TRAFFIC CONTROL BY COMPUTER SIMULATION
AT
THE MINISTRY OF ECONOMY INTERSECTION

BY

ADNAN A. BASHIR

SUPERVISOR

PROF. ARUN WALVEKAR

SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN INDUSTRIAL ENGINEERING

FACULTY OF GRADUATE STUDIES

UNIVERSITY OF JORDAN

FEBRUARY 1991

TRAFFIC CONTROL BY COMPUTER SIMULATION

AT

THE MINISTRY OF ECONOMY INTERSECTION

The examining committee consider this thesis satisfactory and acceptable for the award of the degree of master of science in Industrial Engineering.

Approved :

PPROF. ARUN WALVEKAR

Date : FEB. 26, 1991

ملخص

تعاني بعض التقاطعات المرورية في الأردن وخاصة في العاصمة عمان، من ازمات خانقة وتأخر ملحوظ، وفترة انتظار طويلة نسبيا للعبور من خلال التقاطع، وكان من اهم هذه التقاطعات تقاطع وزارة الصناعة والتجارة.

حلول كثيرة مقترحة لحل مثل هذه المشاكل، ولكن اختيار حل عن آخر يعتمد على مدى نجاعة مثل هذا الحل عن غيره. ولمعرفة أن نتائج مثل هذا الحل مقبولة، هنالك طرق علمية هندسية ومن اهم هذه الطرق وأنجعها واسهلها هي المحاكاة بواسطة الكمبيوتر.

فلقد استخدمت المحاكاة في هذه الرسالة لنرى افضل حل من ثلاثة حلول مقترحة لهذا التقاطع. حيث كان الحل الأول تنظيم وجدولة وقت الاشارات الضوئية حيث تعطي افضل توزيع للضوء الأخضر، والحل الثاني زيادة في عرض شارعي العربي وبئر السبع، والحل الثالث اقامة نفق على شارع الملكة نور.

النتائج بينت أن الحل الأول يمكن أن يعمل به لغاية عام ١٩٩٣م حيث بعد هذا الوقت يصبح عدد السيارات كبيرا بحيث لا يمكن التعامل معها حسب الواقع الموجود. اما في الحل الثاني وبتطبيقه حتى عام ٢٠٠٠م وجد انه غير فعال لتلك الفترة مع وجود بعض المشاكل في شراء أرض من اصحابها، أما الحل الثالث فكان مثاليا من حيث أن فترة الانتظار اصبحت غير مذكورة نسبيا وكذلك انتهاء الازمة أصبح واضحا تماما وذلك بتطبيقه لعام ٢٠٠٠، وذلك بغض النظر عن التكاليف المالية.

ان استخدام المحاكاة وهي احدى الطرق العلمية الجديدة والحديثة، في معرفة النتائج المستقبلية المترتبة على أي تغيير أو تجديد دونما حصول ذلك التغيير او التجديد، لسوف يساعد أصحاب القرارات في اتخاذ قراراتهم على ضوء تلك النتائج.

ABSTRACT

Delay, and long queues are noticed in many intersections in Amman. Ministry of Economy intersection is a good example of such delays. Many alternate solutions were proposed to solve the problem of that intersection. In order to predict the consequences and the performance of such alternatives, many methods, tools, and techniques are available, SIMULATION is one of the simplest and practical methods used in such issues.

Simulation technique by GPSS, is used to simulate three alternative solutions; the first one is to assign the best cycle time for the traffic light signals. The second is to increase the number of lanes in branch 2 and 4 . And the third is to construct a tunnel (underpass) along the Queen Noor street.

The results show that, the first alternative can be applied up to year 1993, and after that time, the intersection can not handle the traffic flow. The second alternative can not be efficient after year 2000, and some difficulties in acquiring the land will be encountered, but the third alternative shows the best and efficient solution, without cost consideration

The use of simulation can be very helpful for the decision makers, because they can see the effects of any changes without actual implementation of these changes.

ACKNOWLEDGMENTS

I wish to express my heartfelt gratitude to professor Parakash Mahajan, the original supervisor of the thesis, for his prudent guidance, supervision, and suggestions, without which this work would not have been accomplished.

I am greatly indebted and grateful to professor Arun Walvekar who continued the supervision and guidance during professor Mahajan's unexpected absence.

I would sincerely like to express my great thanks to the members of examination committee, Dr. Alaa Shahab, and Dr. Bassam Talhouni, for their constructive and useful remarks and comments.

My genuine gratitude and appreciation to my family, specially, my parents for their support and encouragement. I would like to record my thanks to the staff of computer center in Faculty Of Engineering.

Special thanks are due to my colleagues, and to the staff in Industrial Engineering department. I am also grateful to the Greater Amman municipality for providing the needed data for this work.

TABLE OF CONTENTS:

LIST OF TABLES

CHAPTER ONE

INTRODUCTION

In Amman , the capital of Jordan , there is a large number of vehicles compared with it's area ,and the traffic flow faces many problems .Some of these problems are the intersections and conjunctions . In many intersections there are very long queues of vehicles waiting to pass the traffic light signal .

Year by year ,the traffic flow increases and most of the roads and routes have not changed ; that causes delays and long waiting times at the intersections .These delays will bother and annoy the people who use such intersections , and this will be reflected on their performance of the work and the activities . .

Many solutions are available for such problems , but which one to pick ? And why ? And how can you check that it will be the best one before implementing it ?

Traffic simulation , a tool used by traffic engineers in the analysis of roadway capital investment and traffic control management , provides valuable information to decision makers by predicting the likely effects of traffic patterns or geometric changes of a roadway before the changes actually occur .

A big mistake was done when Abd Al-Naser interchange was designed . It was that the designers didn't simulate the interchange before implementing it , in order to see how it will work and if there are any problems that would arise .

Simulation results may be used to decide whether to proceed with the change , modify it , or abandon it . Simulation may determine the most effective way to spend available funds .[11] .

This is the big advantage of simulation : to predict the results of the project without executing it .

1.1 PROBLEM DEFINITION

The intersection which was selected to study is beside the Ministry of Economy and called the " Ministry of Economy Intersection " .

This intersection is selected to be studied, because of the following reasons:

1- It lies in a very important part in Amman i.e. center of Amman (among government departments,banks,markets ,..etc.) .

2- It has a very large flow of traffic .

3- It faces a real problem of long queues and delay times

4- It connects many major parts in Amman within a small travel distance .

By observing that intersection , specially in the morning and afternoon periods , one can easily notice that there is a problem and it must be solved .

This intersection consists of four branches and as follows :

1 - Queen Noor street southern.

2 - Beir Sab'a street .

3 - Al Arabi street .

4 - Queen Noor street northern .

The sketch of the intersection is shown in figure (1) . A very big problem in this intersection is the queue length in Beir Sab'a street and Al-Arabi street .That is because each of these two streets has only two lanes and the period of the green light time to pass is also small,while in Queen Noor street there are four lanes which can help in minimizing the delay and waiting times in the queue .

There are many alternate solutions , such as : changing the geometry of the intersection by increasing number of lanes ,building bridges , constructing a tunnel , or scheduling the existing traffic signals for reasonable queue length and delay times .

Of course any changing in intersection geometry will cost

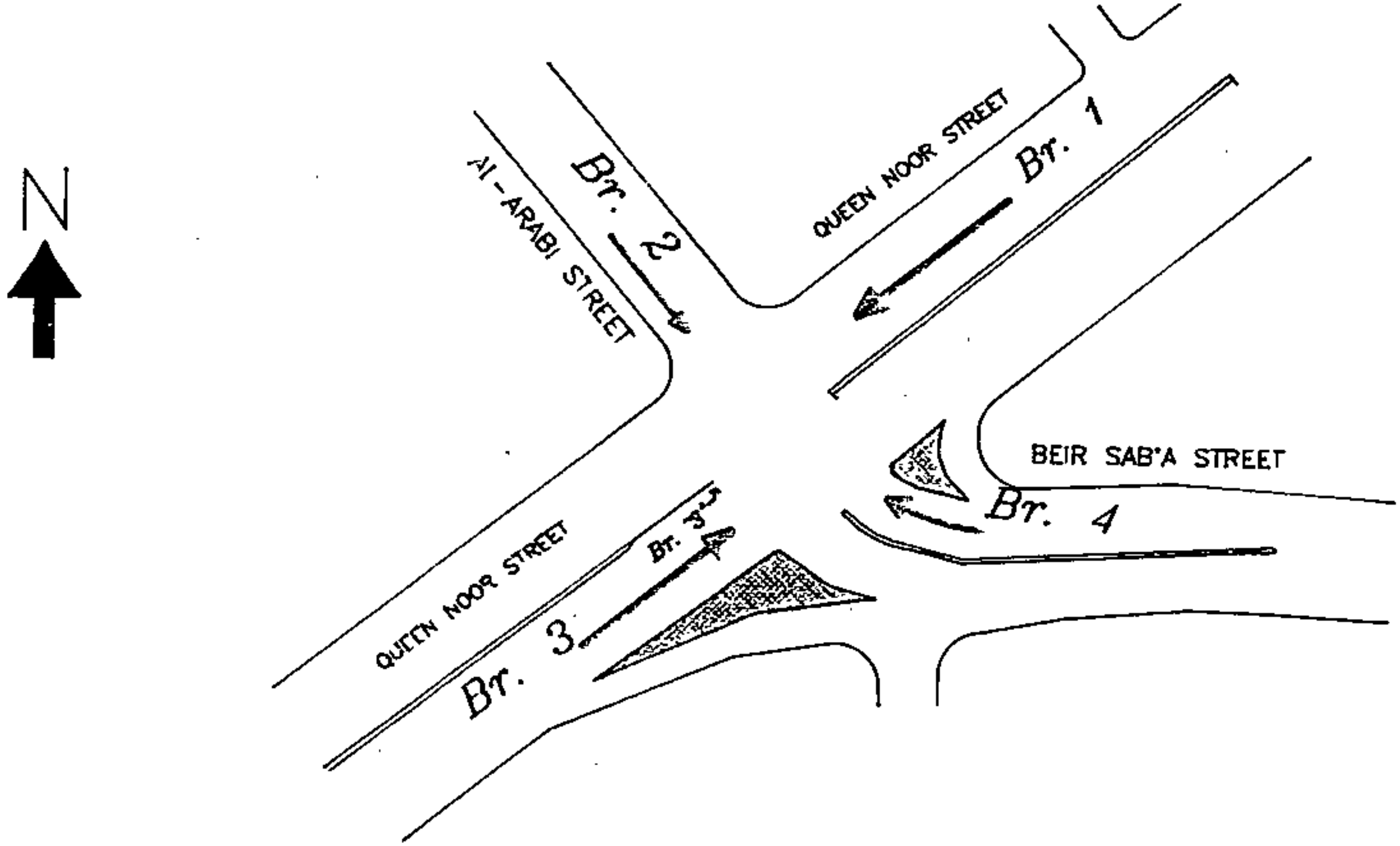


FIG. 1.1 THE MINISTRY OF ECONOMY INTERSECTION.

a lot of money and will make some troubles with land owners beside the intersection .

So in this thesis we will try to solve this problem by simulating each alternative, and comparing the results for each of them, then picking the best one.
the results of each alternate solution and picking the best one of them .

1.2 OBJECTIVES

The objectives of this research are :

- Study the existing situation of the intersection
- Schedule and regulate the traffic signals to reduce the queue lengths and delay times to get easy and smooth flow of the traffic .
- Simulate the alternate solutions and analyze the results .The results of the study will be compared for the performance of each alternative, based on the queue length and delay time in each branch.

CHAPTER TWO

LITERATURE SURVEY

Many researches were done on the subject of traffic control by computer simulation, and many simulation models were developed.

University of Bradford developed some computer simulation models for the simulation of traffic flow at highway junctions controlled by traffic signals and have been used to estimate cycle times which produce minimum delay .[7].

The required input to the program is : simulation time , average and minimum headway of arriving vehicles , demand and saturation flow and cycle and lost times . the output of the program is : average delays to vehicles on each approach , queue on each approach , and total intersection delay . The output and results were validated against the Webster delay formula and Catling queue length formula .[6].

Another simulation model program called (INTERCON) ,(by Roger Plum and Panos Michalopoulos)was developed .[8]. The type of control used in this model is the pretimed signal control with a fixed cycle length , phasing sequence and phase times .

Vehicles arrivals are assumed to occur randomly with each lane . The time used as the arrival time for each vehicle is the time at which the vehicle arrives at the back of the queue , or if no queue is present at the stop line .

For approach that have more than one lane accommodation through traffic , the arrivals of through vehicles are distributed between the lanes so that the total demand in each lane is as balanced as possible with the demand on other lanes of the approach .

Vehicles departures are function of several parameters entered by the user . The actual departure rate is a function of :

- saturation flow .

- lost time . It was assumed that the first five vehicles in a platoon can be affected by a lost time due to driver reaction and acceleration time .

-Average gap in the opposing flow that the driver makes a left turn feels is adequate .

2.1 PRETIMED SIGNALS

This common type of traffic control signal assigns the right of way at an intersection according to predetermined schedule . The time interval for each signal indication in the cycle time is of fixed length .[3].

2.2 SIGNAL TIMING

Timing calculation are based on traffic requirements. Cycle length during off-peak-periods should be as short as possible (40-100)sec..

Larger cycles are used during peak periods to provide more green time for the major street , to permit larger platoons in the peak direction and /or to reduce the number of starting delays .

General procedure is presented to calculate the signal timing [3]:

- Yellow change intervals , based on approach speeds

  3 sec. is used for speeds up to 55 km/h .

  4 sec. is used for speeds (55-80) km/h .

  5 sec, is used for speeds more than 80 km/h .

- Additional clearance time : At wide intersection or approach speed is very high , some drivers may be in a dilemma zone , where they can neither stop safely nor clear the intersection . To determine if an all red clearance interval is necessary to avoid this situation , the following equation can be used:

$$Y = T + \frac{V}{2A} + \frac{W+L}{V} \qquad \ldots\ldots\ldots\ldots\ldots\ldots 2.1$$

Where

Y: non dilemma clearance interval (s) .

T: perception-reaction time normally 1 sec. .

V: approach speed (m/sec.) .

A: deceleration rate , normally 3 m/sec . .

W: width of the intersection (m) .

L: length of the vehicle , normally 6 m .

If Y is greater than the value for the yellow change interval , then the difference is the required ALL-RED interval .

- Pedestrian clearance time : pedestrian walking speed ranges 4-3.5 ft./sec. .

- Minimum green time (MGT):itisequal to pedestrian clearance time - yellow change interval + initial interval time (INT) .Minimum green time must be greater than 15 sec..

- Initial interval time (INT):

1. with pedestrian signals INT=the walk period must be > 7 sec. .

2. without pedestrian signals , INT not <5 sec. .

- Green time (GT) : based on these minimum , in proportion to the approach volume in critical lane , on each street during the heaviest hour . GT > MGT .

- Cycle time is to be adjusted to the next higher 5 sec. interval and redistribute extra green time .

An other method to calculate the theoretical cycle length for random - arrival headway is [5] :

$$C = \frac{3600 * \sum_{x=1}^{n} K_x}{3600 - \sum_{x=1}^{n} V_x \, DK_x} \quad \text{.................2.2}$$

where

C : cycle length (s)

K : 4.75 sec. for typical passenger car .

Dk: constant value = 2.1 sec.

V : volume in vehicles per hour .

n : number of phases .

The above equation gives us theoretical value for the cycle length . Studies have shown that there are two phenomena occurring at nearly each intersection :

1- left turn

2- presence of trucks and other large vehicles in the traffic flow .

Studies have shown that because of delay enforced by opposing traffic , left turn generally require an average of 1.3 additional sec to clear the intersection . Thus time for left turning vehicle ≡ [(2.1+1.3)=1.6 (time for straight through vehicle in sec.)][5] .

For the trucks or large vehicles, it has been found that each truck or bus consumes approximately 1.5 times the amount of departure time required for a passenger vehicle.

2.3 DELAY TIMES

When a red signal interrupts a traffic flow , the vehicles will stopped , and will require time to get started again , so additional number of vehicles may be stopped because of the starting performance of the queue which has been accumulated on the red signal, which will cause the delay [5].

The number of vehicles which will stopped or delayed and the duration of the delay are dependent on :

- red interval
- arrival headway in the flow , and
- the starting performance of the queue .

Let R= interval of stop signal ,sec.

n= number of stopped vehicle in R

i= any selected vehicle of the n vehicles

A= average headway of vehicles on arrival, sec.

D= headway of departure at intersection entry .

d_i= delay for vehicle i ,sec.

T= total delay sec. .

Note that D is variable for the first six vehicles and it will be constant for rest . So the delay for any vehicle becomes :

$$d_i = R - \frac{A\,(2i - 1)\,i}{2} + \sum_{x=1} D_x \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots 2.3$$

and the sum for the individual delays becomes :

$$T = n\,R - \frac{n^{2} A}{2} + \sum_{x=1}^{n} \sum_{x=1}^{i} D_x \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots 2.4$$

and it can be rewritten as :

$$T = n\,R - \frac{n^{2} A}{2} + \frac{2.1\; n\,(n + 1)}{2} + 3.7\; n - Q \quad \ldots\ldots 2.5$$

in which Q is always =3.5 for n >= 4

Some of the needed data is available , and the rest can be obtained by :

1-Calculating it from the equations described above .Or by,

2-Measuring it On the site .

We will use both approaches and compare between them . This will be helpful to start with reasonable values . For example the cycle time can be calculated from the previous equations or can be measured from the site .

CHAPTER THREE

RESEARCH PLAN

A simulation model of the traffic intersection will be developed to describe the traffic system for each alternate solution . In general ,each model represents queues , of the arrival process ,the service process , and thequeue discipline [2] .

1 - The arrival process consists of vehicles , arrival rate , and the distribution of the arrivals . In this system the process is considered as a discrete process .

2 - The service process is characterized by distribution function of the time to serve the arrivals , and the number of arrivals . The server in this system is the traffic signals .

3 - The queue discipline describes the order in which the arrivals are served . In the model which will be developed , we will use " FIRST IN FIRST OUT " (FIFO) , and also include the characteristics of the system, maximum queue length.

3.1 ALTERNATE SOLUTIONS

We will consider the following alternatives :

1 - No changing in geometric configuration and schedule the traffic signals to keep the queue length and the delay times as short as possible

2 - Increase the number of lanes in Beir Sab'a and Al-Arabi streets from two lanes up to three or four lanes . This can be done by expropriating some land beside the intersection .

3 - Changing the geometry of the intersection to become a two level grade intersection . This can be done by building a bridge or constructing a tunnel in the Queen Noor street .

For each alternative a new model will be developed in order to fit the alternate solution and represent the real situation.

There are a lot of models developed to describe a queue systemssuchas :

$M/M/1/\alpha/\alpha$, $G/G/1/\alpha/\alpha$, $M/G/1$, $D/D/1$,...etc. . For example the first model indicates : a single - server system that has an infinite population of potential arrivals , the inter-arrival times are and service time are exponentially distributed

3.2 COLLECTING DATA

As we know , data collection is one of the largest tasks in solving a real life problem, because it must be accurate, precise , and representing almost the existing situation.

The data will consist of geometric configuration , traffic count for each direction , cycle time of the traffic signals maximum queue length , and vehicle clearance time .

All the traffic counts are available in Amman Municipality these counts have been taken at 15 minute periods for the whole day . Other needed data will be collected from the site such as : width of the branch ,number of lane in each branch , number of vehicles arrive at each branch and time for certain number of vehicles to pass through or turn at the intersection .

The counts of traffic flow which is available now is representing the flow in 1988 , but the flow will increase according to

- Normal traffic growth.
- Generated traffic .
- Development traffic .

In order to achieve good solution for long period of time these traffic flows will be projected and forecasted for the next twenty years .

Specific values cannot be cited for traffic projection factors for use in design where no analysis is made of the separate factors of traffic growth .

Projection factors that would apply to a majority of highways improvements today for a 20 years period will be approximately doubled .[10] .

The data will be arranged , checked , and analyzed before applying to the computer simulation program . Then we will apply the data to the program and check if the program is performing properly.If it does,we proceed with the analysis ;if not we check our model and data again .

3.3 MODEL SOLUTION

A computer simulation program will be developed to solve the model using " General Purpose Simulation System " (GPSS) language

VAX terminals will be used to run the GPSSH software , because it provides large number of transactions , facilities and queues , which cannot be found on personal computers .

In the models we developed some variable parameters can be changed such as the cycle time and the phasing . The selection and arrangement of simultaneous flows of movements is known as "phasing" . The objective of phasing is to accommodate all traffic movements with minimum delays .

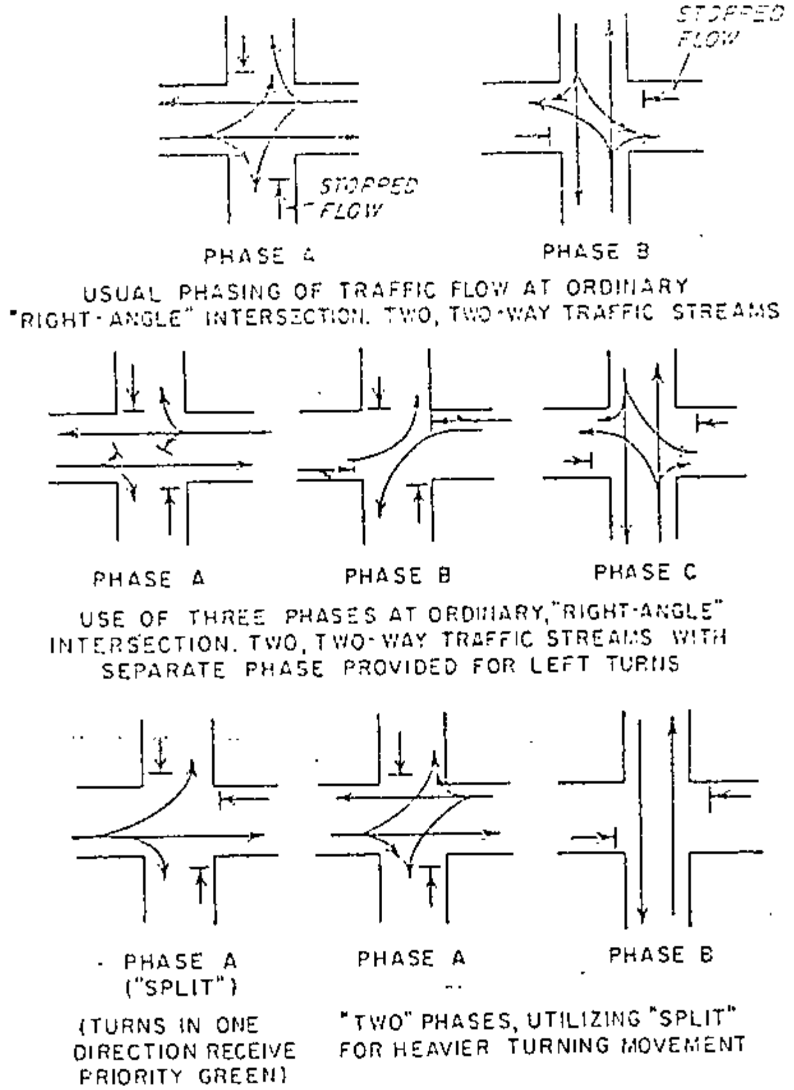
Generally speaking , the number of distinct phases employed should be kept as minimum as possible . The selection of flows in each phase should develop the minimum frequency and severity of conflict , and the sequence of phases should minimize waste of time .Illustrative examples of phasing are shown below :[5] .

3.4 VALIDATION

Validation is the determination that the model is an acceptable in representing the real system , this can be achieved by comparing the results from the computer program with the existing situation at the intersection for the same data .

After checking and verifying the data , each alternate solution will be solved by the computer simulation program. Several runs for each alternative will be made , in each run we change some variable parameters and analyze the results until we get reasonable results .

Then the alternatives will be compared with each other to know which one is the most effective and cheapest .



Phasing of traffic flows.

CHAPTER FOUR

DATA COLLECTION

4.1 INTRODUCTION

As it is known, data collection is one of the largest tasks in solving a real problem. The collected data must be accurate, precise, and representing the exactly the real existing situation. The collection and analysis of data is a critical step in the development of a simulation model. Any small error in data collection or analysis will lead to wrong results and invalidate the model.

4.2 REQUIRED DATA:

The data needed will consist of: geometric configuration, traffic flow in each direction (arrival process), percentage of the flow that pass-throughs, turn left, or turn right, cycle time of the traffic signals, vehicle clearance time (service time), No. of lanes in each direction, signal phasing, and width of each branch.

All the traffic data and counts had been taken from the Municipality of Greater Amman, these counts have been taken at 15-minute periods for the whole day. It had been noticed that there are two peaks, one in the morning period from 7:15-8:15, and the second is in the afternoon period from

CHAPTER FOUR

DATA COLLECTION

4.1 INTRODUCTION

As it is known, data collection is one of the largest tasks in solving a real problem. The collected data must be accurate, precise, and representing the exactly the real existing situation. The collection and analysis of data is a critical step in the development of a simulation model. Any small error in data collection or analysis will lead to wrong results and invalidate the model.

4.2 REQUIRED DATA:

The data needed will consist of: geometric configuration, traffic flow in each direction (arrival process), percentage of the flow that pass-throughs, turn left, or turn right, cycle time of the traffic signals, vehicle clearance time (service time), No. of lanes in each direction, signal phasing, and width of each branch.

All the traffic data and counts had been taken from the Municipality of Greater Amman, these counts have been taken at 15-minute periods for the whole day. It had been noticed that there are two peaks, one in the morning period from 7:15-8:15, and the second is in the afternoon period from

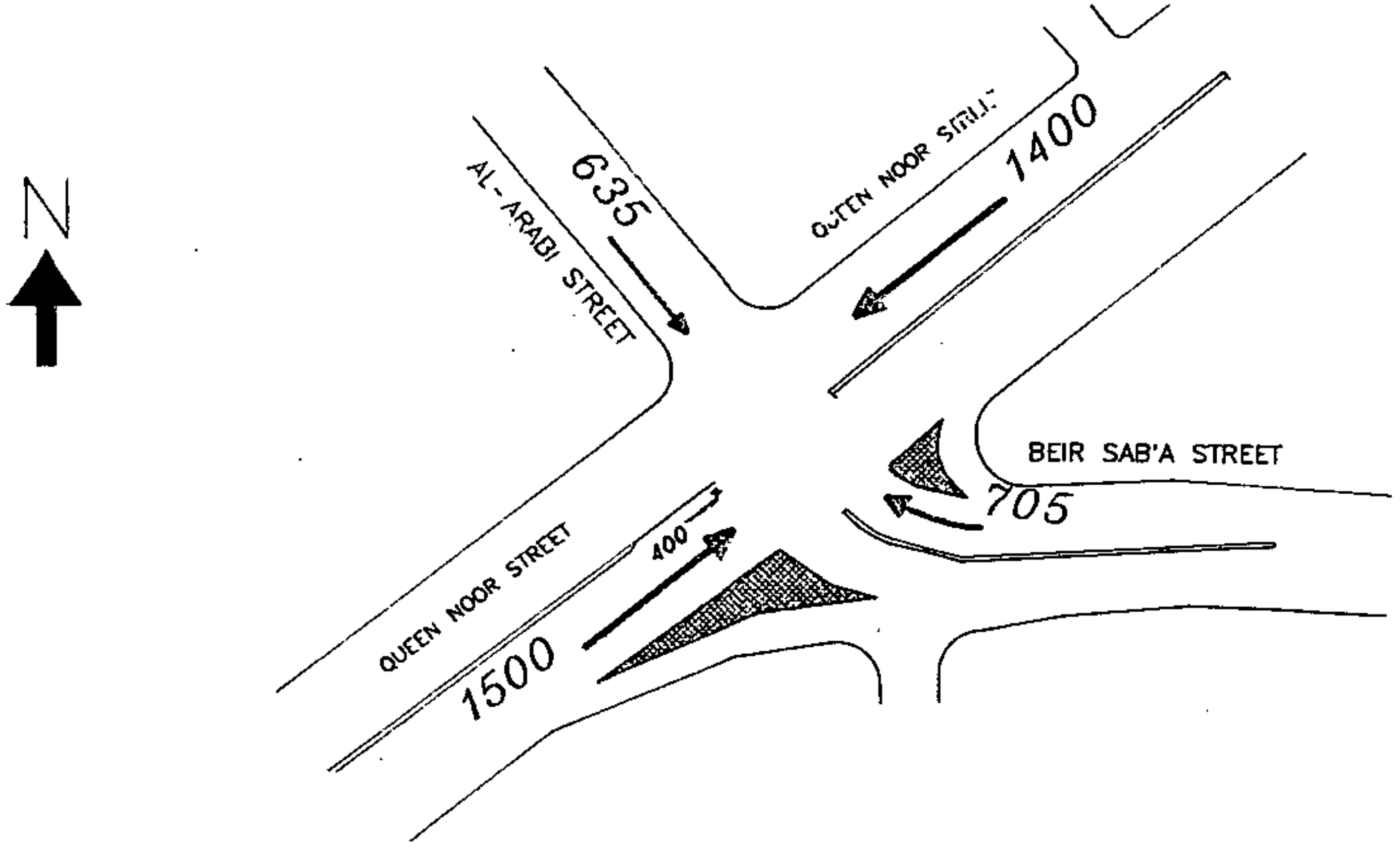


FIG. 4.1 TRAFFIC FLOW IN PEAK HOUR IN YEAR 1988.

13:15-14:15. Figure 4.1 shows the flow in peak hour in 1988.

4.3 DATA COLLECTED ON SITE :

Not all the required data was available, the following were collected on site:

1- The existing signal phase: As shown in figure 4.3, branch number 2 starts to move while the other branches are waiting. Then branch number 3 and 3' start to move while the others are waiting. Branch number 3' stoped, then branch number 1 starts, while branch number 3 is still working. Then branch number 4 start to move while other branches are waiting, and so on .

For existing situation, the existing phase is the best one, because in any other phase, the traffic in branches 2 and 4 will be divided into two directions, the first one is pass-throughs, and the second is the left turn, and there is no enough space to do that in these two branches, because the width of them is very small, and that will cause disturbing to the drivers, and long queues in these two branches.

2- Cycle time for the existing signal phase: About twenty readings were taken, at different times and the average value of the cycle time=115 seconds.

3- Green time for each branch: Many readings were taken for each branch and at different times, and the averages of the green times (G.T.) are listed below:

Green time for branch number 1 = 25 seconds.

Green time for branch number 2 = 20 seconds.

Green time for branch number 3 = 60 seconds.

Green time for branch number 3'= 30 seconds.

Green time for branch number 4 = 20 seconds.

These values and the cycle time are shown in figure 4.4.

4- Vehicle clearance time (service time): This means that how much time needed to cross the intersection, and this can be easily calculated by dividing the number of cars passing the intersection by the period of time taken for that number of cars to cross the intersection. But using this way the results will be approximated, not very accurate, and it will be averaged for the whole cars that cross the intersection without distinguished between the order of the car. A better way for calculating the service time is as follow:

a- Find the time needed for car number 1 in the queue to cross the intersection. take ten readings and find the average of them.

b-For car number 2 in the queue, do the same thing as in step a. And the same thing for car number 3,4,5,....and 10.

c- The service time = time needed for car number (i+1)-time

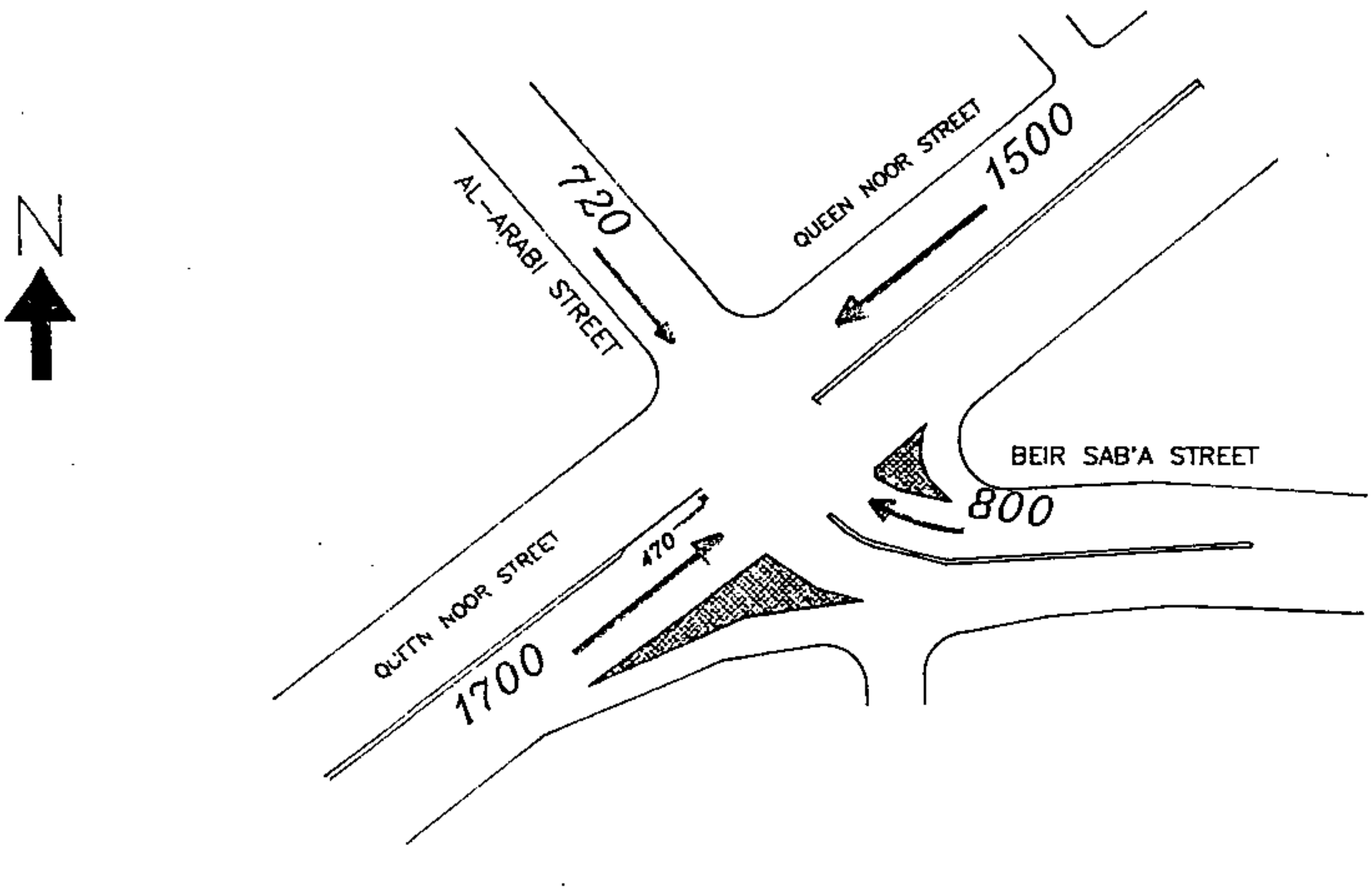


FIG. 4.2 TRAFFIC FLOW IN PEAK HOUR IN YEAR 1990.

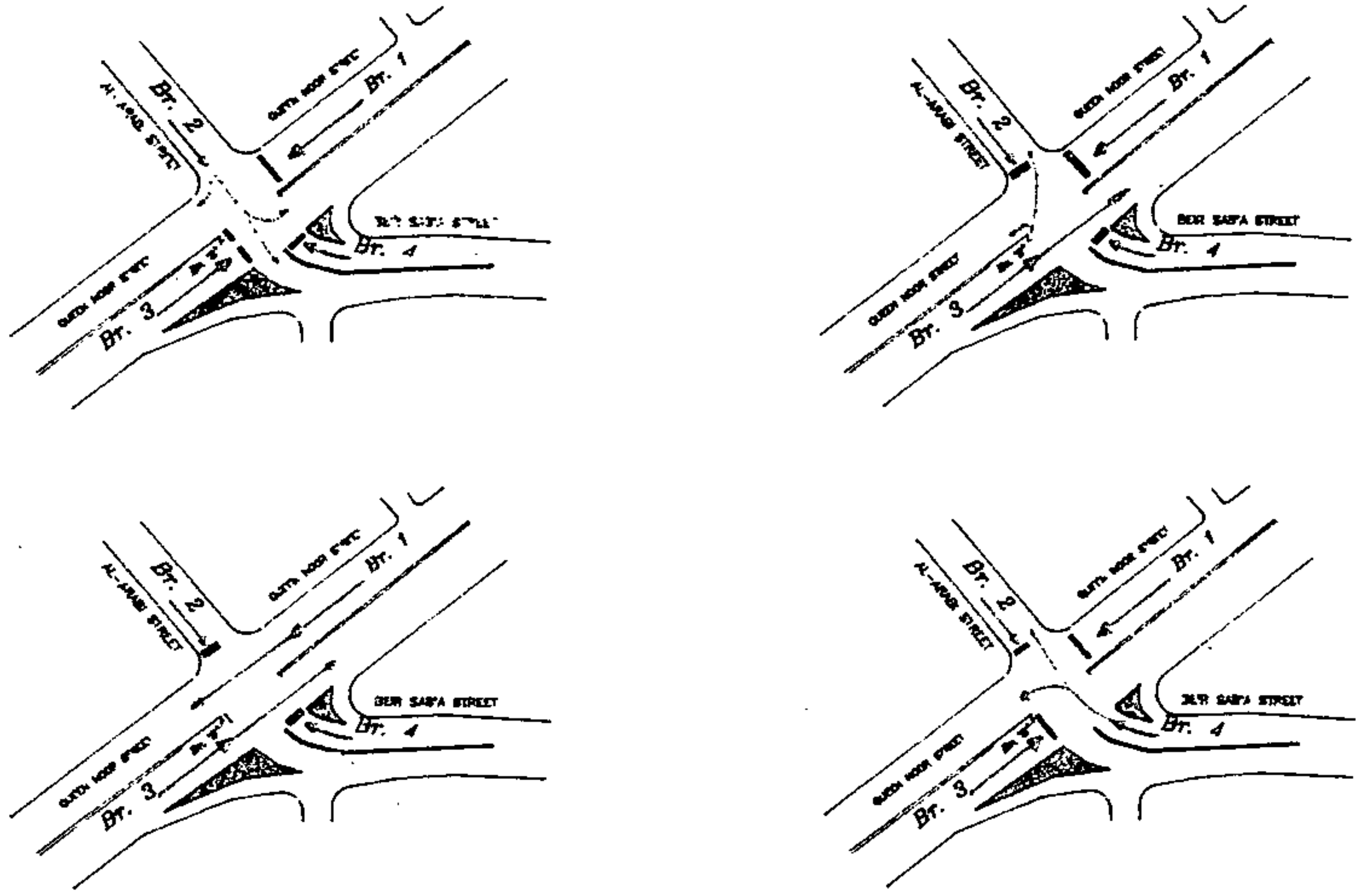


FIG. 4.3 EXISTING SIGNAL PHASE AT THE INTERSECTION.

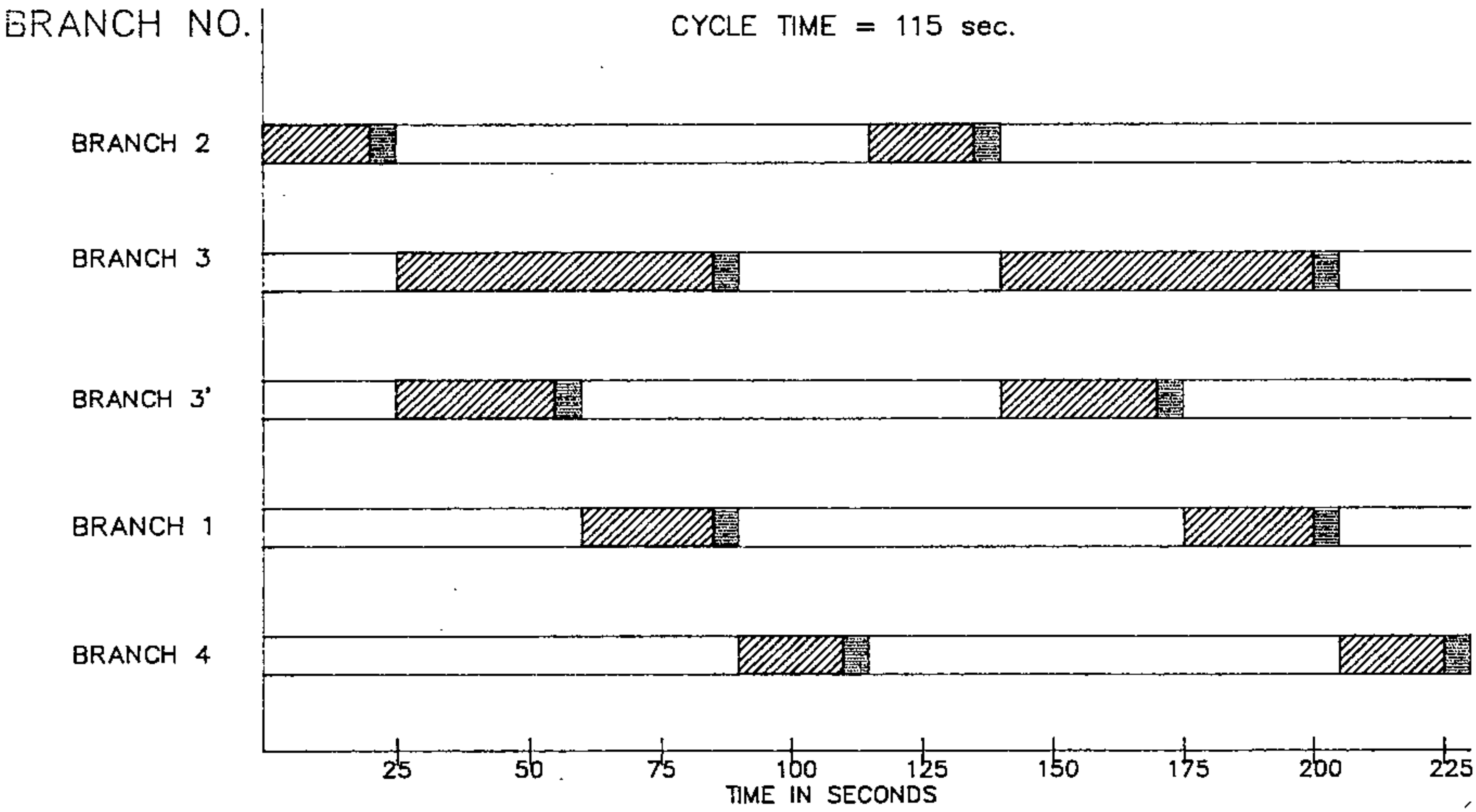


FIGURE 4.4 BAR CHART FOR THE GREEN TIME FOR EACH BRANCH.

TABLE 4.1 COLLECTED DATA FOR SERVICE TIME.

CAR NO.		1	2	3	4	5	6	7	8	9
PASS THROUGH	TIME NEDDED IN sec.	3,4,4 4,5,4 5,4,4	7.5,7, 7,6.5 7,6.5 7,6.5	8,9,9 9,8,9 9,9,8	11,11, 10,11, 12,11, 10,11.5	12,13, 13,12, 13,12 12,13	14,13, 14,14 14,13 14,15	15,15 15,16 15,16 16,16	16,17, 17,18 16,17, 17,18	18,18 18,19 19,18 18,19
	AV.	4.1	6.8	8.6	10.8	12.5	14.1	15.5	17.0	18.3
LEFT TURN	TIME NEDDED IN sec.	5,4,5 4,5,5 5.5,4.5, 5.5,5.5	8,8,7, 8.5,7.5 7,7,7.5 7.5,8.0	10,10,10 11,10,11 105,10 11.0,10	13,12,13 12.5,13 12.5,12 12,13,13	15,16,16 15.5,16 15,15,15 15.5,16	18,16,16 17.5,17 17,17.5 17,17,17	18,19,19 18,17,19 18.5,18 18.5,19	21,20,21 20.5,21 20,21.5 20,20,	22,22, 23,21.5 23,22.5 21.5,21
	AV.	4.8	7.6	10.4	12.6	15.2	17.0	18.7	20.5	22.1
U–TURN	TIME NEDDED IN sec.	6,5,6 6.5,5,5 5.5,5.5, 6,5.5	8.5,8.8, 9,9,9.5 8,8.5, 8.0,9.0	12,12,12 12.5,13 12,12, 12.5,12	15,14,15 14.5,15 15.5,14 14.5,15	16.5,17 17,16,16 17,16.5 17.5,17	19,21 21.5,20 21,20, 19.5,20	23,22, 24.5,22 22.5,23 22,23	26,25 24.5,25 26.5,25 25,25	27,28 28.5,28 29,28 27.5,28
	AV.	5.8	9.1	12.3	14.9	17.3	20.2	22.8	25.7	28.1

needed for car number(i).

Note that the first four or five cars will need larger service times, so skip these readings and find the average of the remaining readings for each car number. Tables 4.1 and 4.2 show these data. The data for the Right Turn was difficult to be taken and recorded, because there is no special lane for that movement, but it is approximately = 3 second.

TABLE 4.2 SUMMERY RESULTS FOR THE DATA IN TABLE 4.1.

	TIME NEEDED TO CROSS THE INTERSECTION FOR CAR No.									
	1	2	3	4	5	6	7	8	9	AV.
PASS THROUGH	4.1	2.7	1.8	2.2	1.7	1.6	1.4	1.5	1.3	1.45
LEFT TURN	4.8	2.8	2.8	2.3	2.6	1.8	1.7	1.8	1.6	1.75
U TURN	5.8	3.3	3.2	2.5	2.5	2.9	2.6	2.9	2.4	2.75

Cycle time and Green time for each branch can be calculated by any mentioned methods in chapter two.

4.4 DATA ANALYSIS :

All the counts and data took from the Municipality of Greater Amman was studied well, and tabulated in tables and figures. And also the other data that took from the site was tabulated.

4.4.1 FORECASTING:

All the traffic counts took from the Municipality of Greater Amman was representing the traffic flow counts in 1988, and when it will be applied to this time, it must be forecasted to this time (1990). When the problem of this intersection is to be solved, it must be solved not only for present time, but also for next certain period of the future time. In this thesis this period will be considered as ten years, so the data must be forecasted for year 2000.

Because there is no historical data available for the traffic flow counts for this intersection, the number of vehicles in Jordan will be good indicator to the traffic flow counts at this intersection. The historical data for the number of vehicles in Jordan is available in the Department of Traffic and Licences. These data was taken and tabulated as shown in table 4.3, and this data can be forecasted for any period of time and then can be used to be good indicator for the traffic flow in that period of time.

Linear regresion method ,is selected to forecast the number of cars in JORDAN, by using the growth forecasting software called FOR.BAS.[12].The results of this forecasting are shown in the next page.

The forecasting linear model is representing in the following equation :

$$Y(T) = 27.18 + 17.85\ T \quad \ldots\ldots\ldots\ldots 4.1$$

and by linear interpolation the flow counts can be calculated for the year 2000, the forecasted flow counts are shown in figure 4.6.

***** TIME SERIES ANALYSIS AND FORECASTING ****

--- Regression Analysis ---

Name of the data set : th

Number of data values input : 12

Forecasting model :

Y(T) = 27.18182 +17.85664*T

Variance of forecast error : 38.53115

Mean absolute deviation : 5.035548

Average absolute percent error : 3.80773

TIME PERIOD	ACTUAL DATA	ESTIMATED VALUE	RESIDUAL
1	48.00	45.04	2.96
2	60.00	62.90	-2.90
3	77.00	80.75	-3.75
4	99.00	98.61	0.39
5	121.00	116.47	4.53
6	127.00	134.32	-7.32
7	147.00	152.18	-5.18
8	177.00	170.03	6.97
9	199.00	187.89	11.11
10	210.00	205.75	4.25
11	219.00	223.60	-4.60
12	235.00	241.46	-6.46

TIME PERIOD	FORECAST VALUE	95% CONTROL LIMITS UPPER	LOWER
13	259.32	271.48	247.15
14	277.17	289.34	265.01
15	295.03	307.20	282.86
16	312.89	325.05	300.72
17	330.74	342.91	318.58
18	348.60	360.77	336.43
19	366.46	378.62	354.29
20	384.31	396.48	372.15
21	402.17	414.34	390.00
22	420.03	432.19	407.86
23	437.88	450.05	425.72
24	455.74	467.91	443.57
25	473.60	485.76	461.43

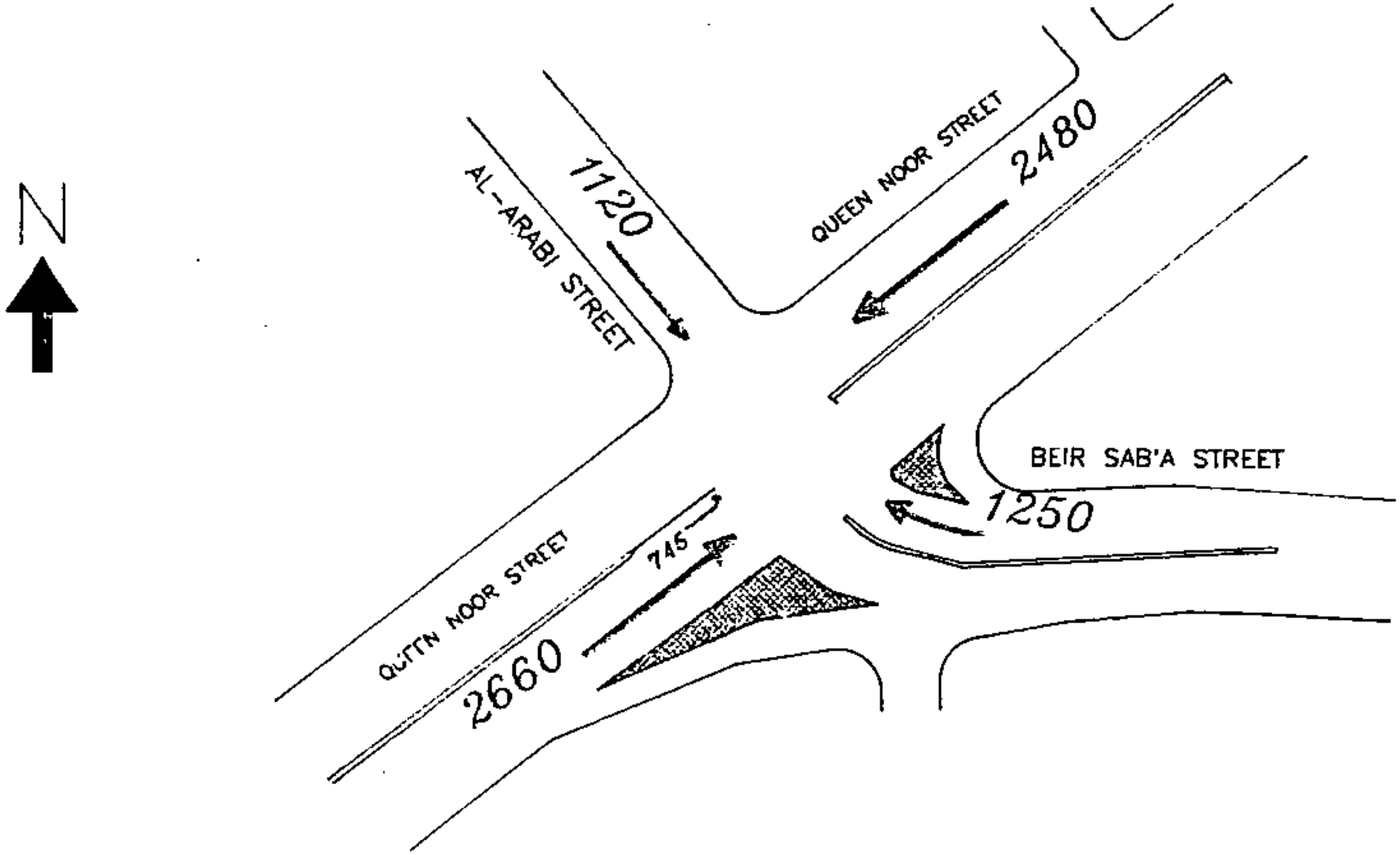


FIG. 4.5 FORCASTED TRAFFIC FLOW IN PEAK HOUR IN YEAR 2000.

CHAPTER FIVE
MODEL DEVELOPMENT

5.1 INTRODUCTION

A simulation model will be developed to represent the real system. In the model development, the description of the system will be made explicitly by quantifying the relationships among all the variables and the performance measures. In order to develop an accurate computer program which implements the model, the system and all of it's elements must be fully understood.

5.2 DESCRIPTION OF THE SYSTEM

The system that will be studied, represents an isolated intersection, this isolated intersection consists of four branches,and because there are arrivals, services, and queues this system is considered as a queuing system.

Any queuing system consists of three elements:

1- An arrival process.

2- A service process.

3- A queuing discipline.[2].

In a queuing system the arrival process is characterized by the distribution of the time between the arrival of successive customers. And in the system we are dealing with, the time between arrivals is exponentially distributed.

An exponential distribution plays a central role in queuing models, because it is a memoryless distribution. It is known that if the time between arrivals is exponentially distributed, with mean = Ø, then the distribution of the number of arrivals during the unit time interval is a poison distribution with mean = 1/Ø.

The service process is characterized by the distribution function of the time to serve the arrivals, and the number of arrivals. In the system we are dealing with, the service process is considered as a uniform or constant function for each type of movement.

The queue discipline describes the order and the way in which arrivals are served. FIFO (First In First Out) and priority queues will be used in the system we are dealing with.

5.3 GENERAL PURPOSE SIMULATION SYSTEM (G P S S)

The General Purpose Simulation System (GPSS) language, will be used as a simulation language to build the computer model that representing the system we are dealing with.

GPSS is a highly structured, special-purpose simulation language using the process-interaction approach and oriented toward queuing simulation.

In this language there are many concepts, as the block; which can be represented by pictorial symbol or by single statement. There are over than 45 standard blocks in GPSS, each block represents a specific action. A fundamental set of GPSS blocks is: GENERATE, TERMINATE, SEIZE, RELEASE, ADVANCE, QUEUE, and DEPART. In addition the following control statements are needed to execute even the simplest model: SIMULATE, START, and END. Each block in GPSS has a unique flow chart symbol. When the flow of transactions in the model is described using these symbols, converting the flow chart to computer code is accomplished by simply recording the corresponding statement for each symbol. [2].

An other concept, is the transaction: which represents active, dynamic entities may be pictured as flowing through the block diagram, and this will execute a GPSS model.

A third concept, is the simulation clock; the GPSS processor automatically maintains a simulation clock and it will advance the clock after finishing certain event or series of events. Note that GPSS automatically updates the simulation clock as required by the logic described in the model

5.4 APPROACH TAKEN IN BUILDING THE MODEL

When simulation begins, a transactions - customers are brought into the model, first; the branch number 1 will take the light as a green light (occupy the facility of crossing the intersection), and will be active to allow the vehicles to cross the intersection, while the other branches will be closed (in the red zone). Then after certain time the green light will be taken by the second branch, to allow the vehicles which were waiting in it's queues, to cross the intersection while the other branches are waiting (they are in red zone) in their queues. Then the third branch takes place in the green light zone. Then the fourth branch takes place in the green light zone. And the cycle will repeat it self again and so on.

This technique can be illustrated by using different priority levels for certain transactions. For example, when the first branch has occupy the green light zone for certain time, and this time is finished, so in order to let the first branch to leave the green light, a pseudo transaction with high priority will occupy the first branch until the cycle is finished and come back to the first branch. This technique is used for all the branches.

In branch number 1 there are four lanes, and four facilities are assigned to each lane. When a transaction is brought into this branch, first it will check the queue length for each lane and occupy the least of them. So before entering any queue in any branch, there will be a test to check and assign the smallest queue length, then entering that queue. Then spending certain time in the queue, then served by the facility. As mentioned before the service time is constant for each type of movement. Then the transaction will leave the system.

Now consider branch number 3. In this branch the flow split into two movements, the first one is passing through, while the second turns left, this second movement is considered as branch number 3'. The branch 3' also split into two movements, the first is turning left, and the second is turning back (U-tern). In this branch the transfer block is used to allow 12% of it's flow to turn back,and to give each type of movements it's exact service time.

In this model, in order to cancel the effect of randomness in several outputs, similar random number generators, and similar exponential function for each GENERATE block, were used. Also same seeds for each random number generator are assigned, by using the R-MULT block.

Also in order to reach a steady state situation, in each case the program was run seven times, and 60 minute for each time.

5.5 DEFINITIONS FOR THE ELEMENTS OF THE MODEL

TRANSACTIONS

MODEL SEGMENT 1	customers in branch 1
Model segment 1-1	red light for lane 1
Model segment 1-2	red light for lane 2
Model segment 1-3	red light for lane 3
Model segment 1-4	red light for lane 4
MODEL SEGMENT 2	customers in branch 2
Model segment 2-1	red light for lane 1
Model segment 2-2	red light for lane 2
MODEL SEGMENT 3	customers in branch 3
Model segment 3-1	red light for lane 1
Model segment 3-2	red light for lane 2
Model segment 3-3	red light for lane 3
MODEL SEGMENT 3'	customers in branch 3'
Model segment 3-1	red light for lane 1
MODEL SEGMENT 4	customers in branch 4
Model segment 4-1	red light for lane 1
Model segment 4-2	red light for lane 2
MODEL SEGMENT 5	timer.

FACILITIES 1-12	each lane for one facility
FUNCTIONS	
XPDS1	functions of exponential
XPDS2	distribution to describe
XPDS3	the arrival process for
XPDS4	customer arrivals in each
XPDS5	model segment.
QUEUES 1-12	queues used to gather statistics for each waiting lines a head of each facility.
TABLES 1-5	tables used to find % of time that queue content occupy the queues.

5.6 THE PROGRAM OUTPUT

The output of the program will include the following:

1- The utilization of each facility in the system. As mentioned earlier the facility will represent the lane. And also the total number of transactions interring each facility is represented.

2- The maximum queue content for each queue, average queue content, average time spent in the queue, the total entries

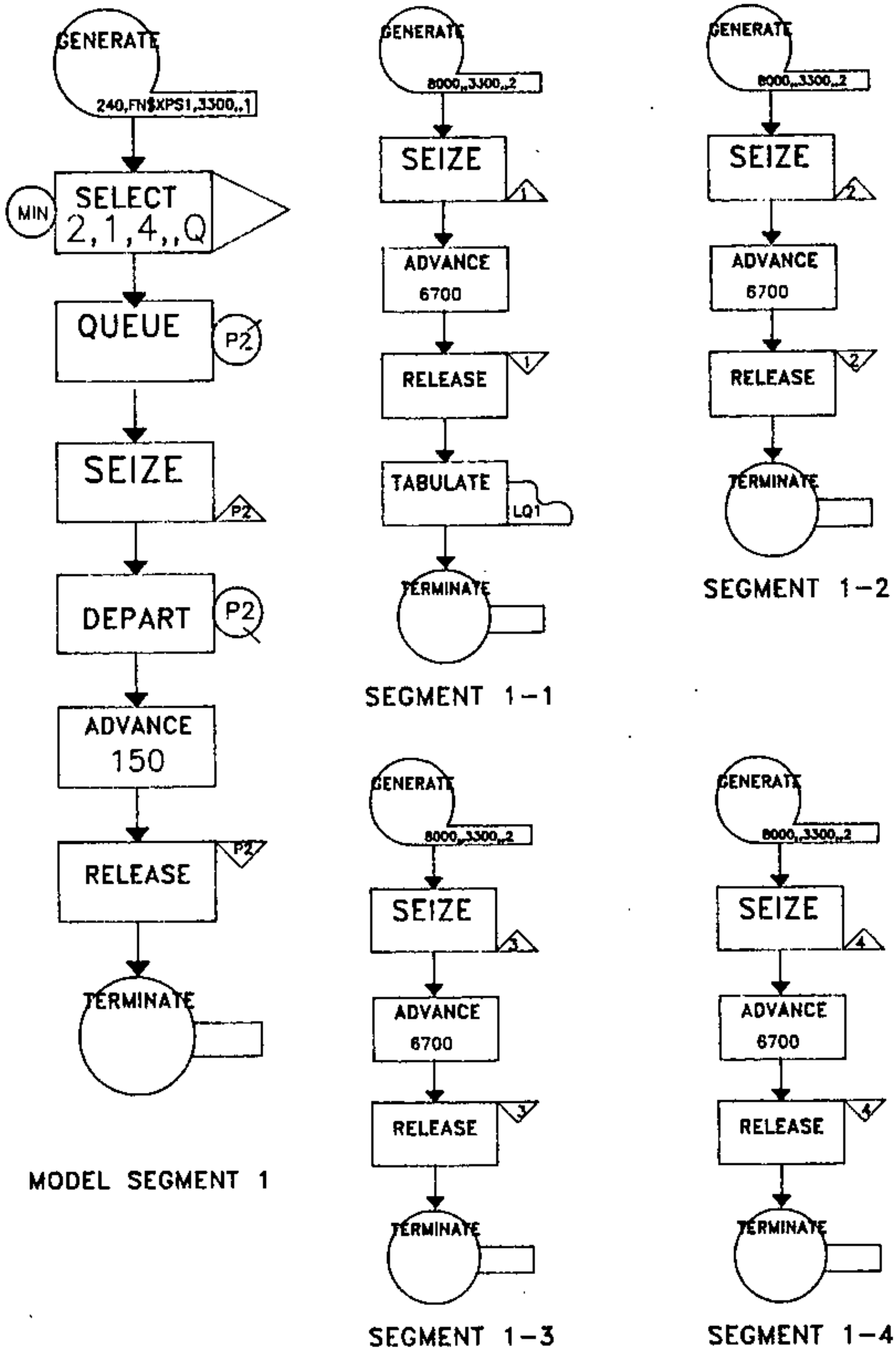
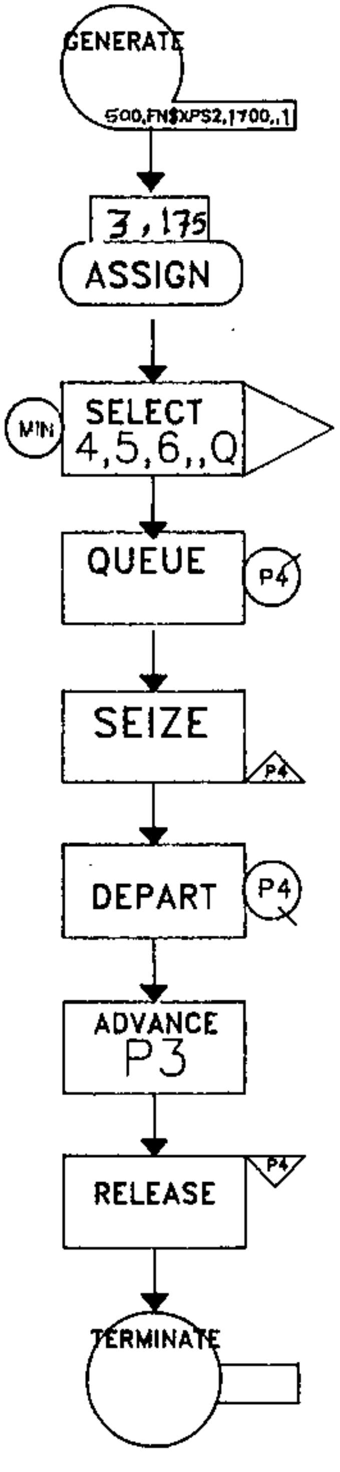
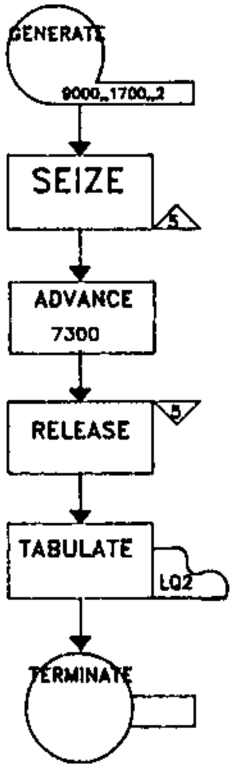
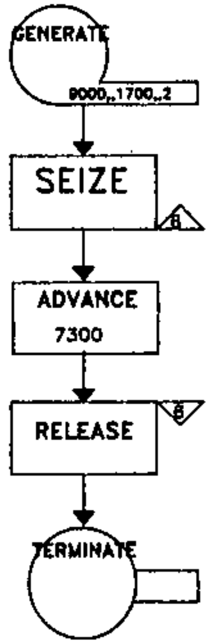


FIGURE 5.1 BLOCK DIAGRAM OF THE MODEL



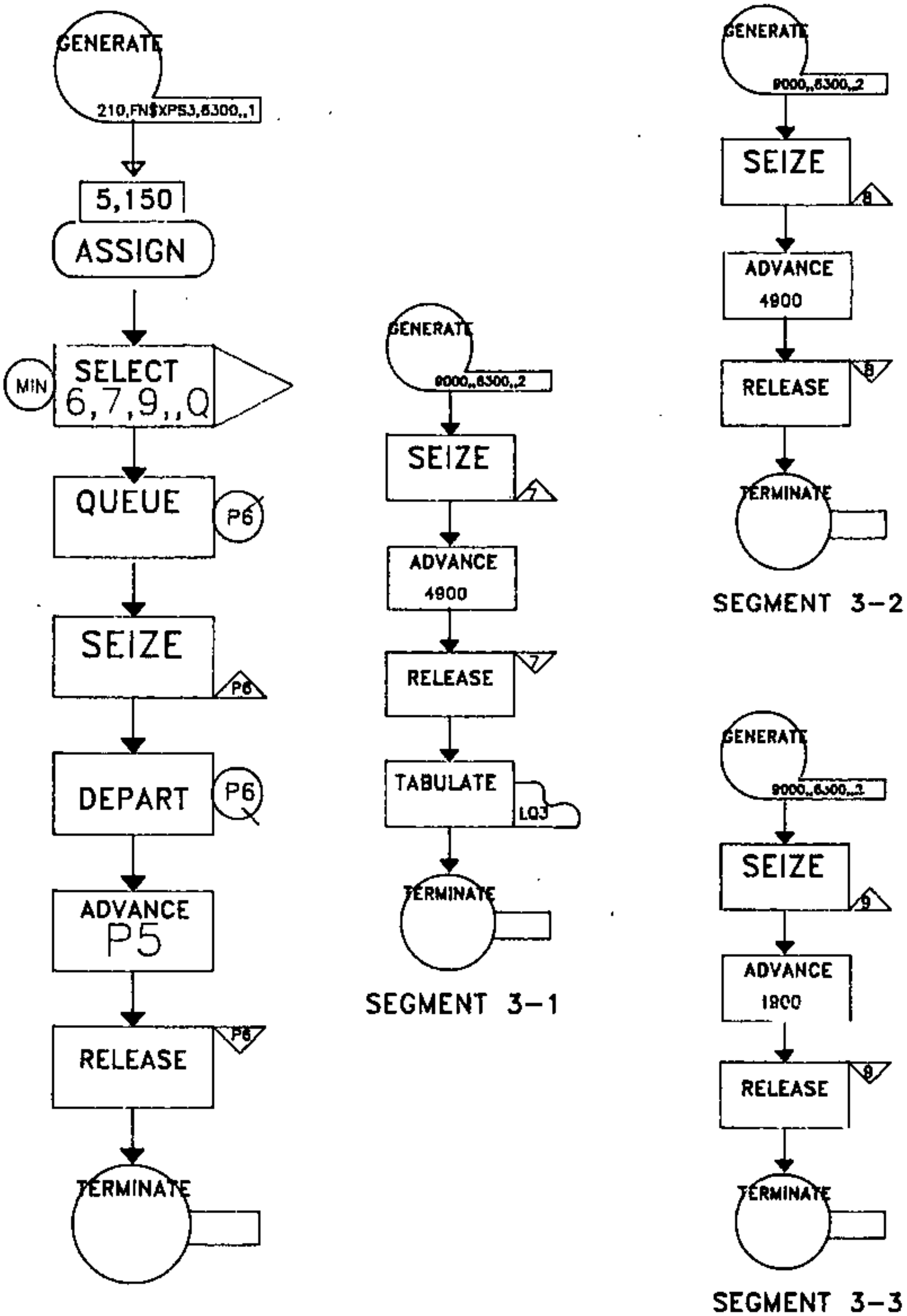


SEGMENT 2-1

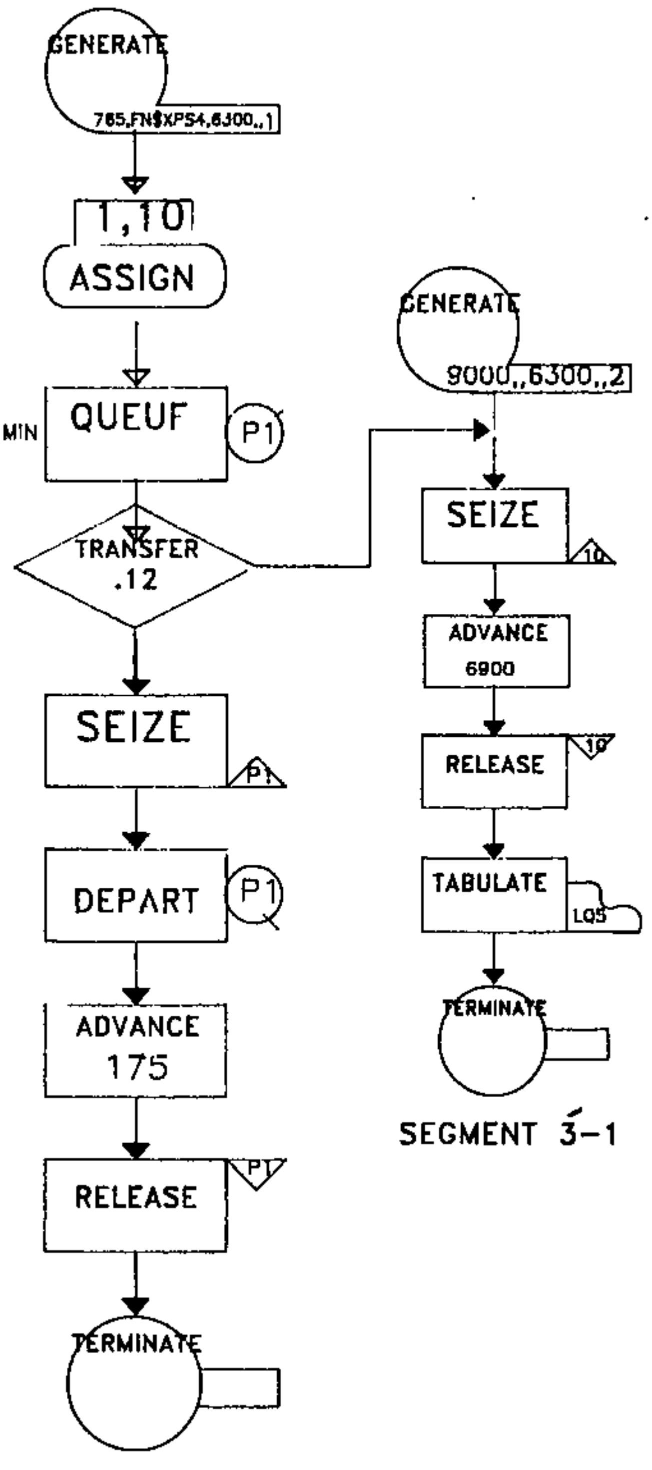


SEGMENT 2-2

MODEL SEGMENT 2

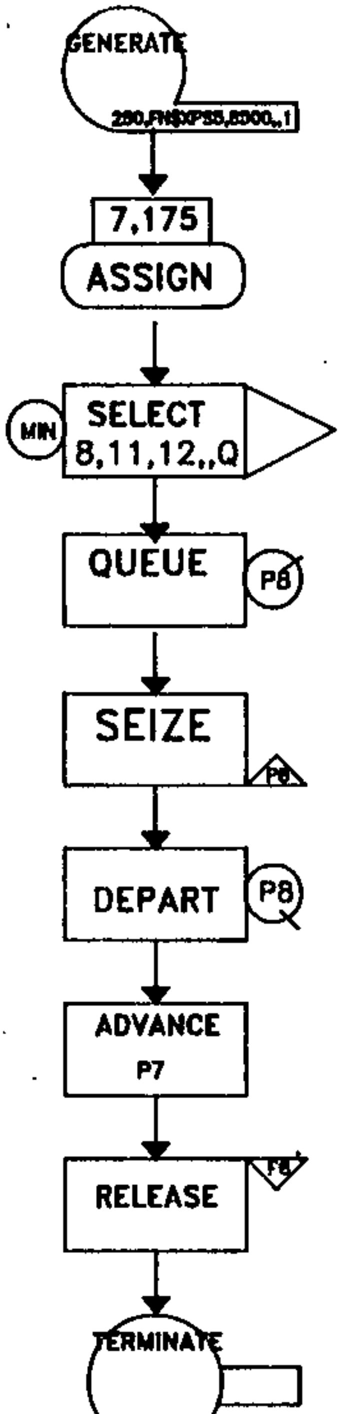


MODEL SEGMENT3

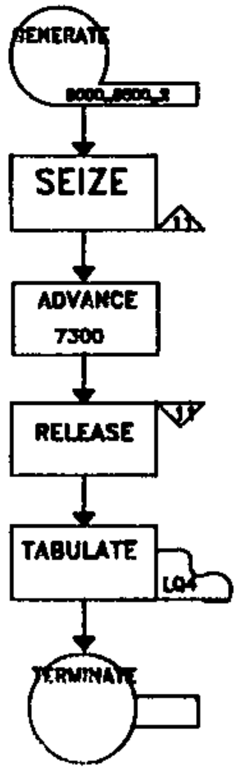


SEGMENT 3́-1

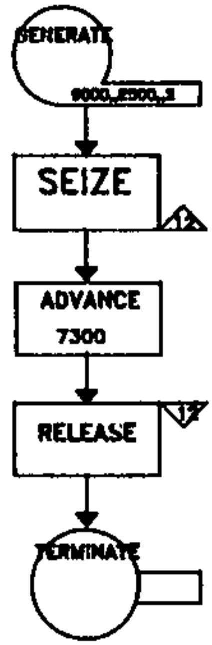
MODEL SEGMENT3́



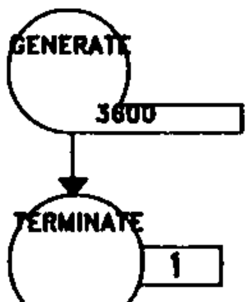
MODEL SEGMENT 4



SEGMENT 4-1



SEGMENT 4-2



MODEL SEGMENT 5

```
GPSS/H VAX/VMS RELEASE 2.0-E (OV088)     29 JAN 1991   14:34:35     FILE: 6FIRST.GPS

LINE# STMT#  IF DO  BLOCK#  *LOC    OPERATION       A,B,C,D,E,F,G   COMMENTS

                              SIMULATE
                              RMULT       511,67,9,669,435
                      XPDS1 FUNCTION      RN1,C24
                      0,0/.1,.104/.2,.222/.3,.355/.4,.509/.5,.69/.6,.915/.7,1.2/.75,1.38
                      .8,1.6/.84,1.83/.88,2.12/.9,2.3/.92,2.52/.94,2.81/.95,2.99/.96,3.2
                      .97,3.5/.98,3.9/.99,4.6/.995,5.3/.998,6.2/.999,7/.9998,8
                      ********************************************************************
                      XPDS2 FUNCTION      RN2,C24
                      0,0/.1,.104/.2,.222/.3,.355/.4,.509/.5,.69/.6,.915/.7,1.2/.75,1.38
                      .8,1.6/.84,1.83/.88,2.12/.9,2.3/.92,2.52/.94,2.81/.95,2.99/.96,3.2
                      .97,3.5/.98,3.9/.99,4.6/.995,5.3/.998,6.2/.999,7/.9998,8
                      ********************************************************************
                      XPDS3 FUNCTION      RN3,C24
                      0,0/.1,.104/.2,.222/.3,.355/.4,.509/.5,.69/.6,.915/.7,1.2/.75,1.38
                      .8,1.6/.84,1.83/.88,2.12/.9,2.3/.92,2.52/.94,2.81/.95,2.99/.96,3.2
                      .97,3.5/.98,3.9/.99,4.6/.995,5.3/.998,6.2/.999,7/.9998,8
                      ********************************************************************
                      XPDS4 FUNCTION      RN4,C24
                      0,0/.1,.104/.2,.222/.3,.355/.4,.509/.5,.69/.6,.915/.7,1.2/.75,1.38
                      .8,1.6/.84,1.83/.88,2.12/.9,2.3/.92,2.52/.94,2.81/.95,2.99/.96,3.2
                      .97,3.5/.98,3.9/.99,4.6/.995,5.3/.998,6.2/.999,7/.9998,8
                      ********************************************************************
                      XPDS5 FUNCTION      RN5,C24
                      0,0/.1,.104/.2,.222/.3,.355/.4,.509/.5,.69/.6,.915/.7,1.2/.75,1.38
                      .8,1.6/.84,1.83/.88,2.12/.9,2.3/.92,2.52/.94,2.81/.95,2.99/.96,3.2
                      .97,3.5/.98,3.9/.99,4.6/.995,5.3/.998,6.2/.999,7/.9998,8

                              REALLOCATE  COM,1500000,FAC,900,QUE,900,CHA,900
                        LQ1   TABLE       Q1,0,1,50
                        LQ2   TABLE       Q5,0,1,50
                        LQ3   TABLE       Q7,0,1,50
                        LQ4   TABLE       Q11,0,1,50
                        LQ5   TABLE       Q10,0,1,50
                    1         GENERATE    230,FN$XPDS1,8000,,1
                    2         SELECT MIN  2,1,4,,Q
                    3         QUEUE       P2
                    4         SEIZE       P2
                    5         DEPART      P2
                    6         ADVANCE     150
                    7         RELEASE     P2
                    8         TERMINATE
                        *
                    9   AA    GENERATE    11500,,8000,,2
                   10         SEIZE       1
                   11         ADVANCE     9500
                   12         RELEASE     1
                   13         TABULATE    LQ1
                   14         TERMINATE
                   15   AA1   GENERATE    11500,,8000,,2
                   16         SEIZE       2
                   17         ADVANCE     9500
                   18         RELEASE     2
                   19         TERMINATE
                   20   AA2   GENERATE    11500,,8000,,2
                   21         SEIZE       3
                   22         ADVANCE     9500
```

FIGURE 5.2 THE PROGRAM FOR THE MODEL USING GPSS LANG

```
GPSS/H VAX/VMS RELEASE 2.0-E (DV088)     29 JAN 1991    14:34:35      FILE: 6FIRST.GPS

LINE# STMT#  IF DO  BLOCK#  *LOC    OPERATION       A,B,C,D,E,F,G   COMMENTS

   57    57              23          RELEASE     3
   58    58              24          TERMINATE
   59    59              25   AA3    GENERATE    11500,,8000,,2
   60    60              26          SEIZE       4
   61    61              27          ADVANCE     9500
   62    62              28          RELEASE     4
   63    63              29          TERMINATE
   64    64                  ***************************************
   65    65              30          GENERATE    500,FN$XPDS2,2300,,1
   66    66              31          ASSIGN      3,175
   67    67              32          SELECT MIN  4,5,6,,Q
   68    68              33          QUEUE       P4
   69    69              34          SEIZE       P4
   70    70              35          DEPART      P4
   71    71              36          ADVANCE     P3
   72    72              37          RELEASE     P4
   73    73              38          TERMINATE
   74    74                  *
   75    75              39   BB     GENERATE    11500,,2300,,2
   76    76              40          SEIZE       5
   77    77              41   B      ADVANCE     9200
   78    78              42          RELEASE     5
   79    79              43          TABULATE    LQ2
   80    80              44          TERMINATE
   81    81              45   BB1    GENERATE    11500,,2300,,2
   82    82              46          SEIZE       6
   83    83              47   B1     ADVANCE     9200
   84    84              48          RELEASE     6
   85    85              49          TERMINATE
   86    86                  *******************************************
   87    87              50          GENERATE    210,FN$XPDS3,8100,,1
   88    88              51          ASSIGN      5,150
   89    89              52          SELECT MIN  6,7,9,,Q
   90    90              53          QUEUE       P6
   91    91              54          SEIZE       P6
   92    92              55          DEPART      P6
   93    93              56          ADVANCE     P5
   94    94              57          RELEASE     P6
   95    95              58          TERMINATE
   96    96                  *
   97    97              59   HH1    GENERATE    11500,,8100,,2
   98    98              60          SEIZE       7
   99    99              61   H1     ADVANCE     6200
  100   100              62          RELEASE     7
  101   101              63          TABULATE    LQ3
  102   102              64          TERMINATE
  103   103              65   HH2    GENERATE    11500,,8100,,2
  104   104              66          SEIZE       8
  105   105              67   H2     ADVANCE     6200
  106   106              68          RELEASE     8
  107   107              69          TERMINATE
  108   108              70   HH3    GENERATE    11500,,8100,,2
  109   109              71          SEIZE       9
  110   110              72          ADVANCE     6200
  111   111              73          RELEASE     9
  112   112              74          TERMINATE
```

```
GPSS/H VAX/VMS RELEASE 2.0-E (OV088)     29 JAN 1991   14:34:35     FILE: 6FIRST.GPS

LINE# STMT#  IF DO  BLOCK#  *LOC    OPERATION      A,B,C,D,E,F,G   COMMENTS

  113   113                 ****************
  114   114            75           GENERATE    765,FN$XPDS4,5300,,1
  115   115            76           ASSIGN      1,10
  116   116            77           QUEUE       P1
  117   117            78           TRANSFER    .12,,UT
  118   118            79           SEIZE       P1
  119   119            80           DEPART      P1
  120   120            81           ADVANCE     175
  121   121            82           RELEASE     P1
  122   122            83           TERMINATE
  123   123            84   UT      SEIZE       P1
  124   124            85           DEPART      P1
  125   125            86           ADVANCE     275
  126   126            87           RELEASE     P1
  127   127            88           TERMINATE
  128   128                 *
  129   129            89           GENERATE    11500,,5300,,2
  130   130            90           SEIZE       10
  131   131            91           ADVANCE     8700
  132   132            92           RELEASE     10
  133   133            93           TABULATE    LQ5
  134   134            94           TERMINATE
  135   135                 ***********************************
  136   136            95           GENERATE    460,FN$XPDS5,11000,,1
  137   137            96           ASSIGN      7,175
  138   138            97           SELECT MIN  8,11,12,,Q
  139   139            98           QUEUE       P8
  140   140            99           SEIZE       P8
  141   141           100           DEPART      P8
  142   142           101           ADVANCE     P7
  143   143           102           RELEASE     P8
  144   144           103           TERMINATE
  145   145           104   DD      GENERATE    11500,,11000,,2
  146   146           105           SEIZE       11
  147   147           106           ADVANCE     9100
  148   148           107           RELEASE     11
  149   149           108           TABULATE    LQ4
  150   150           109           TERMINATE
  151   151           110   DD1     GENERATE    11500,,11000,,2
  152   152           111           SEIZE       12
  153   153           112           ADVANCE     9100
  154   154           113           RELEASE     12
  155   155           114           TERMINATE
  156   156                 ******************************
  157   157           115   GG      GENERATE    360000
  158   158           116           TERMINATE   100
  159   159                         START       1
  160   160                         RMULT       741,543,789,771,121
  161   161                         CLEAR
  162   162                         START       1
  163   163                         RMULT       123,511,657,287,191
  164   164                         CLEAR
  165   165                         START       1
  166   166                         RMULT       87,991,733,655,21
  167   167                         CLEAR
  168   168                         START       1
```

```
GPSS/H VAX/VMS RELEASE 2.0-E (OV088)     29 JAN 1991    14:34:35     FILE: 6FIRST.GPS

LINE# STMT#  IF DO  BLOCK#  *LOC    OPERATION       A,B,C,D,E,F,G   COMMENTS

  169   169                          RMULT       565,989,787,33,7
  170   170                          CLEAR
  171   171                          START       1
  172   172                          RMULT       11,121,,345,569,23
  173   173                          CLEAR
  174   174                          START       1
  175   175                          RMULT       651,537,449,373,111
  176   176                          CLEAR
  177   177                          START       1
  178   178                          END
```

in each queue, and the zero entries (the transactions that will wait zero time in the queue).

3- Tables contain the distribution of the queue content i.e. the queue content that stayed in the queue for certain percentage of time, and also the most likely queue content occurred. This value is helpful in determining the performance of the system better than the maximum value of the queue content.

CHAPTER SIX

IMPLEMENTATION AND RESULTS

All the data prepared for the existing situation was applied to the developed computer program, the program run perfectly, and the results were obtained,analysed, and tabulated.

6.1 VALIDATION :

Comparing the perfomance measures output by the simulation model to the equivalent performance measures taken from the real system, is the most often suggested method of validation a simulation model. The results of the program when the current data was applied to it, and the current situation were compared with each other. Table 6.1 shows this comparison.

Chi-square test will be used to test the goodness of fit for the results in table 6.1.Let $O_1, O_2, \ldots, O_n$, observed frequencies of the maximum queue content, and $E_1, E_2, \ldots, E_K$ is the simulated results frequency of maximum queue content.Then the following hypothesis will be tested:

H_o : Observed frequency for maximum queue content is the same as frequency results from simulation for maximum

TABLE 6.1 COMPARESON BETWEEN ACTUAL AND MODEL RESULTS

Br. No.	REAL SYSTEM		MODEL SOLUTION	
	Max. queue content	Total entry to the system	Max. queue content	Total entry to the system
Br.1	14	1500	13	1496
Br.2	18	720	17	708
Br.3	14	1670	13	1635
Br.3	20	470	21	448
Br.4	28	783	27	765

queue content.

H_1 : Observed frequency for maximum queue content is not the same as frequency results feom simulation for maximum queue content.

We will test :

$$X_o^2 = \sum_{i=1}^{k} \frac{(O_i - E_i)^2}{E_i} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots 6.1$$

X_o^2 approximately follows the Chi-square distribution with k-p-1 degrees of freedom. Where p is the number of parameters of hypothesized distribution estimated by sample statistics. The null hypothesis will be rejected if :

$$X_o^2 > X_{\alpha, k-p-1}^2$$

The data in the following table will be tested :

Sample No.	O_i	E_i	$O_i - E_i$	$(O_i - E_i)^2 / E_i$
1	12	13	-1	1/13
2	14	13	1	1/13
3	13	12	-1	1/12
4	12	14	-2	4/14
5	15	14	1	1/14
6	13	13	0	0
7	14	12	2	4/12

By apllying the data in the above table for equation 6.1,

$$X_0^2 = 0.93$$

and by taking the α = 0.05, and from the tables of the Chi-square we can find that,

$$X^2_{0.05,6} = 12.59$$

Since $X_0^2 < X^2_{0.05,6}$, so we can't reject the null hypothesis and we conclude that the observed frequency of the maximum queue content is the same as the resulted frequency of the maximum queue content taken from the simulation program.

6.2 ALTERNATE SOLUTIONS

Three alternate solutions will be studied.

6.2.1 FIRST ALTERNATE SOLUTION:

In this solution the best cycle time will be assigned based on the best combination for green time, while the cycle time is fixed.

In order to find the best cycle time for this intersection, first, we will find the best combination of green time to each branch, while fixing the cycle time.

Six combinations will be used for this study, as shown in table 6.2. For each combination, seven runs of the computer program were made, and the results were obtained.

All the results are analyzed and studied for each run, and tabulated in tables, as shown in tables 6.3 to 6.9.

TABLE 6.2 GREEN TIME FOR EACH BRANCH FOR DIFFERENT COMBINATIONS.

BRANCH NO.	COMBINATION NO.					
	I	II	III	IV	V	VI
1	25	20	15	20	20	20
2	20	25	30	30	25	23
3	60	50	40	45	45	53
3'	30	25	20	20	20	28
4	20	25	30	25	30	24

TABLE 6.3 SUMMERY OF OUTPUT OF COMBINATION NO. I

RUN NO.	MAX. QUEUE CONTENT					QUEUE CONTENT (MOST LIKELY OCCURED)				
	BR.1	BR.2	BR.3	BR.$\bar{3}$	BR.4	BR.1	BR.2	BR.3	BR.$\bar{3}$	BR.4
1.	13	18	13	19	27	9	13	9	13	18
2.	14	17	13	22	27	10	11	9	12	20
3.	13	16	12	21	27	10	11	8	13	17
4.	12	17	12	21	28	9	11	9	13	20
5.	13	18	13	20	27	9	11	9	12	19
6.	13	16	13	22	24	10	11	10	13	21
7.	14	18	13	20	26	10	12	9	12	20
AV.	13	17	13	21	27	10	11	9	13	19

TABLE 6.4 SUMMERY OF OUTPUT OF COMBINATION NO. II

RUN NO.	MAX. QUEUE CONTENT					QUEUE CONTENT (MOST LIKELY OCCURED)				
	BR.1	BR.2	BR.3	BR.$\bar{3}$	BR.4	BR.1	BR.2	BR.3	BR.$\bar{3}$	BR.4
1.	14	13	14	37	13	11	11	11	25	10
2.	14	13	14	34	13	10	9	10	20	10
3.	13	13	12	46	14	10	9	10	23	11
4.	13	14	14	34	12	11	10	10	22	10
5.	14	14	14	45	13	11	10	10	28	10
6.	12	12	13	58	14	11	9	11	30	11
7.	13	12	13	58	12	11	9	10	31	10
AV.	13	13	13	43	13	11	10	10	25	10

TABLE 6.5 SUMMERY OF OUTPUT OF COMBINATION NO. III

RUN NO.	MAX. QUEUE CONTENT					QUEUE CONTENT (MOST LIKELY OCCURED)				
	BR.1	BR.2	BR.3	BR.$\bar{3}$	BR.4	BR.1	BR.2	BR.3	BR.$\bar{3}$	BR.4
1.	92	11	16	104	12	51	9	12	62	9
2.	84	12	16	96	12	45	9	12	47	9
3.	69	12	14	120	13	40	8	12	59	9
4.	74	14	16	111	11	43	9	12	63	10
5.	90	14	16	104	13	49	9	11	62	11
6.	81	11	15	126	13	46	8	12	62	10
7.	78	11	15	124	12	42	8	11	62	9
AV.	83	12	15	109	12	44	9	12	60	10

TABLE 6.6 SUMMERY OF OUTPUT OF COMBINATION NO. IV

RUN NO.	MAX. QUEUE CONTENT					QUEUE CONTENT (MOST LIKELY OCCURED)				
	BR.1	BR.2	BR.3	BR.$\bar{3}$	BR.4	BR.1	BR.2	BR.3	BR.$\bar{3}$	BR.4
1.	14	12	15	109	13	11	9	11	67	16
2.	15	13	16	103	13	11	9	11	52	10
3.	13	12	13	120	14	10	8	11	59	16
4.	13	14	15	104	12	11	9	11	61	9
5.	14	14	15	107	13	11	9	11	62	10
6.	13	12	15	132	14	11	9	11	62	10
7.	14	12	14	130	15	11	9	12	61	10
AV.	14	13	15	117	13	11	9	11	60	10

TABLE 6.7 SUMMERY OF OUTPUT OF COMBINATION NO. V

RUN NO.	MAX. QUEUE CONTENT					QUEUE CONTENT (MOST LIKELY OCCURED)				
	BR.1	BR.2	BR.3	BR.$\bar{3}$	BR.4	BR.1	BR.2	BR.3	BR.$\bar{3}$	BR.4
1.	14	13	16	109	12	11	11	11	67	9
2.	14	13	15	103	12	11	9	11	52	9
3.	13	13	13	120	13	10	10	11	59	9
4.	14	14	15	104	11	11	10	11	61	11
5.	14	14	15	109	13	11	10	11	62	11
6.	12	12	15	130	13	11	9	11	62	10
7.	13	12	14	124	12	11	9	11	62	9
AV.	13	13	15	113	12	11	10	11	61	10

TABLE 6.0 SUMMERY OF OUTPUT OF COMBINATION NO. VI

RUN NO.	MAX. QUEUE CONTENT					QUEUE CONTENT (MOST LIKELY OCCURED)				
	BR.1	BR.2	BR.3	BR.$\bar{3}$	BR.4	BR.1	BR.2	BR.3	BR.$\bar{3}$	BR.4
1.	15	13	14	26	14	10	10	10	15	10
2.	14	14	14	23	13	10	9	10	13	10
3.	13	13	12	27	15	10	10	10	15	11
4.	14	14	14	23	13	10	10	10	14	10
5.	14	15	14	26	13	10	10	10	16	11
6.	12	13	13	29	14	10	11	10	16	11
7.	16	14	13	25	13	11	9	9	17	10
AV.	14	14	13	26	14	10	10	10	15	10

By analysing these results it can be shown that combination number VI is the best one. This can be decided by considering the following two points:

1- Minimize the maximum queue content.

2- Minimize the current queue content which is the most likely occurred.

Table 6.10 shows the best combination of the green time for all branches. This combination will be used in studying the best cycle time.

To find the best cycle time, varies values of cycle time will be studied; 80, 90, 100, 110, and 120 seconds. Table 6.10 shows the green time for each branch in each cycle time based on the best combination of the green time.

For each cycle time, seven runs of the computer program were performed, and the results were obtained. All the results were analyzed and studied for each run, and tabulated in tables, as shown in tables 6.11 to 6.15.
By analysing the results, it can be shown that the best cycle time is 90 seconds, based on the above two points mentioned above. Figure 6.1 shows different cycle times versus queue content.

To predict the results for the future, the forecasted data of the traffic flow for year 2000 is applied to the

TABLE 6.9 BEST COMBINATION OF GREEN TIME.

Br. No.	1	2	3	3'	4
G.T.	20	23	53	28	24

TABLE 6.10 GREEN TIME FOR EACH BRANCH FOR DIFFERENT CYCLE TIMES

CYCLE TIME	GREEN TIME FOR BRANCH No.				
	1	2	3	3'	4
80	13	15	36	18	14
90	15	17	41	21	17
100	17	20	45	23	20
110	19	22	50	26	23
120	21	25	55	29	25

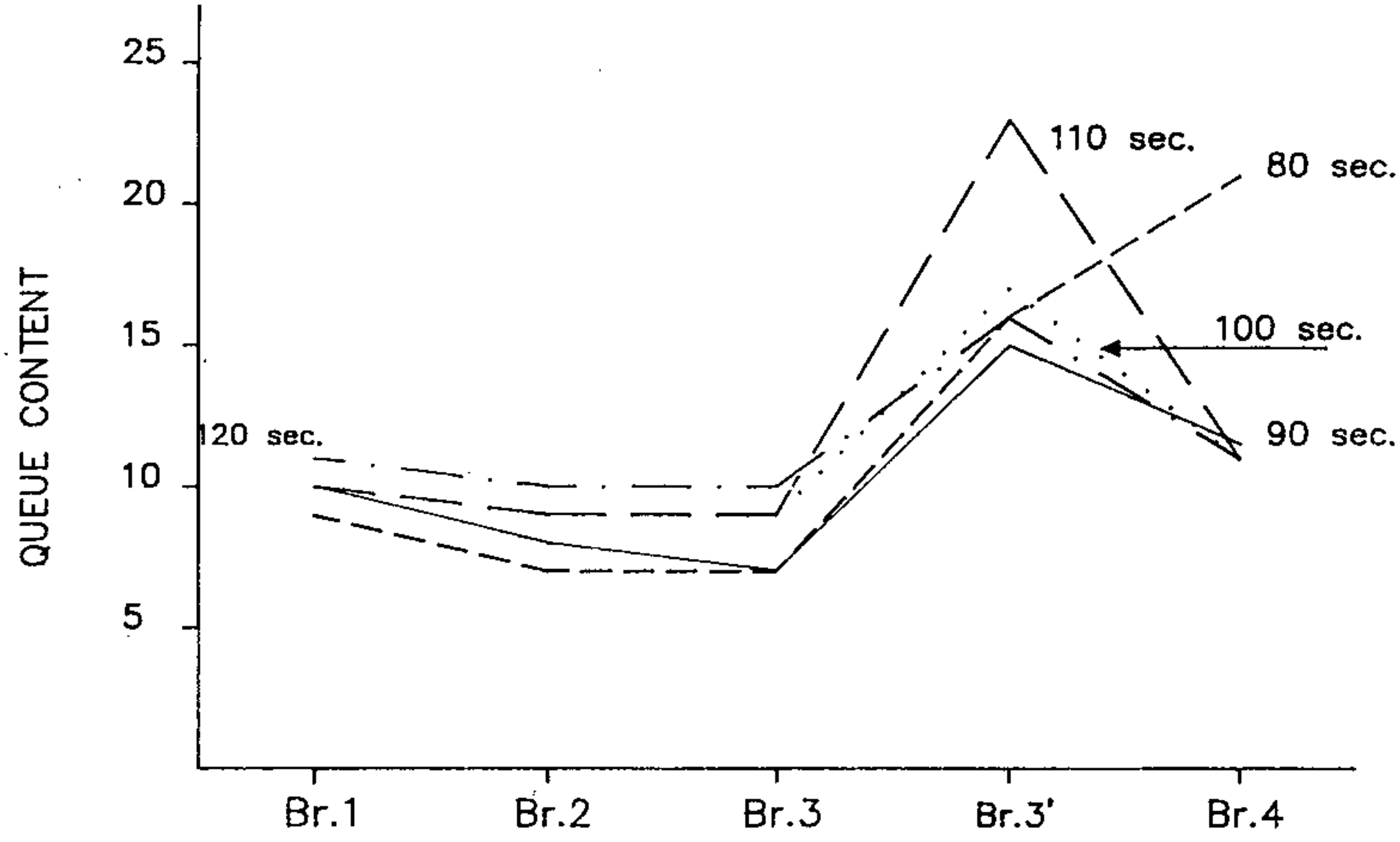


FIGURE 6.1 QUEUE DISTRIBUTION IN EACH BRANCH FOR DIFFERENT CYCLE TIMES

TABLE 6.11 SUMMERY OF OUTPUT OF THE PROGRAM WITH CYCLE TIME = 80 sec.

RUN NO.	MAX. QUEUE CONTENT					QUEUE CONTENT (MOST LIKELY OCCURED)				
	BR.1	BR.2	BR.3	BR.$\bar{3}$	BR.4	BR.1	BR.2	BR.3	BR.$\bar{3}$	BR.4
1.	12	11	11	26	30	9	6	7	13	21
2.	13	11	9	18	36	9	7	7	11	22
3.	11	11	8	33	33	9	8	6	16	19
4.	12	14	9	25	35	9	7	7	14	21
5.	13	13	10	35	35	9	7	7	21	21
6.	11	11	10	40	27	9	8	7	20	19
7.	13	11	9	39	39	9	7	7	20	23
AV.	12	12	9	31	33	9	7	7	16	21

TABLE 6.12 SUMMERY OF OUTPUT OF THE PROGRAM WITH CYCLE TIME = 90 sec.

RUN NO.	MAX. QUEUE CONTENT					QUEUE CONTENT (MOST LIKELY OCCURED)				
	BR.1	BR.2	BR.3	BR.$\bar{3}$	BR.4	BR.1	BR.2	BR.3	BR.$\bar{3}$	BR.4
1.	15	12	12	21	16	10	9	7	12	11
2.	13	12	11	19	15	10	8	7	11	11
3.	14	12	12	31	16	10	9	8	15	11
4.	13	12	9	26	16	9	8	7	14	11
5.	14	13	11	34	15	10	8	7	20	11
6.	13	11	10	28	14	11	9	8	17	11
7.	13	12	11	33	16	9	8	7	19	10
AV.	14	12	11	27	16	10	8	7	15	11

TABLE 6.13 SUMMERY OF OUTPUT OF THE PROGRAM WITH CYCLE TIME = 100 sec.

RUN NO.	MAX. QUEUE CONTENT					QUEUE CONTENT (MOST LIKELY OCCURED)				
	BR.1	BR.2	BR.3	BR.$\bar{3}$	BR.4	BR.1	BR.2	BR.3	BR.$\bar{3}$	BR.4
1.	11	12	12	33	14	10	9	8	16	10
2.	13	12	12	21	13	10	8	9	12	10
3.	14	12	12	36	13	10	9	9	18	10
4.	12	13	11	27	13	10	9	8	15	10
5.	14	13	12	31	12	10	9	8	18	10
6.	11	12	12	38	14	9	9	9	20	9
7.	12	11	13	37	12	10	8	9	20	10
AV.	12	12	12	32	13	10	9	9	17	10

TABLE 6.14 SUMMERY OF OUTPUT OF THE PROGRAM WITH CYCLE TIME = 110 sec.

RUN NO.	MAX. QUEUE CONTENT					QUEUE CONTENT (MOST LIKELY OCCURED)				
	BR.1	BR.2	BR.3	BR.$\overline{3}$	BR.4	BR.1	BR.2	BR.3	BR.$\overline{3}$	BR.4
1.	14	13	13	31	13	11	10	9	19	9
2.	14	12	12	30	13	11	9	9	18	10
3.	13	12	12	52	13	10	9	9	22	10
4.	12	15	12	31	14	10	9	9	21	10
5.	14	14	12	43	13	10	9	9	28	10
6.	14	12	13	49	14	10	9	9	24	10
7.	14	13	12	51	13	10	9	9	29	10
AV.	14	13	12	42	13	10	9	9	23	10

TABLE 6.15 SUMMERY OF OUTPUT OF THE PROGRAM WITH CYCLE TIME = 120 sec.

RUN NO.	MAX. QUEUE CONTENT					QUEUE CONTENT (MOST LIKELY OCCURED)				
	BR.1	BR.2	BR.3	BR.$\bar{3}$	BR.4	BR.1	BR.2	BR.3	BR.$\bar{3}$	BR.4
1.	15	13	14	26	14	11	10	10	15	10
2.	15	16	13	19	13	11	10	10	12	11
3.	16	14	14	28	14	12	10	11	16	11
4.	14	14	13	23	13	11	10	10	14	10
5.	15	16	13	25	14	11	10	10	17	11
6.	13	13	14	25	15	11	10	10	17	11
7.	15	13	14	31	14	11	10	10	20	11
AV.	15	14	14	25	14	11	10	10	16	11

TABLE 6.16 SUMMERY OF OUTPUT OF THE PROGRAM FOR ALTERNATE SOLUTION 1.

RUN NO.	MAX. QUEUE CONTENT					QUEUE CONTENT (MOST LIKELY OCCURED)				
	BR.1	BR.2	BR.3	BR.$\bar{3}$	BR.4	BR.1	BR.2	BR.3	BR.$\bar{3}$	BR.4
1.	244	97	16	259	309	118	57	11	138	158
2.	210	96	15	244	305	112	53	11	119	161
3.	220	99	16	255	302	112	56	11	134	158
4.	218	108	17	253	303	112	53	11	135	159
5.	214	109	15	273	304	110	54	11	140	161
6.	231	94	14	248	318	119	56	11	131	162
7.	213	96	16	247	309	108	54	11	134	163
AV.	220	100	16	254	307	113	55	11	133	160

TABLE 6.17 SUMMERY OF OUTPUT OF THE PROGRAM FOR ALTERNATE SOLUTION 2.

RUN NO.	MAX. QUEUE CONTENT					QUEUE CONTENT (MOST LIKELY OCCURED)				
	BR.1	BR.2	BR.3	BR.$\overline{3}$	BR.4	BR.1	BR.2	BR.3	BR.$\overline{3}$	BR.4
1.	79	19	15	233	90	43	13	9	123	50
2.	73	15	14	225	90	40	11	10	110	52
3.	72	19	13	273	92	37	12	9	142	53
4.	80	22	14	229	89	43	12	9	123	50
5.	70	22	14	253	92	40	12	9	127	52
6.	77	17	12	235	98	41	12	9	125	52
7.	77	18	12	266	92	40	12	9	136	53
AV.	76	19	13	245	91	41	12	9	126	52

```
GPSS/H VAX/VMS RELEASE 2.0-E (OV088)      2 FEB 1991   12:43:54     FILE: FOR2ND.GPS

LINE# STMT#  IF DO  BLOCK#  *LOC    OPERATION       A,B,C,D,E,F,G   COMMENTS

   1     1                          SIMULATE
   2     2                          RMULT       511,67,9,669,435
   3     3                  XPDS1 FUNCTION     RN1,C24
   4     4                  0,0/.1,.104/.2,.222/.3,.355/.4,.509/.5,.69/.6,.915/.7,1.2/.75,1.38
   5     5                  .8,1.6/.84,1.83/.88,2.12/.9,2.3/.92,2.52/.94,2.81/.95,2.99/.96,3.2
   6     6                  .97,3.5/.98,3.9/.99,4.6/.995,5.3/.998,6.2/.999,7/.9998,8
   7     7                  ******************************************************************
   8     8                  XPDS2 FUNCTION     RN2,C24
   9     9                  0,0/.1,.104/.2,.222/.3,.355/.4,.509/.5,.69/.6,.915/.7,1.2/.75,1.38
  10    10                  .8,1.6/.84,1.83/.88,2.12/.9,2.3/.92,2.52/.94,2.81/.95,2.99/.96,3.2
  11    11                  .97,3.5/.98,3.9/.99,4.6/.995,5.3/.998,6.2/.999,7/.9998,8
  12    12                  ******************************************************************
  13    13                  XPDS3 FUNCTION     RN3,C24
  14    14                  0,0/.1,.104/.2,.222/.3,.355/.4,.509/.5,.69/.6,.915/.7,1.2/.75,1.38
  15    15                  .8,1.6/.84,1.83/.88,2.12/.9,2.3/.92,2.52/.94,2.81/.95,2.99/.96,3.2
  16    16                  .97,3.5/.98,3.9/.99,4.6/.995,5.3/.998,6.2/.999,7/.9998,8
  17    17                  ******************************************************************
  18    18                  XPDS4 FUNCTION     RN4,C24
  19    19                  0,0/.1,.104/.2,.222/.3,.355/.4,.509/.5,.69/.6,.915/.7,1.2/.75,1.38
  20    20                  .8,1.6/.84,1.83/.88,2.12/.9,2.3/.92,2.52/.94,2.81/.95,2.99/.96,3.2
  21    21                  .97,3.5/.98,3.9/.99,4.6/.995,5.3/.998,6.2/.999,7/.9998,8
  22    22                  ******************************************************************
  23    23                  XPDS5 FUNCTION     RN5,C24
  24    24                  0,0/.1,.104/.2,.222/.3,.355/.4,.509/.5,.69/.6,.915/.7,1.2/.75,1.38
  25    25                  .8,1.6/.84,1.83/.88,2.12/.9,2.3/.92,2.52/.94,2.81/.95,2.99/.96,3.2
  26    26                  .97,3.5/.98,3.9/.99,4.6/.995,5.3/.998,6.2/.999,7/.9998,8
  27    27
  28    28                          REALLOCATE  COM,1500000,FAC,900,QUE,900,CHA,900
  29    29                   LQ1    TABLE       Q1,0,1,50
  30    30                   LQ2    TABLE       Q5,0,1,50
  31    31                   LQ3    TABLE       Q8,0,1,50
  32    32                   LQ4    TABLE       Q11,0,1,50
  33    33                   LQ5    TABLE       Q14,0,1,50
  34    34              1           GENERATE    145,FN$XPDS1,4600,,1
  35    35              2           SELECT MIN  2,1,4,,Q
  36    36              3           QUEUE       P2
  37    37              4           SEIZE       P2
  38    38              5           DEPART      P2
  39    39              6           ADVANCE     150
  40    40              7           RELEASE     P2
  41    41              8           TERMINATE
  42    42                  *
  43    43              9    AA     GENERATE    9000,,4600,,2
  44    44             10           SEIZE       1
  45    45             11           ADVANCE     7000
  46    46             12           RELEASE     1
  47    47             13           TABULATE    LQ1
  48    48             14           TERMINATE
  49    49             15    AA1    GENERATE    9000,,4600,,2
  50    50             16           SEIZE       2
  51    51             17           ADVANCE     7000
  52    52             18           RELEASE     2
  53    53             19           TERMINATE
  54    54             20    AA2    GENERATE    9000,,4600,,2
  55    55             21           SEIZE       3
  56    56             22           ADVANCE     7000
```

Fig 6.3

```
LINE# STMT#  IF DO  BLOCK#  *LOC    OPERATION        A,B,C,D,E,F,G   COMMENTS

  57    57              23          RELEASE     3
  58    58              24          TERMINATE
  59    59              25   AA3    GENERATE    9000,,4600,,2
  60    60              26          SEIZE       4
  61    61              27          ADVANCE     7000
  62    62              28          RELEASE     4
  63    63              29          TERMINATE
  64    64                  ****************************************
  65    65              30          GENERATE    360,FN$XPDS2,1400,,1
  66    66              31          ASSIGN      3,175
  67    67              32          SELECT MIN  4,5,7,,Q
  68    68              33          QUEUE       P4
  69    69              34          SEIZE       P4
  70    70              35          DEPART      P4
  71    71              36          ADVANCE     P3
  72    72              37          RELEASE     P4
  73    73              38          TERMINATE
  74    74                  *
  75    75              39   BB     GENERATE    9000,,1400,,2
  76    76              40          SEIZE       5
  77    77              41   B      ADVANCE     7600
  78    78              42          RELEASE     5
  79    79              43          TABULATE    LQ2
  80    80              44          TERMINATE
  81    81              45   BB1    GENERATE    9000,,1400,,2
  82    82              46          SEIZE       6
  83    83              47   B1     ADVANCE     7600
  84    84              48          RELEASE     6
  85    85              49          TERMINATE
  86    86              50          GENERATE    9000,,1400,,2
  87    87              51          SEIZE       7
  88    88              52          ADVANCE     7600
  89    89              53          RELEASE     7
  90    90              54          TERMINATE
  91    91                  *********************************************
  92    92              55          GENERATE    135,FN$XPDS3,6600,,1
  93    93              56          ASSIGN      5,150
  94    94              57          SELECT MIN  6,8,10,,Q
  95    95              58          QUEUE       P6
  96    96              59          SEIZE       P6
  97    97              60          DEPART      P6
  98    98              61          ADVANCE     P5
  99    99              62          RELEASE     P6
 100   100              63          TERMINATE
 101   101                  *
 102   102              64   HH1    GENERATE    9000,,6600,,2
 103   103              65          SEIZE       8
 104   104              66   H1     ADVANCE     4300
 105   105              67          RELEASE     8
 106   106              68          TABULATE    LQ3
 107   107              69          TERMINATE
 108   108              70   HH2    GENERATE    9000,,6600,,2
 109   109              71          SEIZE       9
 110   110              72   H2     ADVANCE     4300
 111   111              73          RELEASE     9
 112   112              74          TERMINATE
```

```
GPSS/H VAX/VMS RELEASE 2.0-E (OV088)      2 FEB 1991    12:43:54      FILE: FOR2ND.GPS

LINE# STMT#  IF DO  BLOCK#  *LOC    OPERATION       A,B,C,D,E,F,G   COMMENTS

  113   113             75   HH3   GENERATE    9000,,6600,,2
  114   114             76         SEIZE       10
  115   115             77         ADVANCE     4300
  116   116             78         RELEASE     10
  117   117             79         TERMINATE
  118   118                 ****************
  119   119             80         GENERATE    485,FN$XPDS4,4100,,1
  120   120             81         ASSIGN      1,14
  121   121             82         QUEUE       P1
  122   122             83         TRANSFER    .12,,UT
  123   123             84         SEIZE       P1
  124   124             85         DEPART      P1
  125   125             86         ADVANCE     175
  126   126             87         RELEASE     P1
  127   127             88         TERMINATE
  128   128             89   UT    SEIZE       P1
  129   129             90         DEPART      P1
  130   130             91         ADVANCE     275
  131   131             92         RELEASE     P1
  132   132             93         TERMINATE
  133   133                 *
  134   134             94         GENERATE    9000,,4100,,2
  135   135             95         SEIZE       14
  136   136             96         ADVANCE     6800
  137   137             97         RELEASE     14
  138   138             98         TABULATE    LQ5
  139   139             99         TERMINATE
  140   140                 **********************************
  141   141            100         GENERATE    288,FN$XPDS5,8500,,1
  142   142            101         ASSIGN      7,180
  143   143            102         SELECT MIN  8,11,13,,Q
  144   144            103         QUEUE       P8
  145   145            104         SEIZE       P8
  146   146            105         DEPART      P8
  147   147            106         ADVANCE     P7
  148   148            107         RELEASE     P8
  149   149            108         TERMINATE
  150   150            109   DD    GENERATE    9000,,8500,,2
  151   151            110         SEIZE       11
  152   152            111         ADVANCE     7600
  153   153            112         RELEASE     11
  154   154            113         TABULATE    LQ4
  155   155            114         TERMINATE
  156   156            115   DD1   GENERATE    9000,,8500,,2
  157   157            116         SEIZE       12
  158   158            117         ADVANCE     7600
  159   159            118         RELEASE     12
  160   160            119         TERMINATE
  161   161            120         GENERATE    9000,,8500,,2
  162   162            121         SEIZE       13
  163   163            122         ADVANCE     7600
  164   164            123         RELEASE     13
  165   165            124         TERMINATE
  166   166                 ******************************
  167   167            125   GG    GENERATE    360000
  168   168            126         TERMINATE   100
```

```
GPSS/H VAX/VMS RELEASE 2.0-E (OV088)      2 FEB 1991   12:43:54     FILE: FOR2ND.GPS

LINE# STMT#  IF DO  BLOCK#  *LOC    OPERATION       A,B,C,D,E,F,G   COMMENTS

  169   169                         START        1
  170   170                         RMULT        741,543,789,771,121
  171   171                         CLEAR
  172   172                         START        1
  173   173                         RMULT        123,51,657,87,91
  174   174                         CLEAR
  175   175                         START        1
  176   176                         RMULT        87,991,733,655,21
  177   177                         CLEAR
  178   178                         START        1
  179   179                         RMULT        565,989,787,33,7
  180   180                         CLEAR
  181   181                         START        1
  182   182                         RMULT        11,121,,345,569,23
  183   183                         CLEAR
  184   184                         START        1
  185   185                         RMULT        51,37,49,73.111
  186   186                         CLEAR
  187   187                         START        1
  188   188                         END
```

program using the best cycle time based on the best green time combination. seven runs were performed, the results were obtained, studied for each run, and tabulated, as shown in table 6.16. It is easily noticed that, there are very long queues for most of the branches, and this can't be handled by the existing intersection geometry.

6.2.2 SECOND ALTERNATE SOLUTION:

In this solution number of lanes in branch 2 and, 4 are to be increased up to three lanes for each branch. According to this change, the program also should be modified to accommodate with the new changes. Figure 6.3 shows the modified program that presents the modified model.

The forecasted traffic flow for year 2000 was applied to the modified program, and the program run well, and the results were obtained, and tabulated, as shown in table 6.17. By examining and analysing the results, one can notice that there are large queues in some branches specially in branches 1 and 3'. So this solution cannot help.

6.2.3 THIRD ALTERNATIVE

In this solution, underpass (tunnel) will be constructed to allow continues passing for the traffic flow.

The best position to construct the tunnel will be on the heaviest traffic flow branches, they are branch 1 and 3, this will be along the QUEEN NOOR STREET. In this case number of phases will be reduced, and more movements can be put in this intersection.

The program of the simulation model will be modified to accommodate the new changing in the intersection geometry, so lanes for passing through in branches 1and 3 will be eliminated from the program. Figure 6.4 shows the new modified program which accommodated with the third alternate solution.

The forecasted flow counts for year 2000 is applied to the modified program, and the program was run, and the results were obtained and tabulated as shown in table 6.18. By analysing the results, in the table 6.18, it is easily noticed that there is no problem, and all the branches have reasonable and acceptance queue length, or queue content at any time specially during the rush hour.

So the third alternate solution will be an acceptable solution for the intersection regardless the cost.

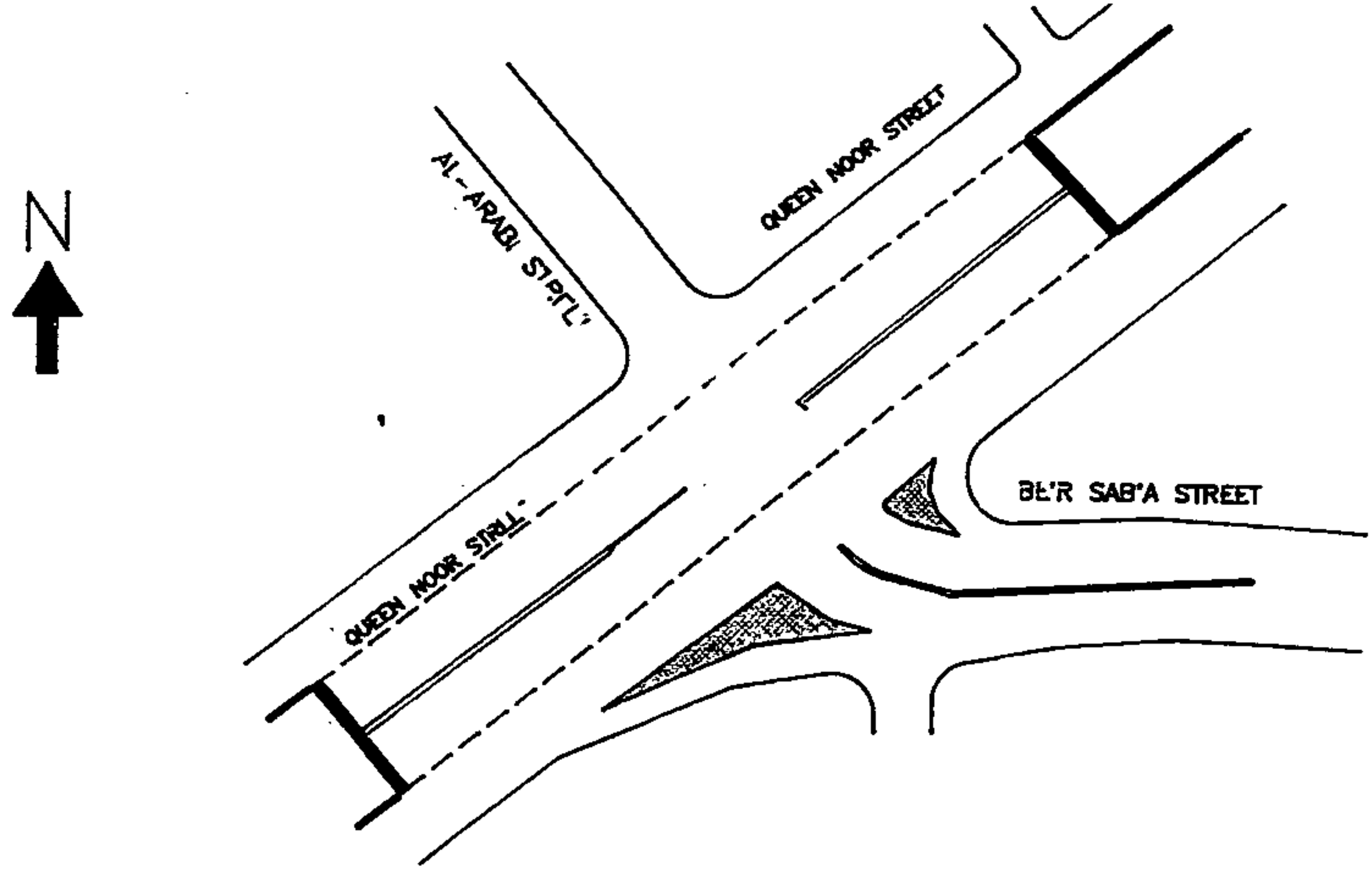


FIGURE 6.2 THE INTERSECTION GEOMETRY WHEN APPLYING THE THIRD ALTERNATE SOLUTION.

```
GPSS/H VAX/VMS RELEASE 2.0-E (DV088)      2 FEB 1991   12:36:02     FILE: 13RD.GPS

LINE# STMT#  IF DO  BLOCK#  *LOC    OPERATION       A,B,C,D,E,F,G   COMMENTS

  1     1                           SIMULATE
  2     2                           RMULT        511,67,9,669,435
  3     3                   XPDS1 FUNCTION    RN1,C24
  4     4                  0,0/.1,.104/.2,.222/.3,.355/.4,.509/.5,.69/.6,.915/.7,1.2/.75,1.38
  5     5                  .8,1.6/.84,1.83/.88,2.12/.9,2.3/.92,2.52/.94,2.81/.95,2.99/.96,3.2
  6     6                  .97,3.5/.98,3.9/.99,4.6/.995,5.3/.998,6.2/.999,7/.9998,8
  7     7                  ******************************************************************
  8     8                   XPDS2 FUNCTION    RN2,C24
  9     9                  0,0/.1,.104/.2,.222/.3,.355/.4,.509/.5,.69/.6,.915/.7,1.2/.75,1.38
 10    10                  .8,1.6/.84,1.83/.88,2.12/.9,2.3/.92,2.52/.94,2.81/.95,2.99/.96,3.2
 11    11                  .97,3.5/.98,3.9/.99,4.6/.995,5.3/.998,6.2/.999,7/.9998,8
 12    12                  ******************************************************************
 13    13                   XPDS3 FUNCTION    RN3,C24
 14    14                  0,0/.1,.104/.2,.222/.3,.355/.4,.509/.5,.69/.6,.915/.7,1.2/.75,1.38
 15    15                  .8,1.6/.84,1.83/.88,2.12/.9,2.3/.92,2.52/.94,2.81/.95,2.99/.96,3.2
 16    16                  .97,3.5/.98,3.9/.99,4.6/.995,5.3/.998,6.2/.999,7/.9998,8
 17    17                  ******************************************************************
 18    18                   XPDS4 FUNCTION    RN4,C24
 19    19                  0,0/.1,.104/.2,.222/.3,.355/.4,.509/.5,.69/.6,.915/.7,1.2/.75,1.38
 20    20                  .8,1.6/.84,1.83/.88,2.12/.9,2.3/.92,2.52/.94,2.81/.95,2.99/.96,3.2
 21    21                  .97,3.5/.98,3.9/.99,4.6/.995,5.3/.998,6.2/.999,7/.9998,8
 22    22                  ******************************************************************
 23    23                   XPDS5 FUNCTION    RN5,C24
 24    24                  0,0/.1,.104/.2,.222/.3,.355/.4,.509/.5,.69/.6,.915/.7,1.2/.75,1.38
 25    25                  .8,1.6/.84,1.83/.88,2.12/.9,2.3/.92,2.52/.94,2.81/.95,2.99/.96,3.2
 26    26                  .97,3.5/.98,3.9/.99,4.6/.995,5.3/.998,6.2/.999,7/.9998,8
 27    27
 28    28                           REALLOCATE   COM,1500000,FAC,900,QUE,900,CHA,900
 29    29                    LQ1    TABLE        Q1,0,1,50
 30    30                    LQ2    TABLE        Q5,0,1,50
 31    31                    LQ3    TABLE        Q7,0,1,50
 32    32                    LQ4    TABLE        Q11,0,1,50
 33    33                    LQ5    TABLE        Q7,0,1,50
 34    34             1             GENERATE     485,FN$XPDS1,2000,,1
 35    35             2             ASSIGN       2,200
 36    36             3             SELECT MIN   1,1,2,,Q
 37    37             4             QUEUE        P1
 38    38             5             SEIZE        P1
 39    39             6             DEPART       P1
 40    40             7             ADVANCE      P2
 41    41             8             RELEASE      P1
 42    42             9             TERMINATE
 43    43                    *
 44    44            10             GENERATE     9000,,2000,,2
 45    45            11             SEIZE        1
 46    46            12             ADVANCE      7000
 47    47            13             RELEASE      1
 48    48            14             TABULATE     LQ1
 49    49            15             TERMINATE
 50    50                    *
 51    51            16             GENERATE     9000,,2000,,2
 52    52            17             SEIZE        2
 53    53            18             ADVANCE      7000
 54    54            19             RELEASE      2
 55    55            20             TERMINATE
 56    56                    *
```

Fig 6.4

```
LINE# STMT#  IF DO  BLOCK#  *LOC    OPERATION      A,B,C,D,E,F,G   COMMENTS

  57    57                  ****************************************
  58    58             21           GENERATE    360,FN$XPDS2,5200,,1
  59    59             22           ASSIGN      3,175
  60    60             23           SELECT MIN  4,5,6,,Q
  61    61             24           QUEUE       P4
  62    62             25           SEIZE       P4
  63    63             26           DEPART      P4
  64    64             27           ADVANCE     P3
  65    65             28           RELEASE     P4
  66    66             29           TERMINATE
  67    67                  *
  68    68             30   BB        GENERATE    9000,,5200,,2
  69    69             31           SEIZE       5
  70    70             32   B         ADVANCE     6300
  71    71             33           RELEASE     5
  72    72             34           TABULATE    LQ2
  73    73             35           TERMINATE
  74    74             36   BB1       GENERATE   9000,,5200,,2
  75    75             37           SEIZE       6
  76    76             38   B1        ADVANCE     6300
  77    77             39           RELEASE     6
  78    78             40           TERMINATE
  79    79                  ********************************************
  80    80             41           GENERATE    485,FN$XPDS4,2000,,1
  81    81             42           SELECT MIN  5,7,8,,Q
  82    82             43           QUEUE       P5
  83    83             44           TRANSFER    .12,,UT
  84    84             45           SEIZE       P5
  85    85             46           DEPART      P5
  86    86             47           ADVANCE     170
  87    87             48           RELEASE     P5
  88    88             49           TERMINATE
  89    89             50   UT        SEIZE       P5
  90    90             51           DEPART      P5
  91    91             52           ADVANCE     275
  92    92             53           RELEASE     P5
  93    93             54           TERMINATE
  94    94                  *
  95    95             55           GENERATE    9000,,2000,,2
  96    96             56           SEIZE       7
  97    97             57           ADVANCE     7000
  98    98             58           RELEASE     7
  99    99             59           TABULATE    LQ5
 100   100             60           TERMINATE
 101   101             61           GENERATE    9000,,2000,,2
 102   102             62           SEIZE       8
 103   103             63           ADVANCE     7000
 104   104             64           RELEASE     8
 105   105             65           TERMINATE
 106   106                  ************************************
 107   107             66           GENERATE    288,FN$XPDS5,8500,,1
 108   108             67           ASSIGN      7,175
 109   109             68           SELECT MIN  8,11,12,,Q
 110   110             69           QUEUE       P8
 111   111             70           SEIZE       P8
 112   112             71           DEPART      P8
```

GPSS/H VAX/VMS RELEASE 2.0-E (OV088) 2 FEB 1991 12:36:02 FILE: 13RD.GPS

LINE#	STMT#	IF DO	BLOCK#	*LOC	OPERATION	A,B,C,D,E,F,G	COMMENTS
113	113		72		ADVANCE	P7	
114	114		73		RELEASE	P8	
115	115		74		TERMINATE		
116	116		75	DD	GENERATE	9000,,8500,,2	
117	117		76		SEIZE	11	
118	118		77		ADVANCE	6200	
119	119		78		RELEASE	11	
120	120		79		TABULATE	LQ4	
121	121		80		TERMINATE		
122	122		81	DD1	GENERATE	9000,,8500,,2	
123	123		82		SEIZE	12	
124	124		83		ADVANCE	6200	
125	125		84		RELEASE	12	
126	126		85		TERMINATE		
127	127			********************************			
128	128		86	GG	GENERATE	360000	
129	129		87		TERMINATE	100	
130	130				START	1	
131	131				RMULT	741,543,789,771,121	
132	132				CLEAR		
133	133				START	1	
134	134				RMULT	123,51,657,87,91	
135	135				CLEAR		
136	136				START	1	
137	137				RMULT	87,991,733,655,21	
138	138				CLEAR		
139	139				START	1	
140	140				RMULT	565,989,787,33,7	
141	141				CLEAR		
142	142				START	1	
143	143				RMULT	11,121,,345,569,23	
144	144				CLEAR		
145	145				START	1	
146	146				RMULT	51,37,49,73,111	
147	147				CLEAR		
148	148				START	1	
149	149				END		

6.3 WHEN TO APPLY THE PROPOSED SOLUTION

In order to determine the best time to apply the third alternate solution, the following small study is applied:
Since the best cycle time, based on best combination is determined, the forecasted traffic flow for years 1990, 1991,.... 2000, and check the results, and determine in which year that the intersection can't handle any more flow, because after that year there is no way to solve the problem of the queue length except by changing the geometry of the intersection, and this can be done by using the third alternate solution.

TABLE 6.18 SUMMERY OF OUTPUT OF THE PROGRAM FOR ALTERNATE SOLUTION 3.

RUN NO.	MAX. QUEUE CONTENT					QUEUE CONTENT (MOST LIKELY OCCURED)				
	BR.1	BR.2	BR.3	BR.4		BR.1	BR.2	BR.3	BR.4	
1.	13	12	11	17		8	8	7	11	
2.	15	13	11	17		8	8	7	11	
3.	11	12	11	17		8	8	8	12	
4.	14	12	10	16		9	8	7	12	
5.	17	13	11	17		9	9	8	12	
6.	12	12	11	22		8	8	7	13	
7.	11	12	11	17		8	8	7	13	
AV.	13	12	11	18		8	8	7	12	

CHAPTER SEVEN
DISCUSSION AND CONCLUSION

7.1 DISCUSSION

This thesis introduces and applies scientific engineering management techniques in evaluating any intersection, and giving best solution, by analysing the results of the output of the computer program developed to that intersection. The developed simulation program provides, a fast, easy, and reliable method of evaluating current or future conditions at the intersections. Three alternatives were simulated, the results were analyzed, and the following issues regarding modeling, data, and results are discussed:

1- In building the model, it is considered that each lane will present a facility and for each facility the queue is introduced to gather statistics for that lane. Note in branch 1, for example there are 4 facilities since there are 4 lanes. When the traffic flow inter branch 1, the flow will be distributed into the 4 lanes, but before that, there will be a check for the least queue length to enroll into it.

2- In branch 2, there is only one marked lane, but actually two cars at the same time are passing the intersection parallel to each other, and this will introduce two queues. In order to be very accurate and present the actual situation , two lanes were considered in branch 2. This happened also in branch 4.

3- As mentioned earlier, some data was not available, so it was taken from the site. In determining the service time for branch 3', some of cars in that lane, turned left, while the others turned back (U turn), the service time for each type will differ from the other, so each type is separated by using the TRANSFER block, and certain service time was assigned to each type.

4- As known the time needed for car No.1 to cross the intersection will be greater than it needed for car No. 2, car No. 3.....until car No.5. In order to assign a fixed service time for all cars, the green time for that branch is postponed for certain time, which equals to the average time needed for the first 5 cars - average time needed for the second 5 cars in the queue.

5- In order to develop an accurate and presented program, the following was done:

- Eliminate the effect of randomness by using R-MULT card, and the same distribution function to generate arrivals.

- Run the program for complete hour, in order to reach steady state.
- The program was run seven times for each case,then the average of the seven outputs were taken as a results of that case.

6- The selected cycle times to be studied were high. Because we have 4 phases, and large traffic flow, it is recommended to increase the cycle time length, in order to allow more time for the green time period without interruption, and reduce the lost time.

7- The best solution regarding the performance and queue length in the intersection, was the third alternative, because it gave the minimum queue length, while using the forecasted traffic flow for year 2000. Alternative two will not solve the problem for long time, and it needed to buy land from it's owners, and this may be difficult. In the first alternative, it is impossible to handle such large traffic flow as in year 2000.

8- When the results of the program were compared with the existing actual situation, they were almost the same, which means that the program is present the actual situation.

9-The time needed to run the program is very small compared with other softwares, it takes about (19-28) seconds.

7.2 CONCLUSIONS

1- For the next two years the problem can be solved by adjusting the cycle time and distribute the green time properly. So the cycle time is to be 90 sec. and then increased to 120 sec., and then to 140 sec.

2- After 1993 the intersection at this situation can't handle the the forecasted traffic. So it is recommended to construct the tunnel as illustrated in the third alternate solution.

3- It is recommended to use the simulation technique approach in order to predict the results of any project before doing it.

7.3 FURTHER RESEARCH

1- Prepare all the needed data to major intersections in JORDAN, to be available when requested.

2- Study the design and construction of the tunnel in details, in order to be ready in 1993.

3- Study more than one intersection, connected together, and apply the computer program to them after modifying it.

4- Modify the program, so it can be run on (PS) computers, to make animation of the transactions.

REFERENCES

1- Jerry Branks , and John S. Carson ,II :Discrete - Event System Simulation ", 1984 .

2- Stewarct V. Hoover , and Ronald Perry " Simulation , a problem solving approach " ,1989 .

3- Wolfgan S Homburger , and James H . Kell , "Fundamentals Of Traffic Engineering " ,1981 .

4- William R. Reily , James H. Kell , and Iris J. Fullerton , " Design Of Urban Streets " , 1980 .

5- Theodore M. Matson , Wilbur S Smith , and Frederick W. Huro ." Traffic Engineering " 1955 .

6- " Transportation and Traffic Engineering Handbook " Institute Of Transportation Engineering .

7- R.J. Salter and M. Tadayon " Optimization Of Signal Cycle time By a Computer Simulation " , Traffic Engineering and Control 1987 ,V 28 ,part 5 , pp 290-293 .

8- Roger Plum and Panos Michalopoulos ," Traffic ControlAt Intersection Sites During Reconstruction " , Transportation Engineering , 1987 , V 113 , Part 4 , pp 422-436 .

9- James O Henriksen and Robert C. Crain " GPSS/H User Manual " ,1983 .

10- Highway Design Manual, Ministry of Public Works , The Hashemite Kingdom of Jordan , 1972 .

11- Juan M. Morales and Jeffrey F. Paniati ," Two-Lane Traffic Simulation : A Field Evaluation of Roadism ", , Transportation Research Record 1100, Federal Highway Administration .

12- David D. Bendworth and James E. Bailey "INTEGRATED PRODUCTION CONTROL SYSTEM ", second edition. Arizona state university.

13- William W. Hines and Douglas C. Montgomery, "PROBABILITY AND STATISTICS IN ENGINEERING AND MANAGEMENT SCIENCE."

14- Thomas J. Schriber "Perspectives on simulation using GPSS", University of Michigan, Ann Arbort MI, 48109-1234, USA.

15- R. J. Salter "TRAFFIC ENGINEERING", University of Bradford, England.