Engineering Management
Field Project

Using Queuing Analysis to Define Appropriate Staffing Levels in a Municipality

By

Hamad Ahmed Altuwaijri

Fall Semester, 2009

An EMGT Field Project report submitted to the Engineering Management Program and the Faculty of the Graduate School of The University of Kansas in partial fulfillment of the requirements for the degree of
Master's of Science

____
Tom Bowlin
Committee Chairperson

____
Herb Tuttle
Committee Member

____
John Conard
Committee Member

Date accepted:____________________________

ACKNOWLEDGEMENTS

I would like to thank my parents and my wife for their support. I will not forget their help.

A special thanks to my adviser, Professor Herb Tuttle, and Professor Tom Bowlin for being flexible and supportive during my study.

I have a great appreciation for the entire engineering management faculty and staff for teaching me the management skills that have helped me to improve my skills.

Lastly, I would like to thank three managers of the sub-municipality, Ibrahim Albakri, Khald Alroished, Bander Al krodis, and the manager of transportation planning in Riyadh higher services, Saleah Alsifa, who supported me by giving me the information that I needed to complete this project. Also, I will not forget all the employees who helped me in the main municipality of Riyadh City.

Executive Summary

This report provides an analysis and evaluation of the current process in the construction departments of the sub-municipalities of Riyadh city in Saudi Arabia. The queue model was used with a G/G/s template to find the current expected wait in the queue. Several mathematical formulas were found and used for the queue analysis. Two different plans were developed to reduce waiting time in the queue (Plans A and B).

Results of data analyzed show that there are different waiting times found in each sub-municipality (branch). Plans A and B were then applied to accelerate the waiting time in the queue. The plan with the lowest cost was chosen, if it met the target waiting time.

Two additional ways were found to improve the work: (a) shifting engineers from overstaffed offices to branches in need of additional help, without applying either Plan A or Plan B in the branches to which they were shifted; or (b) shifting engineers from overstaffed offices to branches in need of additional help and applying Plans A or B in the branches to which they were shifted.

It is recommended that engineers from overstaffed branches be shifted to branches in need of additional help without applying either Plan A or Plan B in branches to which they were shifted. This recommendation will reduce waiting time in the queue as much as possible with the least cost, which is only $16,000/month.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

Project Background

There are many complaints about the processes of the municipality of Riyadh City, Saudi Arabia. This is especially true about the permits departments of many of the sub-municipalities. This aim of this research project was to define the problem and find ways to reduce the waiting time to achieve customer satisfaction.

This research study attempted to find the problems in the processes that each sub-municipality faces.

The important goal of this research was to develop a model that will identify the optimum number of engineers in any construction department currently in the Municipality, or in any department in the future. The model will also help identify the problem in a process and how to fix it to reduce the time an application spends in the system.

Riyadh's Municipality

Riyadh is the capital of Saudi Arabia. The area of Riyadh City is 1,892 Mi^2 and it has more than 5.9 million people (double of Chicago city). This area includes different land uses and encompasses 15 branch municipalities in addition to the central Municipality.

The Riyadh Development Authority has done several studies in the past on the population structure. The first such study was done in 1987. It was repeated in 1991 and 1997 and, most recently, in 2004. These studies stressed the need for building and updating a database of Population, especially with the changes that have occurred, and are occurring, in the city. The comprehensive strategic plan conveyed the fact that Riyadh City is the fastest-growing urban city in the world. Since 1932, its population has increased more than 200 times (see Table & Figure 1.1) and its area has increased more than 1000 times.

Table 1.1

Population Growth in Riyadh City, 1960-2008(Middle East Consultant Center, 2005)

Year	Population
1960	150,000
1970	370,000
1972	500,000
1974	650,000
1988	1,500,000
1990	2,000,000
1997	2,800,000
2008	5,900,000

Figure 1.1
Population Growth in Riyadh City (1950-2009)

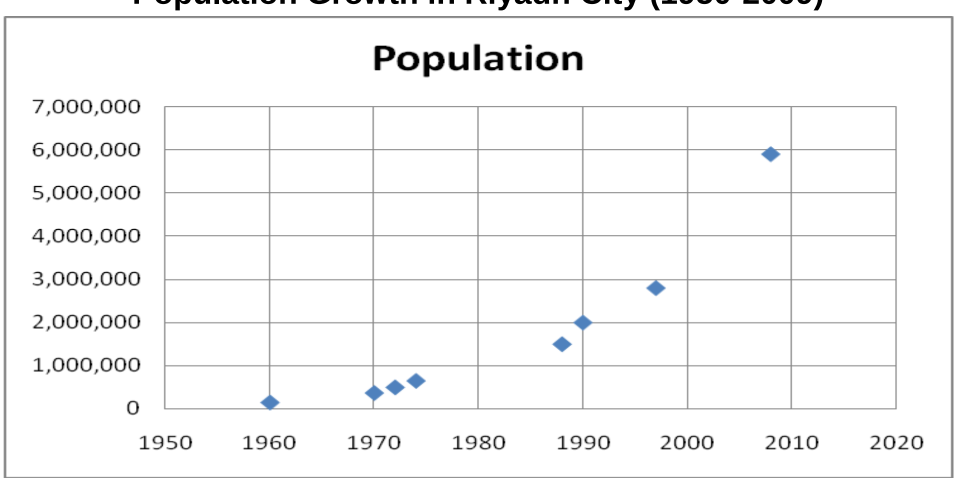


Figure 1.1 reflects the fact that Riyadh City is a very important city and has, since 1990, grown at double the usual growth rate. Since that increase, especially the period between 1997 and 2008, the need for more research and more improvements of all kinds has also increased dramatically. In Saudi Arabia, a municipality is the most important organization providing services to the public, and Riyadh City has, and will continue to have, a very high demand placed on it to provide such services. According to the last study by Investment Climate in the Riyadh city 2005, 25% of the demands made on municipalities through the whole country are made on Riyadh City.

The Municipality

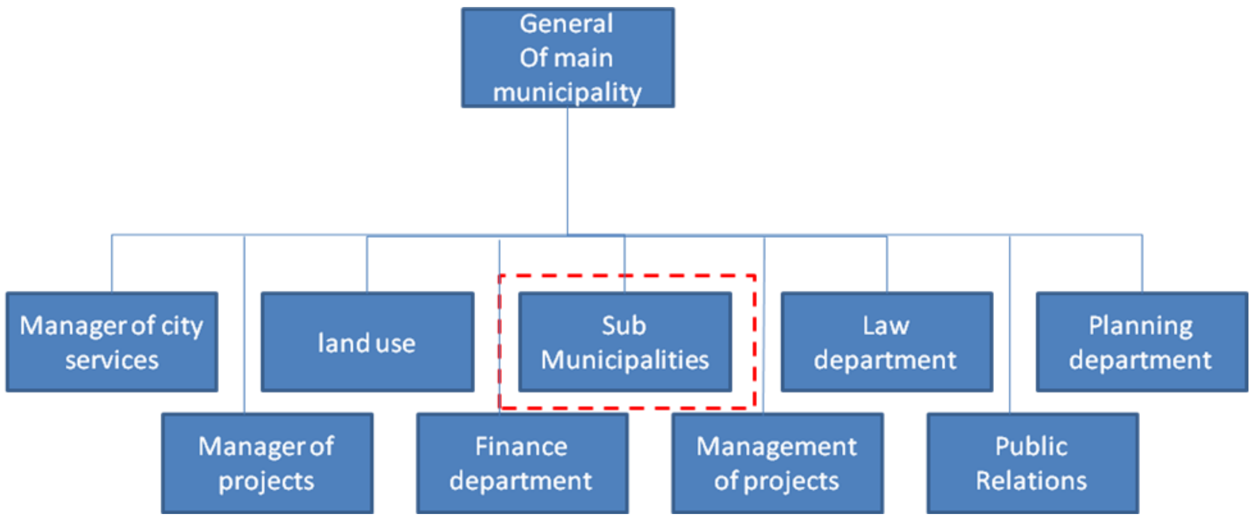
> "A municipality is an administrative entity composed of a clearly defined territory and its population and commonly denotes a city, town, or village, or a small grouping of them" (Gray, 2007, Section 8, p. 21).

In the Middle East, the term 'municipality' is used to refer to the municipal administrative building known as the city hall. The organization known as the Municipality has many processes in its departments. Some of these processes are for service and others are for inspection and monitoring of some businesses. The most important department is Service Permits. This department's responsibility is to issue new permits to persons or companies that want to start either construction of buildings or centers or planning for a new area.

Municipalities have a statement of general business and mission, which usually is to have an organization that provides services to all residents of the city. The Riyadh Municipality's mission is to provide clients across Riyadh with project engineering, inspection, and services for all types of buildings. Its mission also includes planning services, from concept through the project's completion. Figure 1.2 is a flow chart showing the general organization of the Riyadh Municipality.

Figure 1.2

The Main Municipality Chart



<u>The Sub-municipality</u>

The sub-municipality is a small branch of the main municipality. It has been assigned some responsibility by the main municipality in a specific area. Figure 1.3, below, is the sub-municipality's organization chart.

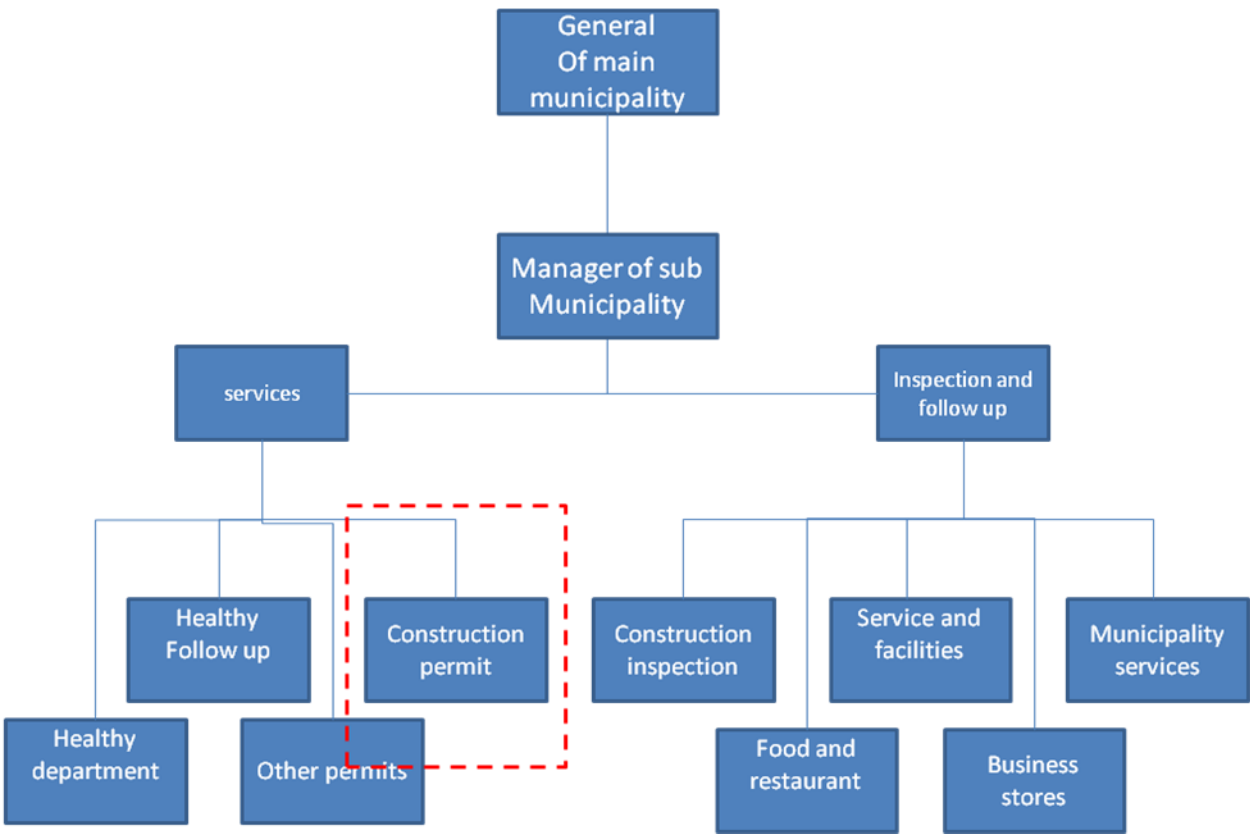
Sub-municipality Goals

A sub-municipality performs two major services, which include issuance of service permits and inspection and follow up:

- <u>Service permits</u>: this department's responsibility is to issue new permits or renew permits for people or companies who want to construct a new building in the area.
- <u>Inspection and follow up</u>: this department is responsible for any violation by individuals or businesses involving their building or the area around it.

Figure 1.3

The Sub-Municipality Chart

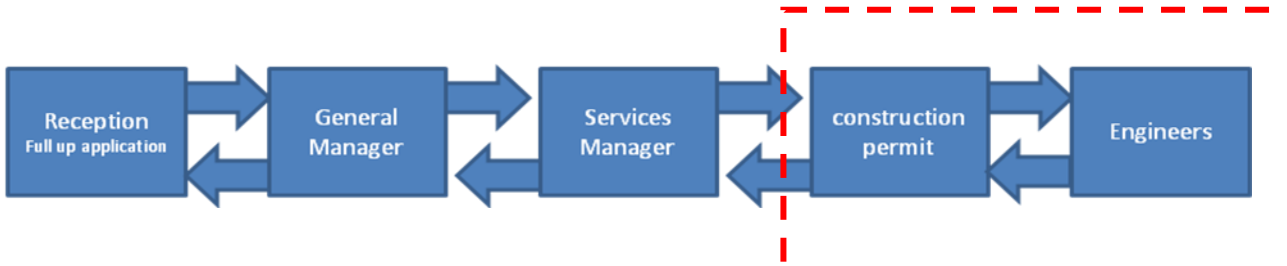


The Processes of the Sub-Municipality

There are several processes in each division of a sub-municipality, such as food and restaurant inspection, healthy department process, and construction permit process. This project focuses on the construction permit division and its process. The process for issuing a new permit or renewing one for a customer can be seen in Figure 1.4.

Figure 1.4

Process to Construction Department



Each application that needs the issuance of a new permit should be in this process. This project will focus on the last process, which is the construction Permit Division.

The Construction Permit

As stated above, this division's responsibility is to issue new permits or renew permits for people or companies wishing to construct a new building in the area. In other words, the construction of any building needs to gain permission from the municipality before the project starts. This division comes under the service department and usually has architectural engineers working there.

Significance of the Research

This research should be helpful in the study of any department in the government organization and municipalities. It should also lead to an improvement in the process of work in different organizations with similar processes. This project will be useful for any researcher in understanding how to analyze problems in any specific area of process.

Waiting Line Model

The waiting line model can best be understood by remembering a time when you had to wait somewhere in a long line, such as at a local bank, fast food restaurant, Wall-Mart, or any local market. For these waiting-in-line places, the time waiting is unacceptable and a waste of your time.

Many models have been developed to help bosses and managers make better decisions when the operation of a department means long waiting lines. In management science theory, there is a model, known as queuing theory, which deals with waiting lines. Waiting-line models usually consist of mathematical formulas that can be used to determine the operating characteristics for a waiting line and include the following:

1. The probability that no units are in the system.
2. The average number of units in the waiting line.
3. The average number of units in the system.
4. The average time a unit spends in a waiting line.
5. The average time a unit spends in the system.

6. The probability that an arriving unit has to wait for service.

With this waiting-line model, this kind of problem can be determined and analyzed. The following defines the structure of the waiting-line system:

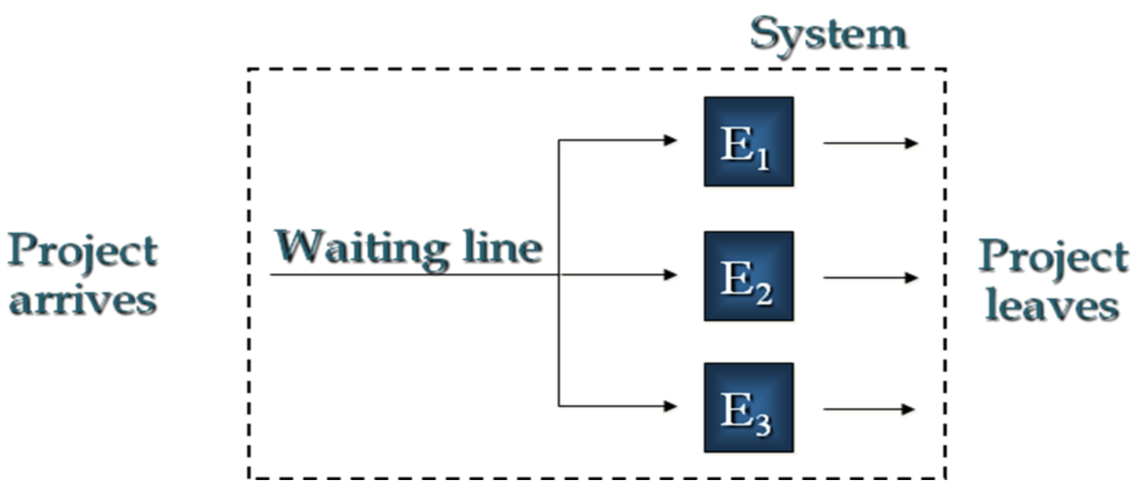
1. Distribution of arrivals: This expresses the arrival of customers into the system, which means the number of the applications that arrived in the department.
2. Distribution of service time: This means the time that each application will take in the process; it is usually a random variable.
3. Queue discipline: There are many different disciplines. The two most important are, first-come first-served and last-come first-served.
4. Single service channel: This means there is only one channel, which serves every person or application inside the system. The advantage of this system is the clear regulation, but the disadvantage is the wasted time that will be spent in the waiting line.
5. Multiple service channels: This model of service channels is applied in municipalities' departments. In this process, no specific application goes to a specific channel; each available channel should take the first application in the waiting line. This may be faster than the single service channel model.

After the model has been identified, a code that will be used for the form to describe various queuing systems must be understood. The form will be A/B/K. The letter A identifies the arrival distribution of the application in the municipalities; the letter B identifies the departure distribution of the application in municipalities; and the letter K defines the number of channels for the system in the municipalities.

The goal of this study was to reduce time of service and waiting for each project inside the construction permits department. Figure 1.5 shows the existing process in the construction permits department by considering the different number of engineers in each sub-municipality.

Figure 1.5

Process In the Construction Permits Department



The kind of model used for this project requires data, and may have assumptions. As has been said, the data which were collected were real data from the Municipality, such as the number of applications, the number of engineers, and the department’s office hours. For the service times, which are the time it takes to finish applications, this researcher took random samples in one sub-municipality and applied the result to all the different sub-municipalities by calculations done by using a standard deviation formula. That formula will be explained in the following section.

CHAPTER 2

LITERATURE REVIEW

This chapter reviews works by other researchers, particularly those relating to queuing analysis and waiting-line models. The works consulted here were of benefit to the current study as this researcher learned what previous researchers had found advantageous or disadvantageous in their studies of similar problems.

The history of queuing theory began in 1909 with Erlang, A. K. He experimented with this theory when looking at the changeable demand in telephone traffic. Over the years, he solved the problem of delays in telephone dialing and published his results.

Sridhar (2001) wrote about the waiting-line model. He pointed out how library service providers totally ignore quantitative methods which may be needed to improve the work. He then discussed how the waiting-line model can be used to reduce delays in the system and increase the quality of library services, which leads to customer satisfaction. Sridhar used assumptions for a queuing model to find all numbers that he needed, such as arriving time, and he collected data such as, the number of arriving library customers, service channels, and expected wait time. He then determined the following:

1. Determine the maximum amount of time that customers will have to wait for service.
2. Apply the waiting-line theory.

3. Find ways by which customers can perceive the waiting time to pass quickly by developing agreeable surroundings.

He recommended some ways to do this, which include: provision for reservations, making wait time comfortable, reducing perception of actual waiting, and enabling some of preliminaries to be done during the waiting.

Brega, Cantarero, and Lee (2004) studied how to improve algorithms for Quick Pass systems. They studied a theme park, where there is a line called “Quick Pass,” which requires an extra fee, so it is faster than the normal queuing line. They analyzed the arrival time and how visitors choose whether to enter the normal queue, or use the Quick Pass queue. In their research, they created several models to determine a boarding pass ratio and the number of Quick Passes throughout the day. By considering all information, such as the number of arrivals to the normal queue or the Quick Pass queue, the time that the guest took to get to the Quick Pass, and the peak arrival times. After they applied their models and after two months of trials, they summarized the performance of each Quick Pass. They found that the average hourly wait times are similar for all models. On other hand, the results gave a large variance for model that vary in the number of Quick Passes issued, which meant fewer people remained in the queues, and also tended to issue fewer Quick Passes in the future.

Frolkin, van der Wyck, and Burgess (2004) determined an optimal system for allocating Quick Passes to theme park visitors. They analyzed two different types of queuing systems: virtual systems and Quick Pass systems. Their goal was to reduce the waiting time in the queue as much as possible. After collecting the data, they used two different simulations for this situation. They then listed systems for allocating Quick Pass by using the simulations. The current system in the theme park gave many people a long wait time. After determining that, Frolkin et al. ran five different systems of Quick Pass allocations, and the results showed that the Quick Pass5 system gave the best results. This system (QP5) gave out many Quick Passes for slots early in the morning and late afternoon. As a result, many people had a short wait and nobody waited more than 40 minutes.

To increase the effectiveness of a hospital emergency room, Green, Soares, Giglio, and Green (2005) used queuing theory. Their evaluation used a queuing model to identify staffing patterns in order to reduce the number of patients who leave without having treatment or without being seen. The data were collected from an urban hospital, and then an M/M/s queuing model was used to analyze and estimate the number of providers who needed to be assigned to the different shifts. After applying the number of new staffing providers in the software, the results showed that 258 fewer patients left without being seen, a reduction of 22.9 percent.

Kammoun, Mehri, and Djemel (2006) showed how a mathematical analysis can be used to estimate the performance of a system. They used a queuing theory model and linear programming to solve a waiting line model in the Tunisia airport. They focused on the cost of services and how that can affect the waiting cost. Their objective was to minimize the total expected cost. The results indicated that, to meet their goals, TUNISAIR Company should employ ten traveling agents for registration at rush hours.

When considering economics, a balance must be reached between the cost of waiting and the cost of service. Fink and Gillett (2006) explained this side of the issue. The service cost is known and easy to find, but the cost of waiting is not clear. They considered waiting time as a level of quality that, in some companies, can be determined by customer satisfaction. Dissatisfied customers can affect sales, cause a loss of reputation, or a decline in employee performance, which may be considered as the cost of waiting. After analyzing what can affect the cost, Fink and Gillett set out several solutions to reduce the cost of customer dissatisfaction. These included such things as a waiting time guarantee, which means giving special offers to those customers who wait more than a specified time in line. For example, if a customer waits more than 5 minutes, he/she may receive 10% off their order. The following list contains the best solutions Fink and Gillett had to reduce waiting time, and keep a balance between the cost of waiting and the cost of service:

1. Increase service points.
2. Post waiting times.
3. Special handling of customer issues.
4. Express-lane categories.
5. Environment.

Liao (2007) studied optimal staffing policy for queuing systems with customer demand in a restaurant. He used an estimation to find the waiting cost, which can help managers or decision makers reach a better decision by determining the optimal number of servers for different periods of time every day to minimize the waiting service-time cost. According to Liao, “small reductions in waiting time will result in better quality of service and lead to enhanced customer loyalty and increased sales” (p.3). He estimated the number of balking customers (i.e., not joining a queue because the prospective customer judges the queue to be too long” (Jones, 1999) by multiplying the queue length with the balking index (average willingness of customers for balking behavior of some queue systems). Liao also found the number of reneging customers (i.e., those who leave the queue after having spent some time in it) by multiplying the expected waiting time in the queue by the reneging index (average willingness of customers for balking behavior in some queue systems). After that, Liao used the SIPP M/M/s model by considering an exponential distribution in this case, and all customers are first-come first-served. The result was that 6 servers provided the optimal solution, which can reduce the expected queue length to 0.33 from around 10, and the expected waiting time in queue to 0.14 from more than 4 minutes. Liao found that the optimal number of 6 servers led to reducing the total cost to $583 from more $1533.

Many researchers have done studies aimed at reducing the waiting time for surgery. Hopkins et al. (2008) studied the cost-effectiveness of reducing waiting time for cataract surgery. Their objective was to reduce the waiting time for cataract surgery, which can lead to better results for the patients, with a reduced volume of extra treatments needed. The data on the cost of extra treatments were collected from an Ontario hospital. Patients who wait for this surgery may have negative outcomes, such as vision loss, reduced quality of life, and an increased rate of injuries, which require a higher volume of additional treatments. A queuing model was used to determine the optimal result. For this queuing model, different assumptions were made in order to produce a numerical answer. The result showed that, to reach the publicly targeted standard waiting time for hospital surgery), annual treatment volumes should be increased by 4 percent. That would reduce the mean waiting time from the current 109 days to 49 days. With this new targeted wait time, the number of patients waiting for services would drop to about 20,955 from the current average of 46,615.

CHAPTER 3

RESEARCH PROCEDURE

As has been stated, it is necessary to study and analyze the construction permit division in order to improve the work and accelerate the process in the organization. Now, it is time to discuss what method and procedure should be used for this kind of process.

How the Topic Was Chosen

The researcher talked to Tom Bowlin, a faculty member at the University of Kansas and Committee Chair for this project, about what research might be of benefit to the researcher's future. After discussion about the researcher's background, the Municipality of Riyadh, Saudi Arabia was chosen as the subject for study in this research paper. The project proposal was approved by the Committee Chair before the researcher began collecting and analyzing data.

How the Information and Data Were Obtained

The researcher traveled to Saudi Arabia to collect and gather all the information needed for the project. There, the author met engineers and employees with knowledge of the work in the municipality in general, and of the construction permit processes specifically. The researcher met with two sub-municipality managers. Then, the following three steps were performed to collect all the data used in this project.

1. The researcher met with individuals from the Riyadh Municipality, which is the main Municipality: Here, the researcher gathered the total number of applications that each sub-municipality produced in the last year. That helped define the number of applications per week.
2. The researcher met with individuals from the sub-municipalities: These individuals helped the researcher determine the number of engineers in each department. They also helped the researcher determine the average working time by collecting a sample of 8 applications from 5 engineers in one of the sub-municipalities.
3. The researcher also determined the average wage of the engineers working in the construction permits department.

Model for This Project

As has been stated, the process to issue or renew permits in the construction department involves a waiting time. The Queue model has been chosen to analyze and reduce that waiting time. A multiple service channel is the best queuing model to analyze the data with a G/G/s template. This model needs several mathematical formulas. Samples were collected from five engineers. Eight samples were collected from each engineer, four for the first review and four for the final review. These samples were used in the Descriptive Statistics Tool to find the mean of the samples and the standard deviation, which can be used in the mathematical model.

The expected wait in the queue was set as the most important element that can be improved to accelerate the process. Two plans were then chosen to reduce the waiting time in the queue.

Analysis of the Information

After the data were collected, the researcher met with his Committee Chair to be sure the mathematical model was running well. After that, variables were developed using the G/G/s template. Finally, different recommendations were developed, each with a different cost.

CHAPTER 4

THE RESULTS

Software Program To Be Used

The software and templates that were used in this project had to be discovered. Excel with a G/G/s template, was used to drive key estimates for the municipality branches' current construction department staffing, as follows:

1. The average time a project spends in the system (waiting time plus service time).
2. The average number of projects in the waiting line.
3. The average time the project spends in the waiting line.
4. The probability that the project has for service.

Mathematical Model:

The following calculations must be done to use the mathematical model software and find numbers that require use in the software:

1. Arrival rate of projects per hour: The average number of projects that arrive per hour can be found by dividing the number of projects by the number of hours the engineers spend working per week.
2. Service rate: The average number of projects that may be done daily, divided by the number of office hours per day.
3. Number of service channels: The number of engineers who are available and can receive an application.

4. Standard deviation: For the standard deviation, the mean of the number of applications that enter the department must be found. Three standard deviations account for about 99% of the distribution. The following formula is used to find the standard deviation:

$$s = \sqrt{\frac{1}{N-1} \sum_{i=1}^{N} (x_i - \overline{x})^2},$$

5. SqCV for inter-arrival times: The mean, which is the office hours per week, must be found and divided by the number of applications that have been completed in a week. For this situation, the standard deviation is equal to the mean because the number is random (expediential distribution), then:

   SqCV for inter-arrival times = (standard deviation/ mean)^2 = SqCV for inter-arrival times

6. SqCV for service times: The standard deviation of service time is divided by the mean of service time (standard deviation of service time/ mean)^2.

To find the mean and standard deviation of the samples, the Descriptive Statistics Tool was used to help get the mean and standard deviation for the service time, which are used in the G/G/s template.

After analyzing each sub-municipality and finding all important outputs, such as the expected wait in the queue, the queue length, the expected wait in the system, and the expected number in the system, the most important output that may help management improve work in the municipality's system was set as the expected wait in the queue. The targeted expected wait time was set at less than one minute. It was then necessary to find which would be best for each municipality to use to improve the work and meet the target, either by adding one more engineer, which would cost $2,500, or by adding overtime for half of the engineers, which would cost $1,400/engineer for the whole month. Another option could be to keep operation of the sub-municipality unchanged.

Plan A and Plan B

Plans A and B were reviewed for all branches and one of them was chosen for each branch. Plan A was to choose half of the engineers in the department to work overtime every day. If there are only two engineers in a branch, one will work overtime for the first half of the month and the other will work overtime for the second half of the month. Plan A will cost $1,400 for each engineer per month, so overtime will cost $700 for each engineer, with a total additional overtime cost per month of $1,400. Plan B was to hire a new engineer in the department, for a cost of $2,500. Plan A can reduce the waiting time in the queue and accelerate the process. If Plan A does not reduce that waiting time to the target waiting time, Plan B, which will cost more than Plan A, will be implemented.

Finding the Mean and Standard Deviation

As has been shown, there are two different samples which state the first review and the last review. A Descriptive Statistics Tool must be used in the data analysis from the Excel software. After plugging all different samples in the Descriptive Statistics Tool software, the mean and standard deviation were found, as shown in the Table 4.1 and Figure 4.1.

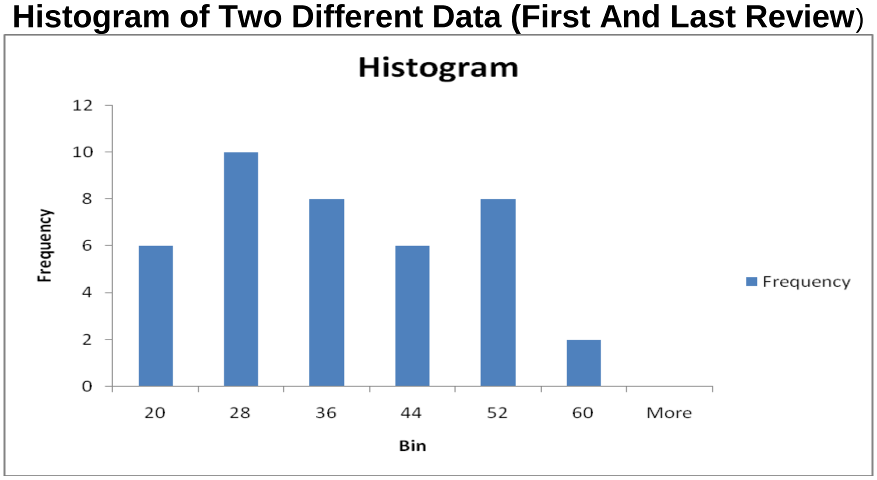
Table 4.1

Descriptive Statistics Tool (First And Last Review)

Variable	Result
Mean	**33.65**
Standard Error	1.856571834
Median	34.5
Mode	25
Standard Deviation	**11.74199127**
Sample Variance	137.874359
Kurtosis	-0.697963143
Skewness	0.309892797
Range	46
Minimum	14
Maximum	60
Sum	1346
Count	40

Figure 4.1

Histogram of Two Different Data (First And Last Review)



Before an analysis of each branch of the main municipality can begin, some calculations must be performed to find the following:

1. Arrival rate: The number of applications submitted for a one-year period to each branch will be divided by 52 weeks to ascertain the average number submitted per week. That number will then be divided by 30 hours (the number of office hours worked per week.
2. Service rate: The service rate is found by dividing the number of daily office hours by the mean of the sample taken from one of the branches:

   360/33.65=10.69 then 10.69/6= 1.78 applications/hour. (The preceding number is fixed for all branches.)
3. Number of engineers: This will be different for each branch, as each branch has a different number of engineers.
4. SqCV for interarrival time: In this situation, and because the time of arrival of an application is random (exponential distribution), the standard deviation will be equal to the mean, which is going to be equal to 1, which number is fixed for all branches.
5. SqCV for service time: According to the data analysis and Table 4.1, which provides the mean and standard deviation of service time:

   SqCV for service time = (Standard deviation/mean)^2 = (11.74/33.65)^2= 0.121. This number is fixed for all branches.

Three inputs from the five are required for all branches, and two of these inputs depend on the data which were gathered from the municipalities. After that has been established, these numbers will be applied to analyze each branch with consideration for the different number of engineers employed and the different number of applications arriving at each branch.

Analysis of the Municipality's Branches

Diera (Alshomisa) Branch

The Diera (Alshomisa) sub-municipality (see Figure 4.2) serves 16 areas in the city, with 228,228 people in 17 Mi^2. The urban density is around 52.5%, which means there are still empty areas for construction.

According to the policy of planning (PP), any areas in the city should include 28%-32% government services such as, roads, building, and facilities. From that, it can be assumed that these services cover 30% in the areas, which means there are still 17.5% empty in the Municipality area.

Figure 4.2
The Alshomisa Sub-municipality

The work in the Diera branch: As has been stated, the focus of this research is on the permits department for each branch in the city. The Diera branch has three engineers in the permits' department and they process 954 applications, which means they will review the application twice (954*2= 1908) yearly, or 36 per week.

Data and assumptions**:** There are three engineers under the department manager. They receive 36 applications per week, and because, as stated above, the time of arrival of an application is random (expediential distribution) it is assumed that the standard deviation will be same as the mean. Every engineer may finish 8 projects per week.

Mathematical model for this branch: The mathematical model for the Diera Branch can be seen in the following charts, below.

Diera (alshomisa)	
Inputs	
Arrival rate	1.223076923
Service rate	1.783
Number of service channel	3
standard deviation	11.74199127
SqCV for interarrival times	1
SqCV for service times	0.1217

G/G/s template using the Allen-Cunneen approximation	
Inputs	
Arrival rate	1.230
Service rate per server	1.780
Number of servers	3
SqCV for interarrival times	1.000
SqCV for service times	0.121000
Calculations of intermediate quantities	
Ratio of arrival rate to service rate	0.691
Server utilization	0.230
A Poisson quantity	0.972

Erlang C-function	0.036
Important outputs	
Expected wait in queue	**0.004869**
Expected queue length	0.005989
Expected wait in system	0.566667
Expected number in system	0.697000

Plan A: adding overtime for half of engineers:	
Important outputs	
Expected wait in queue	0.003080
Expected queue length	0.003234
Expected wait in system	0.564878
Expected number in system	0.593121

Plan B: adding one more engineer:	
Important outputs	
Expected wait in queue	0.000547
Expected queue length	0.000673
Expected wait in system	0.562345
Expected number in system	0.691685

It was observed that Plan B was better for accelerating the process in the department by decreasing the time to 7.35 minutes. However, the cost of the plan, which would be $2,500, had to be considered. Plan B would cost $700/engineer, and that will be addressed at the end of this chapter.

Ma'azar Branch

The Ma'azar sub-municipality serves 9 areas in the northwest of the city, with 267,284 of people. It covers 22 Mi^2 of the total city area (see Figure 4.3). The urban density is around 46%, which means, after adding the PP 30%, there is 24% available for construction.

The Work in the Ma'azar Branch. In the permits department for the Ma’azar branch, there are four engineers checking and working with applications. They review 497*2, or 994 applications yearly, which means 19.1 per week.

Data and Assumptions. There are four engineers under the manager of the department. The department receives 19.1 projects per week.

Figure 4.3

The Ma’azar Sub-municipality

Mathematical Model for This Branch. The mathematical model for the Ma’azar Branch can be seen in the following charts.

Ma’azar	
Inputs	
Arrival rate	0.638461538
Service rate	1.783
Number of service channel	4
standard deviation	11.74199127
SqCV for interarrival times	1
SqCV for service times	0.1217

G/G/s template using the Allen-Cunneen approximation	
Inputs	
Arrival rate	0.636
Service rate per server	1.780
Number of servers	4
SqCV for interarrival times	1.000
SqCV for service times	0.121700
Calculations of intermediate quantities	
Ratio of arrival rate to service rate	0.357
Server utilization	0.089
A Poisson quantity	1.000
Erlang C-function	0.001
Important outputs	
Expected wait in queue	0.000045
Expected queue length	0.000029
Expected wait in system	0.561843
Expected number in system	0.357332

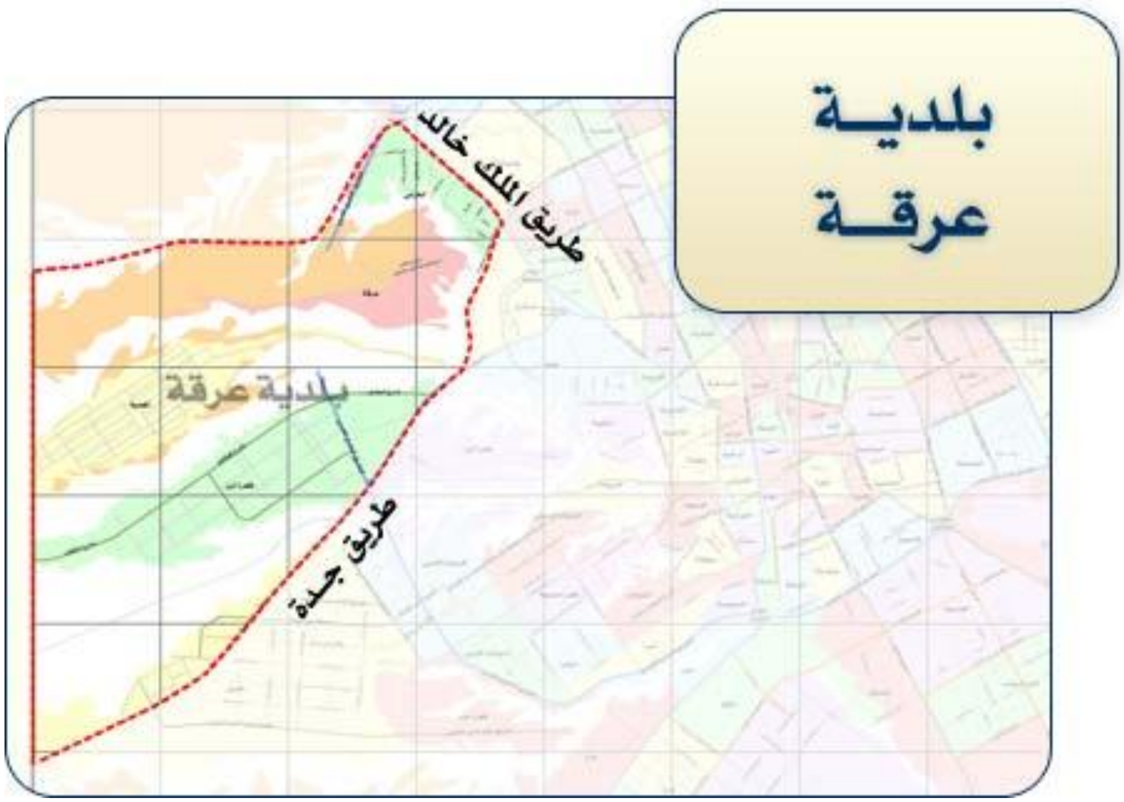
For the Ma’azar branch, the results show that the expected wait in the queue is 0.000045, which means (0.000045*60=0.0027 *60= 0.9 second), so this branch is overstaffed.

Erga Branch:

This sub municipality is the latest branch to come under the Riyadh Municipality. Originally, it was a district outside of Riyadh City before Riyadh expanded. It includes five areas with 45,751 people. It has 56 Mi^2, but more than 30% is comprised of mountains and valleys that are not good for construction (see Figure 4.4).

Figure 4.4

The Erga Sub-Municipality



The Work in the Erga Branch. The four engineers who work with applications process 1,689 applications yearly. Because each is reviewed twice, the engineers conduct 3,378 reviews.

Data and Assumptions. There are four engineers under the manager of the department. The department receives 64.9 projects per week.

Mathematical Model for This Branch. The mathematical model for the Erga Brandh can be seen in the following charts, below.

Erga	
Input	
Arrival rate	2.165384615
Service rate	1.783
Number of service channel	4
standard deviation	11.74199127
SqCV for interarrival times	1
SqCV for service times	0.1217

G/G/s template using the Allen-Cunneen approximation	
Inputs	
Arrival rate	2.160
Service rate per server	1.780
Number of servers	4
SqCV for interarrival times	1.000
SqCV for service times	0.121000
Calculations of intermediate quantities	
Ratio of arrival rate to service rate	1.213
Server utilization	0.303
A Poisson quantity	0.973
Erlang C-function	0.038
Important outputs	
Expected wait in queue	0.004340
Expected queue length	0.009374

Expected wait in system	0.566137
Expected number in system	1.222857

For the Erga branch, the results show the expected wait in the queue is (0.0043*60= 0.26*60= 0.15 seconds), which is less than minute, so this branch is also overstaffed.

Olaya Branch

The Olaya sub-municipality is the most important branch in Riyadh City. It has 15 areas, with 389,613 people, on 47.5 Mi^2. The urban density is more than 57%, which means there is only 13% available for construction (see Figure 4.5).

Figure 4.5
Olaya Sub-Municipality

***The Work in the Olaya Branch*.** The Olaya branch is like any other sub-municipality. There are four engineers working with applications. They process 2,141 applications yearly, which mean they review the applications 4,282 times, based on last year's data.

***Data and Assumptions*.** As stated above, there are 4 engineers in the Olaya branch, and they receive 82.3 applications per week. All the engineers work full time, six hours a day, five days a week.

Mathematical Model for This Branch. The mathematical model for the Olaya Branch can be seen in the following charts, below.

Olaya branch	
Inputs	
Arrival rate	2.744871795
Service rate	1.783
Number of service channel	3
standard deviation	11.74199127
SqCV for interarrival times	1
SqCV for service times	0.1217

G/G/s template using the Allen-Cunneen approximation	
Inputs	
Arrival rate	2.740
Service rate per server	1.780
Number of servers	3
SqCV for interarrival times	1.000
SqCV for service times	0.121000
Calculations of intermediate quantities	
Ratio of arrival rate to service rate	1.539
Server utilization	0.513

A Poisson quantity	0.860
Erlang C-function	0.251
Important outputs	
Expected wait in queue	0.054128
Expected queue length	0.148311
Expected wait in system	0.615926
Expected number in system	1.687637

Plan A: adding overtime for half of the engineers:	
Important outputs	
Expected wait in queue	0.033121
Expected queue length	0.077835
Expected wait in system	0.594919
Expected number in system	1.398060

Plan B: adding one more engineer	
Important outputs	
Expected wait in queue	0.010327
Expected queue length	0.028297
Expected wait in system	0.572125
Expected number in system	1.567623

In the Olaya Branch, the expected wait in the queue is around 3.5 minutes. Adding one more engineer will reduce the number to 0.010, which means less than 1 minute. On the other hand, adding overtime for half of the engineers will reduce the time to around 2 minutes.

South Branch

The South branch is located in the south of Riyadh City. It has 76,403 people living in five different areas. The total density is 38.6Mi^2. Much of this branch is empty, and the urban density is 32.8% (see Figure 4.6). The South branch has a greater chance of an increase in demand based on an empty area of almost 40%.

Figure 4.6
South Sub-Municipality

The Work in the South Branch. The South branch has two engineers in the permits' department. They process 2,103 applications per year, which means they review 4,206 applications yearly, or 80.88 applications per week.

Data and Assumptions. There are two engineers under the department manager. They receive around 80.88 applications per week, and each engineer can finish 40 projects per week. The two engineers work full time every day.

Mathematical Model for This Branch: The mathematical model for the South Branch can be seen in the following charts.

South	
Input	
Arrival rate	2.696153846
Service rate	1.783
Number of service channel	2
standard deviation	11.74199127
SqCV for interarrival times	1
SqCV for service times	0.1217

G/G/s template using the Allen-Cunneen approximation	
Inputs	
Arrival rate	2.690
Service rate per server	1.780
Number of servers	2
SqCV for interarrival times	1.000
SqCV for service times	0.121000
Calculations of intermediate quantities	
Ratio of arrival rate to service rate	1.511
Server utilization	0.756
A Poisson quantity	0.687
Erlang C-function	0.650
Important outputs	
Expected wait in queue	0.419045
Expected queue length	1.127232
Expected wait in system	0.980843
Expected number in system	2.638468

Plan A: adding overtime for half the engineers	
Important outputs	
Expected wait in queue	0.228998
Expected queue length	0.528985
Expected wait in system	0.790796
Expected number in system	1.826738

Plan B: adding one more engineer	
Important outputs	
Expected wait in queue	0.050947
Expected queue length	0.137047
Expected wait in system	0.612745
Expected number in system	1.648283

The process service in the South branch takes a little longer than in the first branches. Here it takes (0.41*60= 24.6 minutes) in the queue. With Plan A. the time of the expected wait in the queue is reduced to 3 minutes. On other hand, Plan B would reduce the time to 13.2 minutes. Plan B would still not satisfy the customers, but the cost (to be discussed at the end of this chapter) must be considered.

Al-Malaz Branch

The Al-Malaz branch serves 15 areas of Riyadh City. It is one of the historical branches in Riyadh City, with 824,640 people living in the area. The total density is 19.3Mi^2. Most of this branch is full, with an urban density of 74% (see Fig. 4.7). The Al-Malaz branch is the one of the most crowded in the city. Most of the work in the permits department is for renewing or remodeling homes.

The Work in the Al-Malaz Branch. There are three engineers in the permits' department and they process 1,420 applications annually, most of which are for renewing or remodeling. As they review each application two times, they will review 2,840 per year, which means 54.6 applications per week.

Figure 4.7

Al-Malaz Sub-Municipality

Data and Assumptions. There are three engineers under the department manager. They receive around 54.6 applications per week, and all engineers work full time.

Mathematical Model for This Branch. The mathematical model for the Al-Malaz Branch can be seen in the following charts, below.

Al Malaz	
Inputs	
Arrival rate	1.820512821
Service rate	1.783
Number of service channel	3
standard deviation	11.74199127
SqCV for interarrival times	1
SqCV for service times	0.1217

G/G/s template using the Allen-Cunneen approximation	
Inputs	
Arrival rate	1.820
Service rate per server	1.783
Number of servers	3
SqCV for interarrival times	1.000
SqCV for service times	0.121700
Calculations of intermediate quantities	
Ratio of arrival rate to service rate	1.021
Server utilization	0.340
A Poisson quantity	0.935
Erlang C-function	0.096
Important outputs	
Expected wait in queue	0.015193
Expected queue length	0.027652
Expected wait in system	0.576046
Expected number in system	1.048404

In the Al-Malaz branch, it takes (0.0151*60= 0.91*60 =0.54 minutes) in the queue. Since it takes only around 1 minute before a customer can be served, it is not necessary to do the two option plan to reduce the waiting time in this branch.

Al Sulay Branch

The clientele for most of the Al-Sulay branch is made up of small-industry companies. The branch serves 10 areas in Riyadh City, and 48,041 people live in these areas. The total density is 111.5Mi^2 (see Figure 4.8). Most of the Al-Sulay area contains companies and business. There are also some residential areas, because the urban density is too low at almost 28.22%. Even though there are so many Mi^2 for companies and business storage, there are some areas ready to build residences.

Figure 4.8

Al Sulay Sub-Municipality

The Work in the Al Sulay Branch. There are two engineers in the permits department and they review 717 applications yearly, and they will review 1,434 per year, which means 27.5 applications per week

Data and Assumptions. There are two engineers under the department manager. They receive around 27.5 applications per week, and all engineers work full time.

Mathematical Model for this Branch. The mathematical model for the Al Sulay Branch can be seen in the following charts.

Al Sulay	
input	
Arrival rate	0.919230769
Service rate	1.783
Number of service channel	2
standard deviation	11.74199127
SqCV for interarrival times	1
SqCV for service times	0.1217

G/G/s template using the Allen-Cunneen approximation	
Inputs	
Arrival rate	0.919
Service rate per server	1.783
Number of servers	2
SqCV for interarrival times	1.000
SqCV for service times	0.121700
Calculations of intermediate quantities	
Ratio of arrival rate to service rate	0.515
Server utilization	0.258
A Poisson quantity	0.919
Erlang C-function	0.106
Important outputs	
Expected wait in queue	0.022377
Expected queue length	0.020565
Expected wait in system	0.583230
Expected number in system	0.535988

Plan A: adding overtime for half of the engineers	
Important outputs	
Expected wait in queue	0.016105
Expected queue length	0.012675
Expected wait in system	0.576958
Expected number in system	0.454066

Plan B: adding one more engineer:	
Important outputs	
Expected wait in queue	0.002082
Expected queue length	0.001913
Expected wait in system	0.562934
Expected number in system	0.517337

The expected wait in the queue for the Al Sulay branch was 1.2 minutes. When applying the two plans, the time was reduced to 7 seconds using Plan A and to 57 seconds (which is less than one minute) using Plan B. Using plan B can meet the target with less cost.

Nomer Branch

The Nomer branch is the one of the new branches that were started several years ago. Most of the area is empty, with 68,456 people living in 40.1Mi^2. The urban density is around 36.19%. The Nomer Branch serves seven areas, of which three are new. The main reason the area is empty is because the southern part of the branch contains mountains and valleys that are not ready for construction (see Figure 4.9).

The Work in the Nomer Branch. There are five engineers in the permits' department and they review 4,190 applications yearly, which works out to 80.5 applications per week.

Data and Assumptions. There are five engineers under the department manager. They receive around 80.5 applications per week, and all engineers work full time.

Figure 4.9

Nomer Sub-Municipality

Mathematical Model for This Branch. The mathematical model for the Nomer Branch can be seen in the following charts.

Nomer	
Inputs	
Arrival rate	2.685897436
Service rate	1.783
Number of service channel	5
standard deviation	11.74199127
SqCV for interarrival times	1
SqCV for service times	0.1217

G/G/s template using the Allen-Cunneen approximation	
Inputs	
Arrival rate	2.680
Service rate per server	1.783
Number of servers	5
SqCV for interarrival times	1.000
SqCV for service times	0.121700
Calculations of intermediate quantities	
Ratio of arrival rate to service rate	1.503
Server utilization	0.301
A Poisson quantity	0.986
Erlang C-function	0.020
Important outputs	
Expected wait in queue	0.001826
Expected queue length	0.004894
Expected wait in system	0.562679
Expected number in system	1.507979

The expected wait in the queue for the Nomer branch was 6.30 seconds. Therefore, this branch is also overstaffed.

Al Naseem Branch

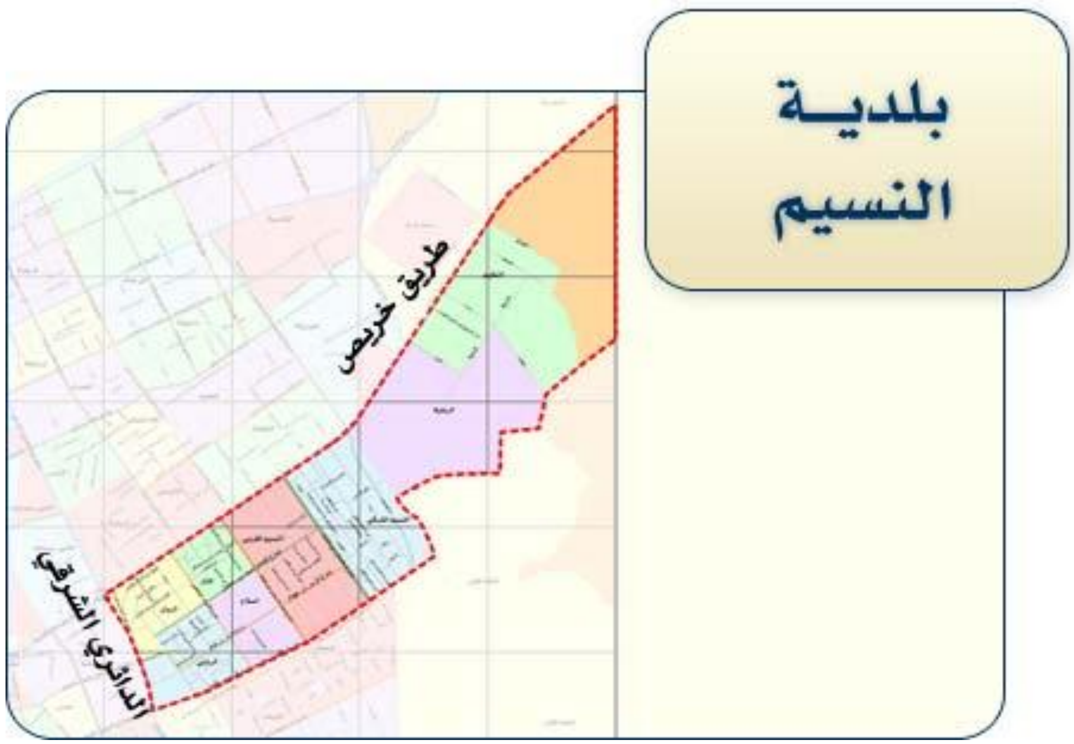
The Al Naseem branch is located in the eastern part of Riyadh City. There are 377,165 people living in 33.5Mi^2, and the urban density is around 43.33% (see Figure 4.10). This branch serves eight areas.

The Work in the Al Naseem Branch. The process in the Al Naseem branch is like any other branch's normal process in the system. There are three engineers in the permits department and they review 3,568 applications yearly.

Data and Assumptions. There are three engineers under the department manager. They receive around 68.6 applications per week, and all engineers work full time.

Figure 4.10

Al-Nasseem Sub-Municipality



Mathematical Model for This Branch. The mathematical model for the Al-Naseem Branch can be seen in the following charts.

Al Naseem	
Inputs	
Arrival rate	2.287179487
Service rate	1.783
Number of service channel	3
standard deviation	11.74199127
SqCV for interarrival times	1
SqCV for service times	0.1217

G/G/s template using the Allen-Cunneen approximation	
Inputs	
Arrival rate	2.280
Service rate per server	1.783
Number of servers	3
SqCV for interarrival times	1.000
SqCV for service times	0.121700
Calculations of intermediate quantities	
Ratio of arrival rate to service rate	1.279
Server utilization	0.426
A Poisson quantity	0.899
Erlang C-function	0.164
Important outputs	
Expected wait in queue	0.029970
Expected queue length	0.068331
Expected wait in system	0.590822
Expected number in system	1.347075

Plan A: adding overtime for half of the engineers	
Important outputs	
Expected wait in queue	0.018942
Expected queue length	0.037126
Expected wait in system	0.579795
Expected number in system	1.136397

Plan B: adding one more engineer:	
Important outputs	
Expected wait in queue	0.005246
Expected queue length	0.011960
Expected wait in system	0.566098
Expected number in system	1.290704

The expected wait in the queue for the Al Naseem branch was 1.44 minutes. When applying the two plans, the time was reduced to 1.04 seconds using Plan A and to 18 seconds (which is less than one minute) using Plan B. Using plan A can meet the target with less cost.

Al-Shafe Branch

The Al-Shafe branch is located in the south of the city. There are more than 133,678 people living in 42Mi^2. The branch serves 6 areas, most of which are empty, as can be seen from the map in Figure 4.11. The total urban density is 23.24%.

Figure 4.11
Al-Shafe Sub-Municipality

The Work in the Al-Shafe Branch. The Al-Shafe branch works full time with a normal process in the system like other sub municipality branches. There are two engineers in the permits department and they review 2,798 applications yearly.

Data and Assumptions. As stated, there are 2 engineers under the department manager. They receive around 53.8 applications per week.

Mathematical Model for This Branch. The mathematical model for the Al-Shafe Branch can be seen in the following charts.

Al shafe	
Inputs	
Arrival rate	1.79359
Service rate	1.783
Number of service channel	2
standard deviation	11.74199
SqCV for interarrival times	1
SqCV for service times	0.1217

G/G/s template using the Allen-Cunneen approximation	
Inputs	
Arrival rate	1.790
Service rate per server	1.783
Number of servers	2
SqCV for interarrival times	1.000
SqCV for service times	0.121700
Calculations of intermediate quantities	
Ratio of arrival rate to service rate	1.004
Server utilization	0.502
A Poisson quantity	0.799
Erlang C-function	0.336

Important outputs	
Expected wait in queue	0.105954
Expected queue length	0.189658
Expected wait in system	0.666807
Expected number in system	1.193584

Plan A: adding overtime for half of the engineers:	
Important outputs	
Expected wait in queue	0.070969
Expected queue length	0.108583
Expected wait in system	0.631822
Expected number in system	0.966687

Plan B: adding one more engineer	
Important outputs	
Expected wait in queue	0.014464
Expected queue length	0.025891
Expected wait in system	0.575317
Expected number in system	1.029817

In the Al-Shafe branch, the expected wait in the queue was 6 minutes. When applying the two plans, the time was reduced to 4.12 minutes using Plan A and to 50 seconds using Plan B. Using plan B can meet the target.

Al Urayja'a Branch

Al Urayja'a is a very important branch because it serves more than 267,599 people living in 30.5Mi^2. It has six big areas, with a total urban density of 35.03% (see Figure 4.12).

The Work in the Al Urayja'a Branch. Even with the large number of people living in these areas, there are more new empty areas available for residential construction. Last year, this branch received more than 4,750 applications.

Figure 4.12
Al-Urayja’a Sub-Municipality

Data and Assumptions. There are 3 engineers under the department manager. They receive around 91.3 applications per week.

Mathematical Model for This Branch. The mathematical model for the Al Urayja’a Branch can be seen in the following charts.

Al Urayja'a	
Input	
Arrival rate	3.044872
Service rate	1.783
Number of service channel	3
Standard deviation	11.74199
SqCV for interarrival times	1
SqCV for service times	0.1217

G/G/s template using the Allen-Cunneen approximation

Inputs	
Arrival rate	3.040
Service rate per server	1.783
Number of servers	3
SqCV for interarrival times	1.000
SqCV for service times	0.121700
Calculations of intermediate quantities	
Ratio of arrival rate to service rate	1.705
Server utilization	0.568
A Poisson quantity	0.834
Erlang C-function	0.315
Important outputs	
Expected wait in queue	0.076550
Expected queue length	0.232712
Expected wait in system	0.637402
Expected number in system	1.937703

Plan A: adding overtime for half of the engineers

Important outputs	
Expected wait in queue	0.045319
Expected queue length	0.117828
Expected wait in system	0.606171
Expected number in system	1.576045

Plan B: adding one more engineer

Important outputs	
Expected wait in queue	0.015025
Expected queue length	0.045676
Expected wait in system	0.575877
Expected number in system	1.750667

In the Al Urayja'a branch, it takes 4.2 minutes to be ready for review. Two options were applied and, by using Plan A, the waiting time was reduced to 54 seconds, which is less than one minute. Using Plan B, the waiting time was reduced to 2.42 minutes. Thus, Plan A became the targeted goal.

Al batha Branch

The Al batha branch is located in the center of Riyadh City. There are 824,640 people living in $15Mi^2$, as shown in Figure 4.13, below. This branch serves 20 areas, and is considered one of the highest urban-density areas at 81.48%. From this percentage, it can be seen that the PP is not applicable here because the history of these areas predates the existence of the PP.

Figure 4.13
Al Batha Sub-Municipality

The Work in the Al batha Branch. The Al batha branch works full time like any process in the system in the other sub-municipality branches. There is only one engineer in the permits' department and he reviewed 1,954 applications last year.

Data and Assumptions. There is one engineer under the department manager. He receives around 37.5 applications per week.

Mathematical Model for This Branch. The mathematical model for the Al batha branch can be seen in the following charts.

Al batha	
Input	
Arrival rate	1.252564
Service rate	1.783
Number of service channel	1
standard deviation	11.74199
SqCV for interarrival times	1
SqCV for service times	0.1217

G/G/s template using the Allen-Cunneen approximation	
Inputs	
Arrival rate	1.250
Service rate per server	1.783
Number of servers	1
SqCV for interarrival times	1.000
SqCV for service times	0.121700
Calculations of intermediate quantities	
Ratio of arrival rate to service rate	0.701
Server utilization	0.701
A Poisson quantity	0.588
Erlang C-function	0.701

Important outputs	
Expected wait in queue	0.737697
Expected queue length	0.922122
Expected wait in system	1.298550
Expected number in system	1.623187

Plan A: adding overtime for the engineer for only two weeks every month	
Important outputs	
Expected wait in queue	0.472052
Expected queue length	0.505095
Expected wait in system	1.032904
Expected number in system	1.105208

Plan B: adding one more engineer	
Important outputs	
Expected wait in queue	0.044065
Expected queue length	0.055081
Expected wait in system	0.604917
Expected number in system	0.756146

As shown in the results, the expected wait in the queue was around 44 minutes. With Plan B, it was reduced to 2.38 minutes. However, Plan A, adding overtime for the only engineer for half of the month, will reduce the waiting time to 28 minutes. Therefore, based on the results, Plan A cannot be chosen because the risk is too high that the overtime with just one engineer could not be entirely consistent, since there is no one to cover for the engineer if he could not work the overtime. The result is also still too far from the minimum requirement time.

Al Rawda Branch

The Al Rawda Branch, located in the northeast part of Riyadh City, is the biggest sub-municipality, with an area of 125.4Mi^2. It has more than 271,935 people living there. It serves 15 areas, with a total urban density of 21% (see Figure 4.14).

Figure 4.14

Al Rawda Sub-Municipality

The Work in the Al Rawda Branch. The two main departments--construction permits and inspection--are the most high stress departments, with very high demands placed on them. There are five engineers in the permits department, and they reviewed 14,378 applications last year.

Data and Assumptions. As stated above, there are 5 engineers under the department manager. They receive around 276.5 applications per week.

Mathematical Model for This Branch. The mathematical model for the Al Rawda Branch can be seen in the following charts.

Al Rawda	
Input	
Arrival rate	9.216667
Service rate	1.783
Number of service channel	5
standard deviation	11.74199
SqCV for interarrival times	1
SqCV for service times	0.1217

G/G/s template using the Allen-Cunneen approximation	
Inputs	
Arrival rate	9.210
Service rate per server	1.783
Number of servers	5
SqCV for interarrival times	1.000
SqCV for service times	0.121700
Calculations of intermediate quantities	
Ratio of arrival rate to service rate	5.165
Server utilization	1.033
A Poisson quantity	0.702
Erlang C-function	1.084
Important outputs	
Expected wait in queue	-2.061794
Expected queue length	-18.989119
Expected wait in system	-1.500941
Expected number in system	-13.823668

Plan A: adding overtime for half of the engineers	
Important outputs	
Expected wait in queue	0.404375
Expected queue length	3.194560
Expected wait in system	0.965227
Expected number in system	7.625295

Plan B: adding one more engineer	
Important outputs	
Expected wait in queue	0.244449
Expected queue length	2.251379
Expected wait in system	0.805302
Expected number in system	7.416830

In the Al Rawda branch, the results for the expected waiting time in the queue was a negative value, which means the number of service engineers is not high enough to handle the service load. It takes more than two hours, which may affect customers' satisfaction. This problem needs to be solved as quickly as possible. Using Plan B, the time was reduced to around 14 minutes, which is not bad when compared to something over two hours. On the other hand, Plan A reduced the waiting time in the queue to 24 minutes. This could not be used because it was very far from the target time.

North Branch

The North branch, located in the north of Riyadh City, has more than 19,000 residents living in 172.5Mi^2. It services 15 areas, most of which are empty. Work in this branch started just a few years ago. The total urban density is 8.2% (see Figure 4.15).

The Work in the North Branch. The North branch works full time, like any process in the system in the other sub-municipality branches. There are five engineers in the permits department, and they review 11,730 applications yearly.

Figure 4.15

North Sub-Municipality

Data and Assumptions. As stated above, there are five engineers under the department manager. They receive around 225.5 applications per week.

Mathematical Model for This Branch. The mathematical model for the North Branch can be seen in the following charts.

North	
Input	
Arrival rate	7.519231
Service rate	1.783
Number of service channel	5
Standard deviation	11.74199
SqCV for interarrival times	1
SqCV for service times	0.1217

G/G/s template using the Allen-Cunneen approximation

Inputs	
Arrival rate	7.510
Service rate per server	1.783
Number of servers	5
SqCV for interarrival times	1.000
SqCV for service times	0.121700
Calculations of intermediate quantities	
Ratio of arrival rate to service rate	4.212
Server utilization	0.842
A Poisson quantity	0.782
Erlang C-function	0.639
Important outputs	
Expected wait in queue	0.254963
Expected queue length	1.914768
Expected wait in system	0.815815
Expected number in system	6.126771

Plan A: adding overtime for half of the engineers

Important outputs	
Expected wait in queue	0.093896
Expected queue length	0.604688
Expected wait in system	0.654748
Expected number in system	4.216578

Plan B: adding one more engineer

Important outputs	
Expected wait in queue	0.059674
Expected queue length	0.448153
Expected wait in system	0.620527
Expected number in system	4.660156

The expected wait in the queue was 15 minutes. By applying Plan A, which is adding overtime, it was reduced to 5.32 minutes. On other hand, with Plan B, it was reduced to 3.31 minutes.

Summary of the Results and Solution of the Problem

After the results were found that showed which plan can be used to meet the goal, and the cost of each plan which was chosen, the total cost would be $21,000. With these results, all branches will meet the target waiting time in the queue except four branches (South, Al batha, Al Rawda, and North), but even those will improve the current waiting time in the queue, as shown in Table 4.2.

Table 4.2

Summary of the Results of Plans A and B

Branch Name	applying Plan A&B												
	Number of engineer before the improve	from G/G/s Tamplete in hours			In minutes*			Cost of Plan A &B		Result of plan A&B	cost of the result	Expected wait in queue	Number of engineer after the improve
		Current Expected wait in queue	Expected wait in Queue after improving		Current Expected wait in queue	Expected wait in Queue after improving		$1,400	$2,500				
			option A/$1400	option B/$2500		Plan A	Plan B	option A	option B				
Diera (alshomisa)	3	0.004869			0.17					0	0	0.17	3
Ma'azar	4	0.000045			0.01					0	0	0.01	4
Erga	4	0.00434			0.15					0	0	0.15	4
Olaya	3	0.054128	0.033121	0.010327	3.14	1.58	0.37	$2,100	$2,500	option B	$2,500	0.37	4
South	2	0.419045	0.228998	0.050947	25.08	13.43	3.03	$1,400	$2,500	option B	$2,500	3.03	3
Al malaz	3	0.015193			0.54					0	0	0.54	3
Al Sulay	2	0.022377	0.016105	0.002082	1.2	0.57	0.07	$1,400	$2,500	option A	$1,400	0.57	2
Nomer	5	0.001826			0.06					0	0	0.06	5
Al Naseem	3	0.02997	0.018	0.0052	1.47	1.04	0.18	$2,100	$2,500	option A	$2,100	1.04	3
Al shafe	2	0.105954	0.070969	0.014464	6.21	4.15	0.52	$1,400	$2,500	option B	$2,500	0.52	3
Al Urayja'a	3	0.07655	0.045319	0.015025	4.35	2.42	0.54	$2,100	$2,500	option B	$2,500	0.54	4
Al batha	1	0.737697	0.472052	0.044065	44.15	28.19	2.38	$700	$2,500	option B	$2,500	2.38	2
Al Rawda	5	-2.061794	0.404375	0.244449	123.36	24.15	14.39	$3,500	$2,500	option B	$2,500	14.39	6
North	5	0.254963	0.093896	0.059674	15.17	5.37	3.34	$3,500	$2,500	option B	$2,500	3.34	6
total	45										$21,000		52

*All numbers are a combination of seconds and minutes in a decimal value.

As noted above, there are two branches which are overstaffed with engineers, which means the number of engineers can be reduced and still meet the target waiting time in the queue. In addition, other improvements have been applied to reduce the waiting time in the queue. One improvement was to shift overstaffed engineers to branches which have long waiting times in the queues without having to apply either Plan A or Plan B to the branches that receive the overstaffed engineer. Table 4.3 shows the different number of engineers and the different costs of reducing waiting time in the queue without using Plans A and B. The total cost of this option is $16,000.

Table 4.3

Summary Of The Result Of Shifting Overstaffed Engineers Without Applying Either Plan A Or Plan B To Branches To Which They Were Shifted

Branch Name	moving overstaff engineers without applying Plan A&B inbranches that engineers moved to									
	Number of engineer before the improve	from G/G/s Tamplete in hours			In minutes*	moving engineers	Result	cost of this improvement	Expected wait in queue	Number of engineer after the moved
		Current Expected wait in queue	Expected wait in Queue after improving		Current Expected wait in queue					
			Plan A/$1400	Plan B/$2500						
Diera (alshomisa)	3	0.004869			0.17	0	0	0	0.17	3
Ma'azar	4	0.000045			0.01	2 to AlRawda	0	0	0.36	2
Erga	4	0.00434			0.15	0	0	0	0.15	4
Olaya	3	0.054128	0.033121	0.010327	3.14	0	option B	$2,500	0.37	4
South	2	0.419045	0.228998	0.050947	25.08	0	option B	$2,500	3.03	3
Al malaz	3	0.015193			0.54	0	0	0	0.54	3
Al Sulay	2	0.022377	0.016105	0.002082	1.2	0	option A	$1,400	0.57	2
Nomer	5	0.001826			0.06	1 to North	0	0	0.34	4
Al Naseem	3	0.02997	0.018	0.0052	1.47	0	option A	$2,100	1.04	3
Al shafe	2	0.105954	0.070969	0.014464	6.21	0	option B	$2,500	0.52	3
Al Urayja'a	3	0.07655	0.045319	0.015025	4.35	0	option B	$2,500	0.54	4
Al batha	1	0.737697	0.472052	0.044065	44.15	0	option B	$2,500	2.38	2
Al Rawda	5	-2.061794	0.404375	0.244449	123.36	0	2 from Ma'azar	0	3.45	7
North	5	0.254963	0.093896	0.059674	15.17	0	1 from Nomar	0	3.34	6
total	45							$16,000		50

The second improvement was done by shifting overstaffed engineers to branches which need more than one engineer and applying Plans A and B. Two engineers moved from the Ma'azar branch to the Al Rawda branch. This would reduce waiting time in the queue to 1.25 minutes instead of 14.39 minutes, using Plan B, the cost of which is $2,500. Also, one engineer moved from the Nomer branch to the North branch to reduce the expected waiting time in the queue to 1.07 minutes. The total cost to reduce the time, as shown in Table 4.4, is the same as applying Plans A and B ($21,000) with a greater reduction in the time.

Table 4.4

Summary of Results of Shifting Overstaffed Engineers by Applying Plans A and B to branches to Which They Were Shifted

Branch Name	moving overstaff engineers by applying Plan A&B in branches that engineers moved to									
	Number of engineer before the improve	from G/G/s Tamplete in hours			In minutes*	moving engineers	Result	cost of this improvement	Expected wait in queue	Number of engineer after the moved
		Current Expected wait in queue	Expected wait in Queue after improving		Current Expected wait in queue					
			Plan A/$1400	Plan B/$2500						
Diera (alshomisa)	3	0.004869			0.17	0	0	0	0.17	3
Ma'azar	4	0.000045			0.01	2 to AlRawda	2 to AlRawda	0	0.36	2
Erga	4	0.00434			0.15	0	0	0	0.15	4
Olaya	3	0.054128	0.033121	0.010327	3.14	0	Plan B	$2,500	0.37	4
South	2	0.419045	0.228998	0.050947	25.08	0	Plan B	$2,500	3.03	3
Al malaz	3	0.015193			0.54	0	0	0	0.54	3
Al Sulay	2	0.022377	0.016105	0.002082	1.2	0	Plan A	$1,400	0.57	2
Nomer	5	0.001826			0.06	1 to North	1 to North	0	0.34	4
Al Naseem	3	0.02997	0.018	0.0052	1.47	0	Plan A	$2,100	1.04	3
Al shafe	2	0.105954	0.070969	0.014464	6.21	0	Plan B	$2,500	0.52	3
Al Urayja'a	3	0.07655	0.045319	0.015025	4.35	0	Plan B	$2,500	0.54	4
Al batha	1	0.737697	0.472052	0.044065	44.15	0	Plan B	$2,500	2.38	2
Al Rawda	5	-2.061794	0.404375	0.244449	123.36	0	Plan B+2 Engineers	$2,500	1.28	8
North	5	0.254963	0.093896	0.059674	15.17	0	Plan B + 1 Engineer	$2,500	1.07	7
total	45							$21,000		52

CHAPTER 5:

RECOMMENDATIONS AND SUGGESTIONS FOR ADDITIONAL WORK

In Chapter 4, three results were been developed that managers in the municipality can use. Table 5.1 explains the option that this researcher recommends to minimize waiting time in the queue with the least cost.

Table 5.1

Summary of the Recommendation (Result of Shifting Overstaffed Engineers without applying Plans A and B to the Branches to Which They Were Shifted)

Branch Name	NOW		FUTUR			
	Number of engineer before the improve	Current Expected wait in queue	Result	cost of this improvement	Number of engineer after the improve	Expected wait in queue
Diera (alshomisa)	3	0.17	0	0	3	0.17
Ma'azar	4	0.01	0	0	2	0.36
Erga	4	0.15	0	0	4	0.15
Olaya	3	3.14	option B	$2,500	4	0.37
South	2	25.8	option B	$2,500	3	3.03
Al malaz	3	0.54	0	0	3	0.54
Al Sulay	2	1.2	option A	$1,400	2	0.57
Nomer	5	0.06	0	0	4	0.34
Al Naseem	3	1.47	option A	$2,100	3	1.04
Al shafe	2	6.21	option B	$2,500	3	0.52
Al Urayja'a	3	4.35	option B	$2,500	4	0.54
Al batha	1	44.15	option B	$2,500	2	2.38
Al Rawda	5	123.36	2 from Ma'azar	0	7	3.45
North	5	15.17	1 from Nomar	0	6	3.34
total	45			$16,000	50	

Using this recommendation, municipalities can reduce waiting time in the queue to less than one minute for 10 branches. In the other branches, the waiting time in the queue was reduced as much as possible with the least cost. The South branch reduced its waiting time from more than 25 minutes to 3.04 minutes. The Al batha branch reduced its waiting time from more than 44 minutes to 2.38 minutes. The Al Rawda branch reduced its waiting time from over 2 hours to 3.45 minutes. The North branch reduced its waiting time from 15.17 minutes to 3.36 minutes.

REFERENCES

Anderson, D.R., Sweeney,D.J., Williams,T.A., Martin,R.K.(2007), An interdiction to Management Science Quantitative Approaches to Decision Making

Brega, M.L., Cantarero, A.L. & Lee, C.L. (2004). Developing improved algorithms for QuickPass Systems.

Fink, R. & Gillett, J. (2006, Spring). Queuing theory and the Taguchi loss function: The cost of customer dissatisfaction in waiting lines, *International Journal of Strategic Cost Management.*

Frolkin, A.V., van der Wyck, F.D.W. & Burgess, S. (2004). Theme-Park Queueing Systems,

Green, L.V., Soares, J., Giglio, J.F. & Green, R.A. (2005). Using Queuing Theory to Increase the Effectiveness of Emergency Department Provider Staffing,

Hopkins, R.B., Tarride, J.E., Bowen, J., Blackhouse, G., OReilly, D., Campbell, H., Lim, M. & Goeree, R. (2008). Cost- effectiveness of reducing wait time for cataract surgery in Ontario.

Jewgeni H. D. (1995), Advances in Queuing Theory, Methods, and Open Problems, Section 1.3.

Jones, L.K. Inferring balking behavior from transactional data. Operations Research 1999; 47(5); 778-784.

Kammoun, H., Mehri, H. & Djemel, T. (2006). Solving of waiting lines models in the airport using queuing theory model and linear programming, Liao, P.Y. (2007). Optimal staffing policy for queuing systems with cyclic demands: Waiting cost approach,

Middle East Consultant Center (2005), Investment Climate In Arriyadh. Riyadh, Saudi Arabia.

Sridhar, M.S. (2001). Waiting Lines And Customer Satisfaction,