get the best out of the "man." The application of Deming's theory can assist in overcoming the challenge.

The theory is based on four belief systems. These paradigms are those that a group or an individual use to understand data about conditions and circumstances. The assumptions of management practice are destabilized by Deming's paradigms.

- Paradigm 1
  The best way to inspire people is to mix both intrinsic and extrinsic motivation and not through extrinsic motivation only.
- Paradigm 2
  It is best to manage an organization using both a process and a result orientation instead of just results orientation.
- Paradigm 3
  Optimization of the entire system is sensible instead of optimization of components of the system. System components are interdependent.
- Paradigm 4
  Cooperation between members functions better than competition between them.

Deming's theory of management also consists of four components, they are:

- Appreciation of a System
  Knowing what the system is and managing it to optimization.
- Theory of Variation
  All processes have inherent variation, both common and special
- Theory of Knowledge
  Knowledge gives the ability to explain past events and predict future ones with a measurable risk. Knowledge provokes questioning.
- Psychology
  Understanding psychology assists to understand the interaction between people, between people and the system, and understanding the people themselves.

Application of the management theory is done through implementation of Deming's 14 Points for Management. The points, shown in the figure below, reflect Deming's paradigm shift.

j

Figure 35 : Deming's 14 Points for Management

Not all the points listed can be applicable to the management of the clinic but significant points are mentioned such as points 6 and 7. Point 6 mentions that on the job training should be instituted. That is significant because employees (i.e. nurses) are the most important asset in an organization and training them effectively will increase the skill level which will improve the product or service (medical care service).

Transformation from current leadership to a new style of leadership at the clinic, or at any other organization, will not be easy. The 14 points can help the current management to compare and contrast the way they operate with what Deming's suggestions. Another advantage from using Deming's 14 points is that Key Performance Indicators (KPIs) can be developed and implemented. KPI's will contribute to quality management.

CONCLUSION

Recommended alterations to the system components such as the facility layout and operation processes allow for sub optimization of the system components. All the minor changes will improve the operation of the clinic holistically with proper management.

Implementation of the System of Profound Knowledge will open way for a changed and improved leadership at the clinic and in turn an improved healthcare service at Olifantsfontien Community Clinic through better management of the facility.

The ultimate goal of process improvement and innovation efforts is to create products and services whose quality is so high that consumers (both external and internal) extol them. (Oppenheim, 2005)

References

1. Fomundam, S. and Herrmann, J. (2007) A Survey of Queuing Theory Applications in Healthcare. ISR Technical Report, Accessed March 11, 2010,<http://0-www.lib.umd.edu.innopac.up.ac.za/drum/bitstream/1903/7222/1/tr_2007-24.pdf, >
2. Balfour, T. MUNICIPAL HEALTH SERVICES IN SOUTH AFRICA, OPPORTUNITIES AND CHALLENGES., Accessed March 11, 2010,<http://www.dbsa.org/Research/Documents/Municipal%20health%20services%20in%20South%20Africa%20Opportunities%20and%20challenges.pdf, >
3. Silvester, K. and Lendon, R. and Bevan, H. (2004) Reducing waiting times in the NHS., Accessed March 11,2010<http://0-www.internetgroup.ca.innopac.up.ac.za/clientnet_new/docs/CIM12_3_Silvester.pdf>
4. Huchzermeyer, M., and Baumann, T., and Mohamed, S. (2004). Background Report 3: Informal Settlement Practice in South Africa's Metropolitan Cities. University of the Witwatersrand Research Team.
5. Niebel, B & Frievalds, A 2004, "*Methods, Standards, and Work Design", 11edn, McGraw Hill ,Asia*
6. Jacobs, FR, Chase, RB & Aquilano, NJ 2009, "*Operations & Supply Management*", 12 edn, McGraw Hill, New York
7. Winston, WL 2004," Operations Research", 4 edn, Duxbury, Canada
8. Johnson, J, 'Simple queuing theory tools you can use in healthcare', North Colorado Medical Centre.
9. Singh, V 2006,"Use of Queuing Model in Health Care", Department of Policy and Management, University of Arkansas for Medical Science.
10. Gitlow, HS, Oppenheim, AJ, Oppenheim, R & Levine, DM 2005, "*Quality Management*", 3 edn, McGraw Hill, New York

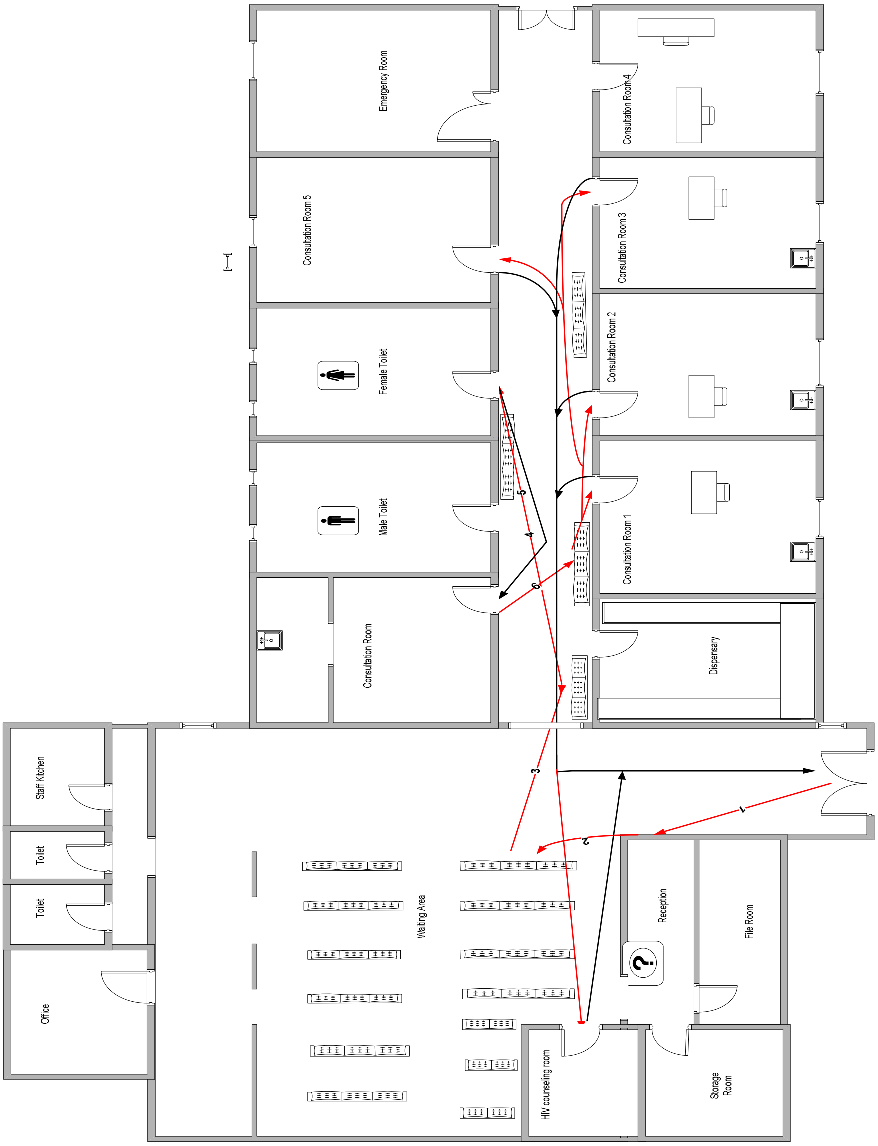
Appendix

Appendix A

Gantt chart: Planned Project Schedule

ID	Task Description	Start	Finish	Duration	Q1 10: Feb, Mar; Q2 10: Apr, May, Jun; Q3 10: Jul, Aug, Sep; Q4 10: Oct, Nov, Dec
1	Project Search	2010/02/09	2010/02/23	2w 1d	
2	Project Topic Selection	2010/02/24	2010/02/24	0w	
3	Project Topic and Project Leader Allocation	2010/03/03	2010/03/03	0w	
4	Introduction to Project Leader	2010/03/08	2010/03/08	1d	
5	Perform Project Research	2010/03/10	2010/03/17	1w 1d	
6	Consult Project Leader	2010/03/18	2010/11/08	33w 3d	
7	Create Project Proposal	2010/03/17	2010/03/23	1w	
8	Submit Project Proposal for Assesment	2010/03/24	2010/03/24	0w	
9	Conduct Literature Review	2010/04/19	2010/05/03	2w 1d	
10	Create Preliminary Project Report	2010/04/30	2010/05/13	2w	
11	Submit Preliminary Project Report	2010/05/14	2010/05/14	0w	
12	Prepare for Project Presentation	2010/05/17	2010/05/28	2w	
13	Present Project	2010/05/31	2010/05/31	0w	
14	Collect Data and Information from the clinic	2010/05/20	2010/06/18	4w 2d	
15	Process Data Collected	2010/06/07	2010/06/30	3w 3d	
16	Develop Model	2010/07/27	2010/08/20	3w 4d	
17	Document Solution	2010/08/20	2010/11/05	11w 1d	
18	Submit Final Report	2010/10/05	2010/10/05	1d	
19	Project Presentation	2010/11/01	2010/11/01	1d	

APPENDIX B



APPENDIX C

Universiteit van Pretoria
University of Pretoria

	7th July				8th July				9th July				12th July				13th July			
	Arrival times	Arrival time in hours	Inter Arrival	Inter Arrival times in hours	Arrival times	Arrival time in hours	Inter Arrival	Inter Arrival times in hours	Arrival times	Arrival time in hours	Inter Arrival	Inter Arrival times in hours	Arrival times	Arrival time in hours	Inter Arrival	Inter Arrival times in hours	Arrival times	Arrival time in hours	Inter Arrival	Inter Arrival times in hours
0	07:30:00	7.5			07:30:00	7.5			07:30:00	7.5			07:30:00				07:30:00			
1	07:30:10	7.52777778	00:00:10	0.027778	07:30:05	7.513889	00:00:05	0.013889	07:31:05	7.530556	00:01:05	0.030556	07:30:01	7.502778	00:00:01	0.002778	07:33:00	7.55	00:03:00	0.05
2	07:40:30	7.75	00:10:20	0.222222	07:30:07	7.519444	00:00:02	0.005556	07:31:07	7.536111	00:00:02	0.005556	07:30:02	7.505556	00:00:01	0.002778	07:34:09	7.591667	00:01:09	0.041667
3	07:41:16	7.72777778	00:00:46	0.127778	07:30:08	7.522222	00:00:01	0.002778	07:33:08	7.572222	00:02:01	0.036111	07:30:10	7.527778	00:00:08	0.022222	07:34:26	7.638889	00:00:17	0.047222
4	07:56:06	7.95	00:14:50	0.372222	07:30:09	7.525	00:00:01	0.002778	07:33:09	7.575	00:00:01	0.002778	07:31:03	7.525	00:00:53	0.147222	07:34:51	7.708333	00:00:25	0.069444
5	08:10:01	8.16944444	00:13:55	0.369444	07:31:09	7.541667	00:01:00	0.016667	07:34:09	7.591667	00:01:00	0.016667	07:32:45	7.658333	00:01:42	0.133333	07:35:02	7.588889	00:00:11	0.030556
6	08:15:57	8.40833333	00:05:56	0.238889	07:31:13	7.552778	00:00:04	0.011111	07:34:13	7.602778	00:00:04	0.011111	07:32:57	7.691667	00:00:12	0.033333	07:36:10	7.627778	00:01:08	0.038889
7	08:15:59	8.41388889	00:00:02	0.005556	07:31:17	7.563889	00:00:04	0.011111	07:34:17	7.613889	00:00:04	0.011111	07:34:00	7.566667	00:01:03	0.025	07:36:12	7.633333	00:00:02	0.005556
8	08:20:45	8.45833333	00:04:46	0.194444	07:31:25	7.586111	00:00:08	0.022222	07:35:25	7.652778	00:01:08	0.038889	07:34:05	7.580556	00:00:05	0.013889	07:36:19	7.652778	00:00:07	0.019444
9	08:20:46	8.46111111	00:00:01	0.002778	07:31:29	7.597222	00:00:04	0.011111	07:36:29	7.680556	00:01:04	0.027778	07:34:16	7.611111	00:00:11	0.030556	07:36:45	7.725	00:00:26	0.072222
10	08:20:58	8.49444444	00:00:12	0.033333	07:31:48	7.65	00:00:19	0.052778	07:36:48	7.733333	00:00:19	0.052778	07:34:34	7.661111	00:00:18	0.05	07:37:01	7.619444	00:00:16	0.044444
11	08:23:06	8.4	00:02:08	0.055556	07:32:07	7.552778	00:00:19	0.052778	07:38:07	7.652778	00:01:19	0.069444	07:36:09	7.625	00:01:35	0.113889	07:37:12	7.65	00:00:11	0.030556
12	08:23:19	8.43611111	00:00:13	0.036111	07:32:34	7.627778	00:00:27	0.075	07:39:34	7.744444	00:01:27	0.091667	07:36:17	7.647222	00:00:08	0.022222	07:37:35	7.713889	00:00:23	0.063889
13	08:23:30	8.46666667	00:00:11	0.030556	07:32:40	7.644444	00:00:06	0.016667	07:39:40	7.761111	00:00:06	0.016667	07:36:18	7.65	00:00:01	0.002778	07:38:36	7.733333	00:01:01	0.019444
14	08:23:31	8.46944444	00:00:01	0.002778	07:33:08	7.572222	00:00:28	0.077778	07:40:08	7.688889	00:00:28	0.077778	07:36:31	7.686111	00:00:13	0.036111	07:40:01	7.669444	00:01:25	0.086111
15	08:24:05	8.41388889	00:00:34	0.094444	07:33:24	7.616667	00:00:16	0.044444	07:41:24	7.75	00:01:16	0.061111	07:37:00	7.616667	00:00:29	0.080556	07:42:04	7.711111	00:02:03	0.041667
16	08:25:45	8.54166667	00:01:40	0.127778	07:33:30	7.633333	00:00:06	0.016667	07:45:30	7.833333	00:04:06	0.083333	07:39:26	7.722222	00:02:26	0.105556	07:42:05	7.713889	00:00:01	0.002778
17	08:28:13	8.50277778	00:02:28	0.111111	07:33:36	7.65	00:00:06	0.016667	07:45:36	7.85	00:00:06	0.016667	07:40:08	7.688889	00:00:42	0.116667	07:45:00	7.75	00:02:55	0.186111
18	08:28:20	8.52222222	00:00:07	0.019444	07:33:46	7.677778	00:00:10	0.027778	07:47:46	7.911111	00:02:10	0.061111	07:43:00	7.716667	00:02:52	0.177778	07:45:23	7.813889	00:00:23	0.063889
19	08:30:34	8.59444444	00:02:14	0.072222	07:33:50	7.688889	00:00:04	0.011111	07:48:50	7.938889	00:01:04	0.027778	07:50:01	7.836111	00:07:01	0.119444	07:46:35	7.863889	00:01:12	0.05
20	08:31:06	8.53333333	00:00:32	0.088889	07:33:57	7.708333	00:00:07	0.019444	07:48:57	7.958333	00:00:07	0.019444	07:50:41	7.947222	00:00:40	0.111111	07:46:43	7.886111	00:00:08	0.022222
21	08:31:08	8.53888889	00:00:02	0.005556	07:39:25	7.719444	00:05:28	0.161111	07:50:25	7.902778	00:01:28	0.094444	07:54:54	8.05	00:04:13	0.102778	07:47:00	7.783333	00:00:17	0.047222
22	08:31:09	8.54166667	00:00:01	0.002778	07:39:26	7.722222	00:00:01	0.002778	07:50:26	7.905556	00:00:01	0.002778	07:54:55	8.052778	00:00:01	0.002778	07:48:07	7.819444	00:01:07	0.036111
23	08:45:03	8.75833333	00:13:54	0.366667	07:41:00	7.683333	00:01:34	0.111111	08:00:09	8.025	00:09:43	0.269444	07:56:23	7.997222	00:01:28	0.094444	07:48:37	7.902778	00:00:30	0.083333
24	08:53:07	8.90277778	00:08:04	0.144444	07:41:07	7.702778	00:00:07	0.019444	08:02:07	8.052778	00:01:58	0.177778	07:57:34	8.044444	00:01:11	0.047222	07:48:59	7.963889	00:00:22	0.061111
25	09:05:06	9.1	00:11:59	0.347222	07:42:09	7.725	00:01:02	0.022222	08:02:09	8.058333	00:00:02	0.005556	08:00:01	8.002778	00:02:27	0.108333	07:49:09	7.841667	00:00:10	0.027778
26	09:11:17	9.23055556	00:06:11	0.130556	07:42:32	7.788889	00:00:23	0.063889	08:05:32	8.172222	00:03:23	0.113889	08:00:56	8.155556	00:00:55	0.152778	07:49:18	7.866667	00:00:09	0.025
27	09:16:03	9.275	00:04:46	0.194444	07:42:58	7.861111	00:00:26	0.072222	08:10:58	8.327778	00:05:26	0.155556	08:01:41	8.130556	00:00:45	0.125	07:51:09	7.875	00:01:51	0.158333
28	09:16:05	9.28055556	00:00:02	0.005556	07:44:47	7.863889	00:01:49	0.152778	08:11:42	8.3	00:00:44	0.122222	08:03:14	8.088889	00:01:33	0.108333	07:52:52	8.011111	00:01:43	0.136111
29	09:18:04	9.31111111	00:01:59	0.180556	07:49:07	7.836111	00:04:20	0.122222	08:11:53	8.330556	00:00:11	0.030556	08:05:17	8.130556	00:02:03	0.041667	07:53:35	7.980556	00:00:43	0.119444
30	09:28:03	9.475	00:09:59	0.313889	07:50:23	7.897222	00:01:16	0.061111	08:13:24	8.283333	00:01:31	0.102778	08:05:51	8.225	00:00:34	0.094444	07:55:14	7.955556	00:01:39	0.125
31	09:28:18	9.51666667	00:00:15	0.041667	07:52:35	7.963889	00:02:12	0.066667	08:13:35	8.313889	00:00:11	0.030556	08:08:05	8.147222	00:02:14	0.072222	07:55:20	7.972222	00:00:06	0.016667
32	09:42:08	9.72222222	00:13:50	0.355556	07:52:37	7.969444	00:00:02	0.005556	08:13:36	8.316667	00:00:01	0.002778	08:09:11	8.180556	00:01:06	0.033333	07:55:21	7.975	00:00:01	0.002778
33	09:45:57	9.90833333	00:03:49	0.186111	07:52:42	7.983333	00:00:05	0.013889	08:14:11	8.263889	00:00:35	0.097222	08:11:12	8.216667	00:02:01	0.036111	07:56:00	7.933333	00:00:39	0.108333
34	10:51:08	10.8722222	01:05:11	1.113889	07:55:59	8.080556	00:03:17	0.097222	08:14:47	8.363889	00:00:36	0.1	08:11:25	8.252778	00:00:13	0.036111	07:56:06	7.95	00:00:06	0.016667
35	11:06:04	11.1111111	00:14:56	0.388889	07:56:45	8.058333	00:00:46	0.127778	08:16:08	8.288889	00:01:21	0.075	08:13:00	8.216667	00:01:35	0.113889	07:56:07	7.952778	00:00:01	0.002778

36	11:06:18	11.15	00:00:14	0.038889	07:59:31	8.069444	00:02:46	0.161111	08:16:59	8.430556	00:00:51	0.141667	08:13:33	8.308333	00:00:33	0.091667	07:56:45	8.058333	00:00:38	0.105556
37	11:26:01	11.4361111	00:19:43	0.436111	08:00:02	8.005556	00:00:31	0.086111	08:17:03	8.291667	00:00:04	0.011111	08:15:01	8.252778	00:01:28	0.094444	07:58:54	8.116667	00:02:09	0.058333
38	11:55:18	11.9666667	00:29:17	0.530556	08:28:07	8.486111	00:28:05	0.480556	08:18:14	8.338889	00:01:11	0.047222	08:15:37	8.352778	00:00:36	0.1	07:59:00	7.983333	00:00:06	0.016667
39	11:55:20	11.9722222	00:00:02	0.005556	08:29:01	8.486111	00:00:54	0.15	08:22:28	8.444444	00:04:14	0.105556	08:18:04	8.311111	00:02:27	0.108333	07:59:06	8	00:00:06	0.016667
40	12:10:36	12.2666667	00:15:16	0.294444	08:30:24	8.566667	00:01:23	0.080556	08:22:49	8.502778	00:00:21	0.058333	08:19:18	8.366667	00:01:14	0.055556	07:59:10	8.011111	00:00:04	0.011111
41	12:20:48	12.4666667	00:10:12	0.2	08:30:41	8.613889	00:00:17	0.047222	08:24:10	8.427778	00:01:21	0.075	08:21:02	8.355556	00:01:44	0.138889	07:59:30	8.066667	00:00:20	0.055556
42		**Lamda**	**00:07:06**	**7.5**	08:41:24	8.75	00:10:43	0.286111	08:24:12	8.433333	00:00:02	0.005556	08:21:03	8.358333	00:00:01	0.002778	07:59:57	8.141667	00:00:27	0.075
43					08:41:36	8.783333	00:00:12	0.033333	08:24:13	8.436111	00:00:01	0.002778	08:24:31	8.486111	00:03:28	0.127778	08:00:03	8.008333	00:00:06	0.016667
44					08:41:47	8.813889	00:00:11	0.030556	08:26:25	8.502778	00:02:12	0.066667	08:25:10	8.444444	00:00:39	0.108333	08:00:07	8.019444	00:00:04	0.011111
45					08:42:57	8.858333	00:01:10	0.044444	08:28:22	8.527778	00:01:57	0.175	08:25:23	8.480556	00:00:13	0.036111	08:00:11	8.030556	00:00:04	0.011111
46					08:45:08	8.772222	00:02:11	0.063889	08:30:18	8.55	00:01:56	0.172222	08:26:43	8.552778	00:01:20	0.072222	08:00:12	8.033333	00:00:01	0.002778
47					08:53:36	8.983333	00:08:28	0.211111	08:30:19	8.552778	00:00:01	0.002778	08:27:07	8.469444	00:00:24	0.066667	08:00:17	8.047222	00:00:05	0.013889
48					08:54:45	9.025	00:01:09	0.041667	08:49:20	8.872222	00:19:01	0.319444	08:29:16	8.527778	00:02:09	0.058333	08:00:37	8.102778	00:00:20	0.055556
49					08:54:47	9.030556	00:00:02	0.005556	08:49:22	8.877778	00:00:02	0.005556	08:29:56	8.638889	00:00:40	0.111111	08:00:58	8.161111	00:00:21	0.058333
50					08:55:05	8.930556	00:00:18	0.05	08:51:09	8.875	00:01:47	0.147222	08:31:20	8.572222	00:01:24	0.083333	08:01:00	8.016667	00:00:02	0.005556
51					08:59:08	9.005556	00:04:03	0.075	08:53:21	8.941667	00:02:12	0.066667	08:31:23	8.580556	00:00:03	0.008333	08:01:34	8.111111	00:00:34	0.094444
52					09:23:04	9.394444	00:23:56	0.538889	08:55:32	9.005556	00:02:11	0.063889	08:37:00	8.616667	00:05:37	0.186111	08:02:00	8.033333	00:00:26	0.072222
53					10:05:42	10.2	00:42:38	0.805556	08:59:16	9.027778	00:03:44	0.172222	08:41:07	8.702778	00:04:07	0.086111	08:02:03	8.041667	00:00:03	0.008333
54					10:53:53	11.03056	00:48:11	0.830556	09:02:08	9.055556	00:02:52	0.177778	08:45:57	8.908333	00:04:50	0.205556	08:02:55	8.186111	00:00:52	0.144444
55					11:08:51	11.275	00:14:58	0.394444	09:02:12	9.066667	00:00:04	0.011111	08:48:03	8.808333	00:02:06	0.05	08:03:41	8.163889	00:00:46	0.127778
56					11:42:43	11.81944	00:33:52	0.694444	09:07:14	9.155556	00:05:02	0.088889	08:50:01	8.836111	00:01:58	0.177778	08:04:13	8.102778	00:00:32	0.088889
57					12:19:14	12.35556	00:36:31	0.686111	09:12:31	9.286111	00:05:17	0.130556	09:22:08	9.388889	00:32:07	0.552778	08:04:45	8.191667	00:00:32	0.088889
58					12:25:07	12.43611	00:05:53	0.230556	09:13:08	9.238889	00:00:37	0.102778		**Lamda**	**00:01:58**	**5.625**	08:04:48	8.2	00:00:03	0.008333
59					12:32:37	12.63611	00:07:30	0.2	09:13:09	9.241667	00:00:01	0.002778					08:04:49	8.202778	00:00:01	0.002778
60					12:52:34	12.96111	00:19:57	0.475	09:13:10	9.244444	00:00:01	0.002778					08:06:00	8.1	00:01:11	0.047222
61						**Lamda**	**00:05:23**	**6.792453**	09:45:08	9.772222	00:31:58	0.677778					08:08:36	8.233333	00:02:36	0.133333
62									10:16:34	10.36111	00:31:26	0.588889					08:10:55	8.319444	00:02:19	0.086111
63									10:16:45	10.39167	00:00:11	0.030556					08:11:09	8.208333	00:00:14	0.038889
64									10:53:06	10.9	00:36:21	0.658333					08:15:05	8.263889	00:03:56	0.205556
65									10:58:04	10.97778	00:04:58	0.227778					08:18:50	8.438889	00:03:45	0.175
66									11:08:45	11.25833	00:10:41	0.280556					08:18:51	8.441667	00:00:01	0.002778
67									11:31:45	11.64167	00:23:00	0.383333					08:20:07	8.352778	00:01:16	0.061111
68									11:31:46	11.64444	00:00:01	0.002778					08:21:48	8.483333	00:01:41	0.130556
69										**Lamda**	**00:03:33**	**7.058824**					08:23:02	8.388889	00:01:14	0.055556
70																	08:25:19	8.469444	00:02:17	0.080556
71																	08:49:20	8.872222	00:24:01	0.402778
72																	08:49:22	8.877778	00:00:02	0.005556
73																	08:51:09	8.875	00:01:47	0.147222
74																	08:53:21	8.941667	00:02:12	0.066667
75																	08:59:16	9.027778	00:05:55	0.236111
76																	09:02:08	9.055556	00:02:52	0.177778
77																	09:12:31	9.286111	00:10:23	0.230556
78																	09:13:08	9.238889	00:00:37	0.102778
79																	10:19:43	10.43611	01:06:35	1.197222
80																	10:48:09	10.825	00:28:26	0.538889
81																	11:18:45	11.425	00:30:36	0.6
82																	11:30:40	11.61111	00:11:55	0.336111
83																		**Lamda**	**00:02:56**	**5.294118**

APPENDIX D

	Day One		Day Two		Day Three		Day Four		Day Five	
	Starting Time	Service Duration	Starting Time	Service Duration	Starting Time	Service Duration	Starting Time	Service Duration	Starting Time	Service Duration
1	08:05:01		08:30:07		08:00:36		08:05:16		08:15:11	
2	08:07:18	00:02:17	08:32:13	00:02:06	08:03:17	00:02:41	08:09:01	00:03:45	08:17:23	00:02:12
3	08:09:28	00:02:10	08:34:50	00:02:37	08:05:20	00:02:03	08:11:49	00:02:48	08:19:56	00:02:33
4	08:11:53	00:02:25	08:36:03	00:01:13	08:09:04	00:03:44	08:13:34	00:01:45	08:21:03	00:01:07
5	08:13:51	00:01:58	08:38:18	00:02:15	08:11:46	00:02:42	08:15:57	00:02:23	08:22:58	00:01:55
6	08:16:07	00:02:16	08:41:10	00:02:52	08:14:00	00:02:14	08:18:00	00:02:03	08:24:41	00:01:43
7	08:18:43	00:02:36	08:43:24	00:02:14	08:16:19	00:02:19	08:20:59	00:02:59	08:26:12	00:01:31
8	08:20:19	00:01:36	08:45:59	00:02:35	08:19:05	00:02:46	08:22:31	00:01:32	08:29:07	00:02:55
9	08:22:37	00:02:18	08:48:04	00:02:05	08:21:41	00:02:36	08:40:40	00:18:09	08:32:31	00:03:24
10	08:50:09	00:27:32	08:50:59	00:02:55	08:23:56	00:02:15	08:43:32	00:02:52	08:35:02	00:02:31
11	08:52:35	00:02:26	08:52:01	00:01:02	08:26:01	00:02:05	08:46:10	00:02:38	08:37:50	00:02:48
12	08:54:00	00:01:25	08:55:06	00:03:05	08:28:35	00:02:34	08:48:51	00:02:41	08:39:00	00:01:10
13	08:56:47	00:02:47	08:57:53	00:02:47	08:30:19	00:01:44	08:50:50	00:01:59	08:41:58	00:02:58
14	08:58:15	00:01:28	08:59:42	00:01:49	08:33:03	00:02:44	08:53:00	00:02:10	08:44:08	00:02:10
15	09:01:40	00:03:25	09:02:31	00:02:49	08:35:21	00:02:18	08:55:01	00:02:01	08:46:43	00:02:35
16	09:03:26	00:01:46	09:30:17	00:27:46	08:38:36	00:03:15	08:57:58	00:02:57	09:30:05	00:43:22
17	09:05:50	00:02:24	09:32:13	00:01:56	09:07:36	00:29:00	08:59:49	00:01:51	09:33:00	00:02:55
18	09:11:53	00:06:03	09:34:52	00:02:39	09:10:02	00:02:26	09:02:47	00:02:58	09:35:10	00:02:10
19	09:13:52	00:01:59	09:36:59	00:02:07	09:12:42	00:02:40	09:04:38	00:01:51	09:37:01	00:01:51
20			09:38:26	00:01:27	09:15:23	00:02:41	09:06:14	00:01:36	09:39:04	00:02:03
21			09:40:41	00:02:15	09:17:16	00:01:53	09:08:59	00:02:45	09:41:54	00:02:50
22			09:42:56	00:02:15	09:20:01	00:02:45	09:10:31	00:01:32	09:43:21	00:01:27
23			09:45:10	00:02:14	09:50:27	00:30:26	09:59:09	00:48:38	09:45:02	00:01:41
24					09:53:18	00:02:51	10:02:37	00:03:28	09:48:00	00:02:58
25					09:56:09	00:02:51			09:50:02	00:02:02
26					09:58:57	00:02:48			09:52:43	00:02:41
27					10:07:36	00:08:39			09:54:29	00:01:46
28									09:56:03	00:01:34
29									09:58:35	00:02:32
30									10:01:03	00:02:28
31									10:03:12	00:02:09