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Traffic Signal Design of an Isolated Intersection for Dhaka City Condition

Noman Hyder[1] and Md. Ruhul Amin[2]

Traffic signal is a widely used traffic operation control system at urban roadway intersections. The capacity of urban road network mainly depends on the capacity of the traffic signals. Here in Dhaka, in recent time we are facing severe traffic congestion and delay problem threatening the economic viability of the city. The main queuing and delay points are the traffic signals of Dhaka city. Due to poor management and ill design, the traffic signals of Dhaka are being operated in non-engineered manual fashion. In order to improve the situation, it is required to develop a simplified design method for traffic signal of Dhaka. In the present study, different established equations have been used as the basis for developing a computer program which would be able to help the scientific design of Dhaka city traffic signals. Relevant data at a few intersection of Dhaka city are collected. Then data are used in a computer program to design the signal timings for those intersections. The computer program with Graphical User Interface (GUI) interface is developed using Java for designing signal time considering Dhaka city condition. Results from the computer program and relevant real field values are compared and presented in this paper.

Field of Research: Civil Engineering (Transportation)

Keywords: Traffic Signal, Intersection, Saturation flow.

1. Introduction

Traffic signals are an essential component of traffic control devices. The installation of traffic signals has a central role in controlling traffic hazards at the intersection. An intersection is the crucial point of conflicts and congestion in the road network.

A traffic signal is a power operated traffic control device which is warned and directed to take some specific action. Ogden and Bennett (1981) explained that the primary aims of signal control at an intersection are:

1. To reduce conflicts and hence the potential for accidents,
2. To better regulate and stabilize traffic movements, and
3. Hence reduce delays.

Dhaka, the capital city of Bangladesh with about 10 million people is the centre point of majority of the economic activities of the country. With rapid urbanization

Noman Hyder [1], Sub-Divisional Engineer, Bangladesh Water Development Board, Dhaka, Bangladesh. E-mail: hydern97@gmail.com,
Md. Ruhul Amin [2], Assistant Professor, Department of Civil Engineering, Bangladesh University of Engineering & Technology (BUET), Dhaka, Bangladesh. E-mail: ruhulamin@ce.buet.ac.bd,

over the years over the years coupled with unplanned limited roadway facilities Dhaka is experiencing severe road traffic congestion problem in recent years. Delay and congestion problem is hampering normal as well as economic activities of the city dwellers. Every conscious citizen feels that something has to be done in order to improve the situation.

2. Literature Review

Traffic control signals are primarily used to control the vehicular and pedestrian traffic at intersections. It is used to avoid vehicle conflicts and to reduce the number and severity of accidents at intersections.

The traffic signal device (or head) is an assembly that contains one or more signal faces. Each signal face, except in pedestrian signals, is comprised of three to five optical units that display color coded indications (red, yellow, green, green arrow, etc.)

Flaherty (1974) stated that there are generally two types of signals in general use: fixed-time and vehicle-actuated. Another intermediate type, semi-vehicle-actuated signal with detectors on the side roads is also used.

- ***Fixed-time signal:*** In this system, the green periods, and the cycle times are predetermined and the duration is fixed. The controllers are simple and relatively of low cost but they are not flexible. Generally, they are successfully used in linked systems. They can be set with time switches to change the settings at certain periods of the day, to adjust with different traffic conditions.
- ***Vehicle-actuated signals:*** With this type of signals the green periods are associated to the traffic demands. Using detectors which are usually installed on all approaches the green period is determined. In the absence of demands, the signals will continue for an indefinite period on the phase which was served. Several low voltage electronic timers are used here. According to Flaherty (1974), the basic technique in vehicle-actuated signal utilizes the following two basic features: (1) initial vehicle interval and (2) vehicle extension (passage time).
- ***Semi-vehicle-actuated signals:*** In this type of signals, detectors are installed on the side roads only and the right-of-way normally rests with the main road, being transferred immediately (or at the end of a pre-set period) to the side road when a vehicle passes over the side-road detector. (Flaherty, 1974)

Saturation flow: According to Flaherty (1974), the term saturation flow is used to describe the constant maximum rate of discharge from the approach road, and it is usually expressed in veh/hr of green time for existing intersections. Saturation flow is an important consideration in traffic signal design.

The saturation flow can be calculated in different ways. It can be calculated by taking field data but it is a time consuming process. There are also many equations available for the determination of saturation flow. But the calculating the saturation flow using these equations in Bangladesh where both motorized and non-motorized vehicles run together is not satisfactory. So an empirical equation for the determination of the saturation flow developed by Hossain (2001) was used. This equation is satisfactory for Bangladesh which considers both motorized and non-motorized vehicles. The equation is given below:

Saturation flow = 1500 + 430*width + 10.5*pnmv - 30*phv - 2*plt - 10*prt

Where Saturation flow is in vehicle per hour
Width in meter
Pnmv: percentage of non-motorized vehicles
Phv: percentage of heavy vehicles
Plt: percentage of left turning proportion
Prt: percentage of right turning proportion

Cycle time: The number of seconds required for one complete revolution of the timing dial or for one complete sequence of signal indications. The cycle time may be measured as the time required for the complete sequence of events from the start of green again for that phase. (Pignataro and Louis, 1973)
For an individual intersection the cycle time for which the total delay at all approaches is a minimum is represented by (Flaherty, 1974),

$$C_0 = \frac{1.5L+5}{1-y_1-y_2 \ldots -y_n}$$

Where C_0=optimum cycle time, sec
Y_1, y_2, … y_n =max. ratios of actual flow to saturation flow for phases 1, 2, … n.
L=total lost time per cycle, sec.
Cycle lengths during peak periods normally range from 80 to 120 seconds as compared with 60 to 80 seconds at other times. (MATSON et al. 1955)

Delay formula: Webster (1961) has suggested the following formula for determining the average delay per vehicle:

$$d = c(1-y)^2/\{2(1-yx)\} + x^2/\{2q(1-x)\} - 0.65(c/q^2)^{1/3} * X^{(2+5Y)}$$

Here,
d =average delay per vehicle;
c =cycle time;
y=proportion of cycle which is effectively green (i.e. g/c);
q= flow;
s= saturation flow;
x=degree of saturation; (i.e. q/(ys));
g= effective green time;

Webster & Cobbe (1966) explained that the last term in the above equation gives a value which is between 5 and 15% of the average delay in cases. As a result the following equation is often used in practice to obtain an approximation to the delay:

$$d = 9/10[c(1-y)^2/\{2(1-yx)\} + x^2/\{2q(1-x)\}]$$

This is one of the most widely used formulas for the estimation of delays to vehicles approaching isolated intersections.

According to Sharma (1985), traffic signal has the following advantages:

a) Provide for the orderly movement of traffic.
b) Reduce the frequency of certain types of accidents e.g., right angle collisions.
c) Provide a means of interrupting heavy traffic to allow other traffic, both vehicular and pedestrians, to enter or cross.
d) Promote driver confidence by assuring right-of-way.

3. Methodology

The data for present condition of traffic was gathered from the field. These data were used to calculate the delay at the present condition. The existing green period and cycle time was also determined from the field condition. The data were collected from Moghbazar and Banglamotor intersections. For data collection stop watch was used for time measurement. Qualitative observation was done for mixed traffic behaviour. Direct measurement was taken of road width and time for estimation of traffic signal planning and timing data. Classified vehicle counts data during the discharge were manually taken. The collected data are shown in the result section. Then a signal design program was developed using Java. The developed program has a graphical user interface (GUI). So this program is very easy to use. From the collected field data this program can design and show signal timing including delay time. In the program saturation flow equation, cycle time formula and delay formula were used. The program calculated the cycle time and signal time using the mathematical formula and equations stated in the literature review section. In the program both two phase and four phase type design options are used. The program can be used for both four legged and three legged intersection. From this study the existing signal time and calculated signal time using the computer program was compared. In addition to this, delay from the existing condition and delay from the program generated signal timing was also compared.

Main Features of the Computer Program:

- The computer program is a user friendly tool which was developed keeping in mind the inhibitions on the part of field engineers to follow scientific signal phasing approach.
- It is a very user friendly program to enable the field engineers to use it even without knowing the in depth concepts about the parameters and the different variables used in it with taking help from the help file.
- It can accommodate different signal plans according to needs of users based on actual field condition.
- It will give saturation flow; signal timing, optimum cycle time, delay and loss time with phase diagram as output.
- For two phase design the range in the program for cycle time is set 30-120 seconds. While For four phase design the range in the program for cycle time is set 30-200 seconds.
- Java was the language to develop this computer program. Java 2 Development Kit (J2SDK) version 1.3.0 has been used for the compilation of the program. Java can be used to create any kind of program. This is a very strong and platform-independent (that is, architecture neutral) language. For this reason java programs can run in Windows, UNIX and Macintosh- all kinds of environments.

Program inputs: In the input interface of the program eight inputs are required for one approach i.e. total thirty two inputs for four approaches. The inputs are described below in brief:

1) Width: In this box the approach width is to be put in metre.

2) pnmv: It means percentage of non-motorized vehicles. In this box the percentage of non-motorized vehicles is to be given. For example if the value is 25% then the value in the box should be given 25.

3) phv: It means percentage of heavy vehicles.

4) prt: It means percentage of right turning vehicles.

5) plt: It means percentage of left turning vehicles.

6) Initial veh. No : It means No. of vehicles passing in first six seconds. In this box the No. of vehicles passing in first six seconds should be given.

7) Final veh. No : It means No. of vehicles passing in last six seconds.

8) Flow: In this box flow value should be given in vehicle/hour.

These eight parameters are to be put for each direction. Some other options are also to be supplied. They are:

1) For four legged intersection "Four Approach" option should be taken and for "T" intersection "Three Approach" option should be taken.

2) For Two phase design "Two Phase option" should be taken and for multiphase design "Multiphase" option should be taken.

3) For the developed program for Four Approach “Multiphase” refers to Four Phase and for Three Approach it refers to Three Phase.

For "T" intersection the "prt" and "plt" values should be such that their summation equals to 100% in the Direction Two as there is no straight portion of vehicles and all the required values should be given properly otherwise the program will not work or will give erroneous results

Program outputs: The outputs of the program are:

a) Saturation flow in vehicle/hour.
b) Delay in second.
c) Green time in second.
d) Initial loss time in second.
e) Final loss time in second.
f) Optimum Cycle time in second. This is the cycle time found from calculation.
g) Cycle time in second. This cycle time is used. It may be equal to Optimum Cycle time if its value is within the acceptable range. The acceptable range is taken as 30-120 seconds for two phase and 30-200 seconds for multiphase.

4. Results and Discussions

Moghbazar intersection: The collected data from existing conditions along with calculated results from Moghbazar intersection are shown in Table 1. The Moghbazar intersection is shown in Figure 1.

Table 1: Cycle time (Manually by traffic police) at Moghbazar Intersection (Two phase)

	DIRECTION 3		DIRECION 2				
Observation no.	Green(h:m:s)	Red(h:m:s)	Green	Red	Cycle time	Total	Avg. Cycle Time
1	0:03:20	0:04:40	0:04:40	0:03:20	0:08:00	1:04:15	0:09:11
2	0:03:40	0:04:55	0:04:55	0:03:40	0:08:35		
3	0:03:50	0:06:45	0:06:45	0:03:50	0:10:35		
4	0:03:30	0:05:05	0:05:05	0:03:30	0:08:35		
5	0:03:20	0:05:15	0:05:15	0:03:20	0:08:35		
6	0:03:25	0:06:05	0:06:05	0:03:25	0:09:30		
7	0:04:15	0:06:10	0:06:10	0:04:15	0:10:25		

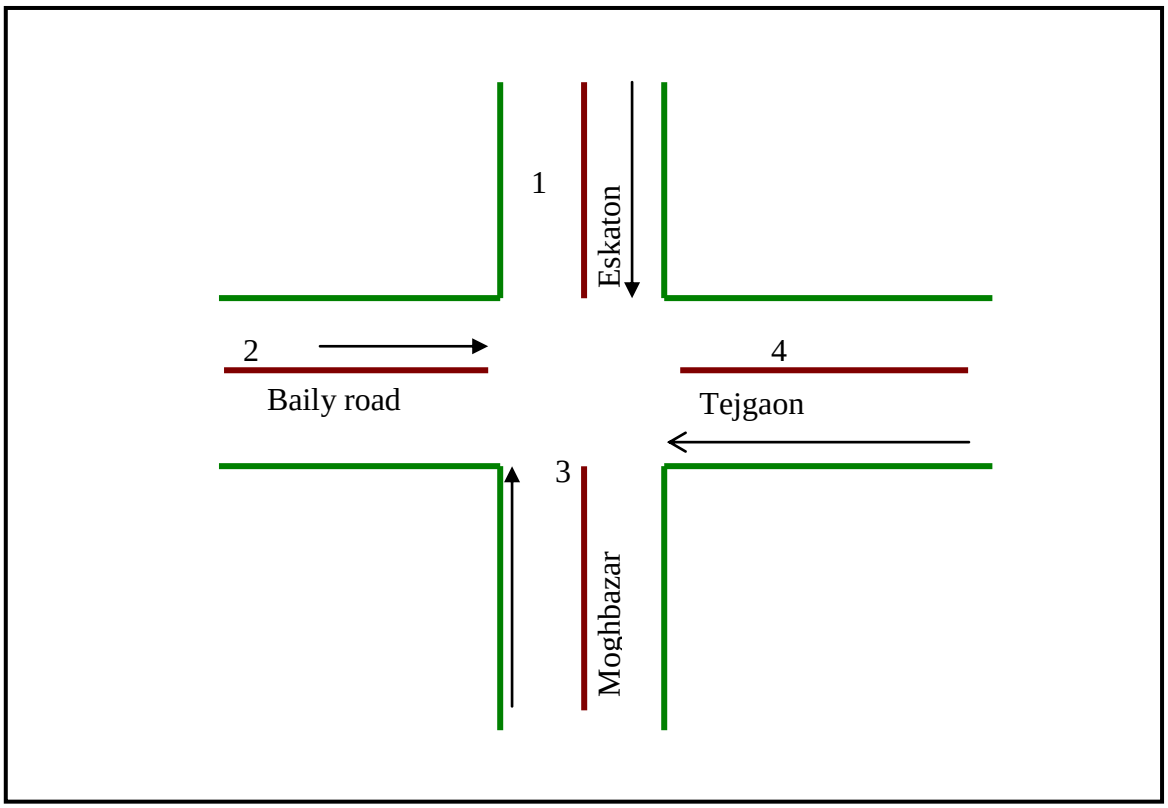


Figure 1: Moghbazar Intersection

In Table 2 data for delay calculation and in Table 3 delay calculation results are shown.

Table 2: data for delay calculation at Moghbazar Approach

Vehicle	Time (h:m:s)	time(sec)	Travel distance in metre
Cng	0:07:40	460	129.6
Micro	0:07:22	442	109.2
Rickshaw	0:07:19	439	104
Bus	0:10:22	622	104.9
Car	0:10:15	615	114.7
Rickshaw	0:06:30	390	132
Rickshaw	0:06:20	380	99
Car	0:07:05	425	90
CNG	0:06:50	410	108
Micro	0:08:09	489	110

Table 3: Delay at Moghbazar Approach

vehicle type	travel distance in metre	travel time in sec.	desired speed in kmph	desired travel time in sec	Delay in sec.
CNG	129.6	460	45	10.368	449.63
Micro	109.2	442	45	8.736	433.26
Rickshaw	104	439	12	31.2	407.80
Bus	104.9	622	45	8.392	613.61
Car	114.7	615	45	9.176	605.82
Rickshaw	132	390	12	39.6	350.40
Rickshaw	99	380	12	29.7	350.30
Car	90	425	45	7.2	417.80
Cng	108	410	45	8.64	401.36
Micro	110	489	45	8.8	480.20

Flow and other data are shown in the following Table 4.

Table 4: Flow and other data at different intersections

Name of intersection	Approach	Flow(vph)	pnmv	phv	prt	plt
Moghbazar	Eskaton	1599	50	6	12	25
	Baily road	1883	60	7	30	20
	Moghbazar	2183	60	3	15	25
	Tejgaon	1992	50	3	20	30
Banglamotor	Banglamotor	1600	50	6	12	25
	Shahbag	1900	0	10	30	20
	Eskaton	1650	60	3	15	25
	Firmgate	2200	0	10	20	30

Program input for Moghbazar intersection is shown in the following Figure 2.

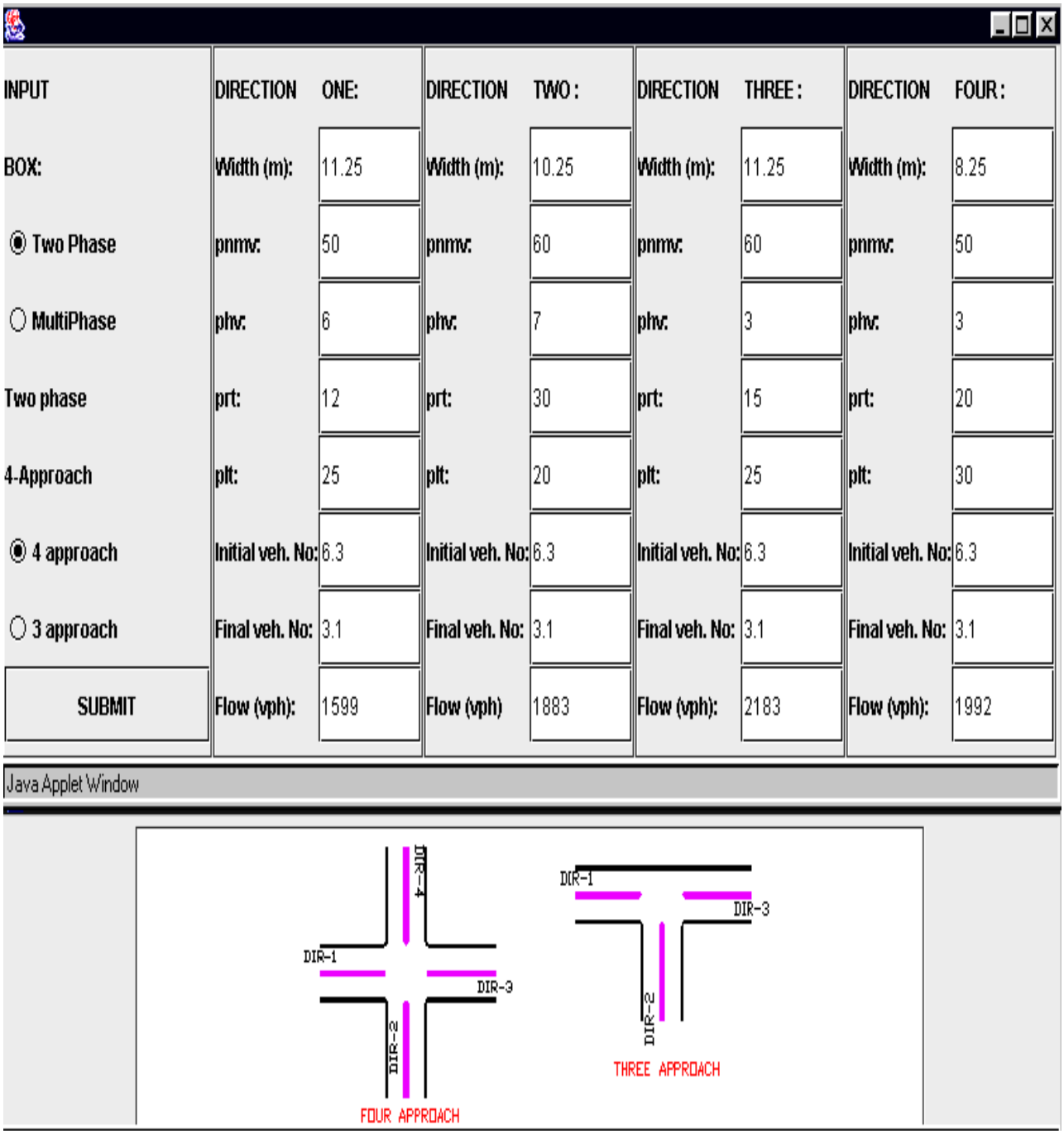
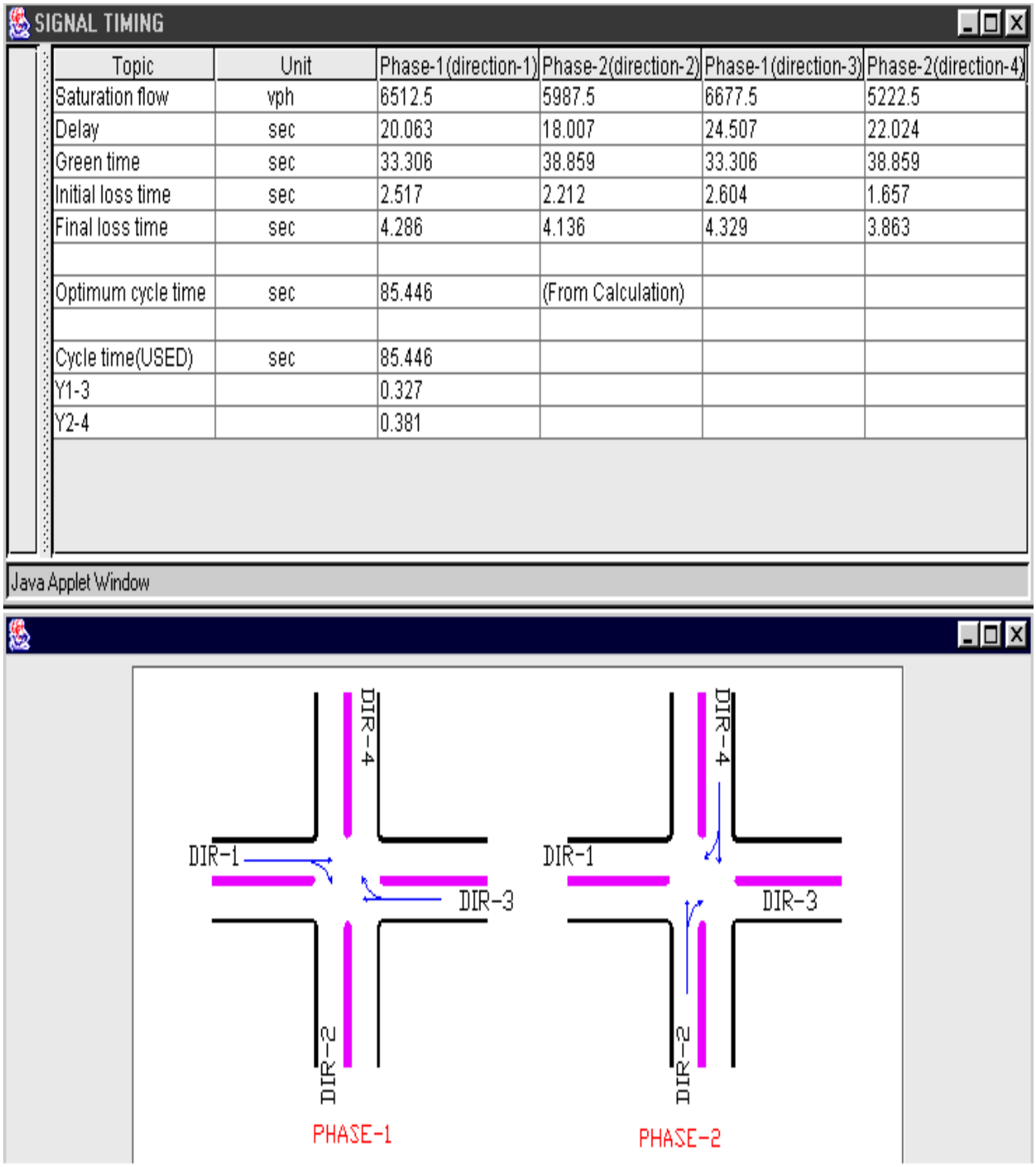


Figure 2: Input for Moghbazar intersection

Program output for Moghbazar intersection is shown in the Figure 3.



Topic	Unit	Phase-1(direction-1)	Phase-2(direction-2)	Phase-1(direction-3)	Phase-2(direction-4)
Saturation flow	vph	6512.5	5987.5	6677.5	5222.5
Delay	sec	20.063	18.007	24.507	22.024
Green time	sec	33.306	38.859	33.306	38.859
Initial loss time	sec	2.517	2.212	2.604	1.657
Final loss time	sec	4.286	4.136	4.329	3.863
Optimum cycle time	sec	85.446	(From Calculation)		
Cycle time(USED)	sec	85.446			
Y1-3		0.327			
Y2-4		0.381			

Figure 3: Output for Moghbazar intersection

Some graphs are plotted from the values of program output and field data. The Figure 4 shows comparison of different delay results calculated from field data and the delay calculation from program output. The program gives the designed cycle time and signal time. The delay time calculated from program is very small compared to field value. It means that if the designed signal system could have been used then the delay would have been very small. This is an important finding of the study. It shows that a scientific traffic signal system can reduce the delay

time and thus reduce congestion and can also help our economy by reducing delay time which costs us a lot.

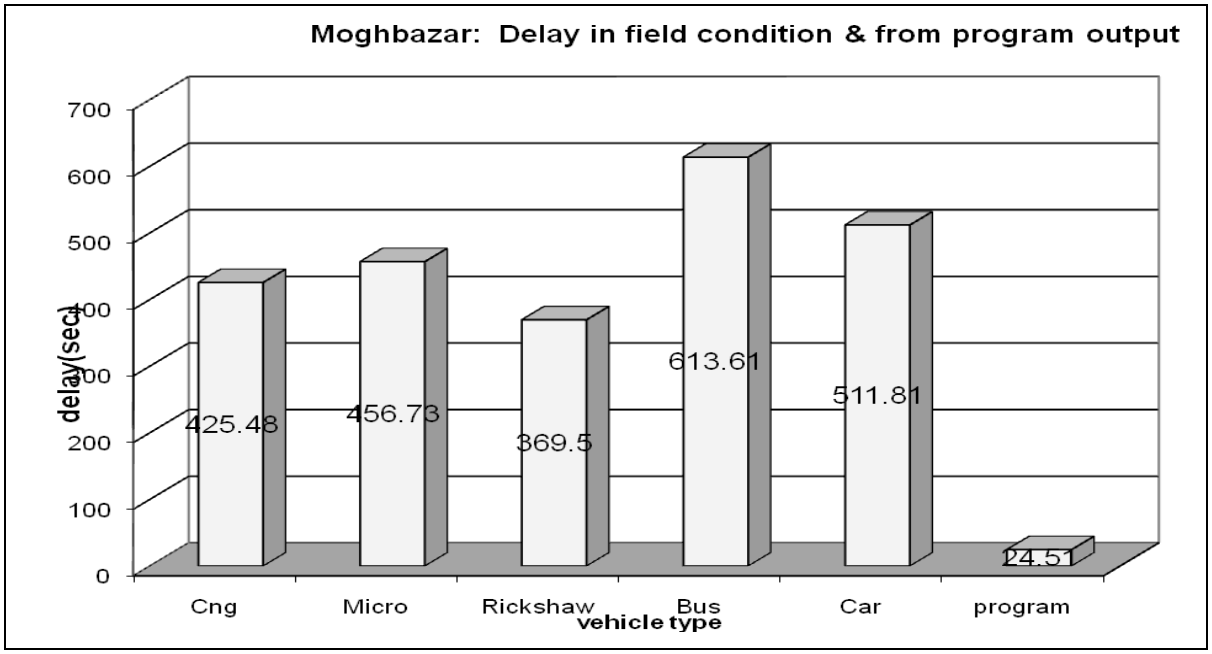


Figure 4: Delay for different vehicles & program output in Moghbazar intersection

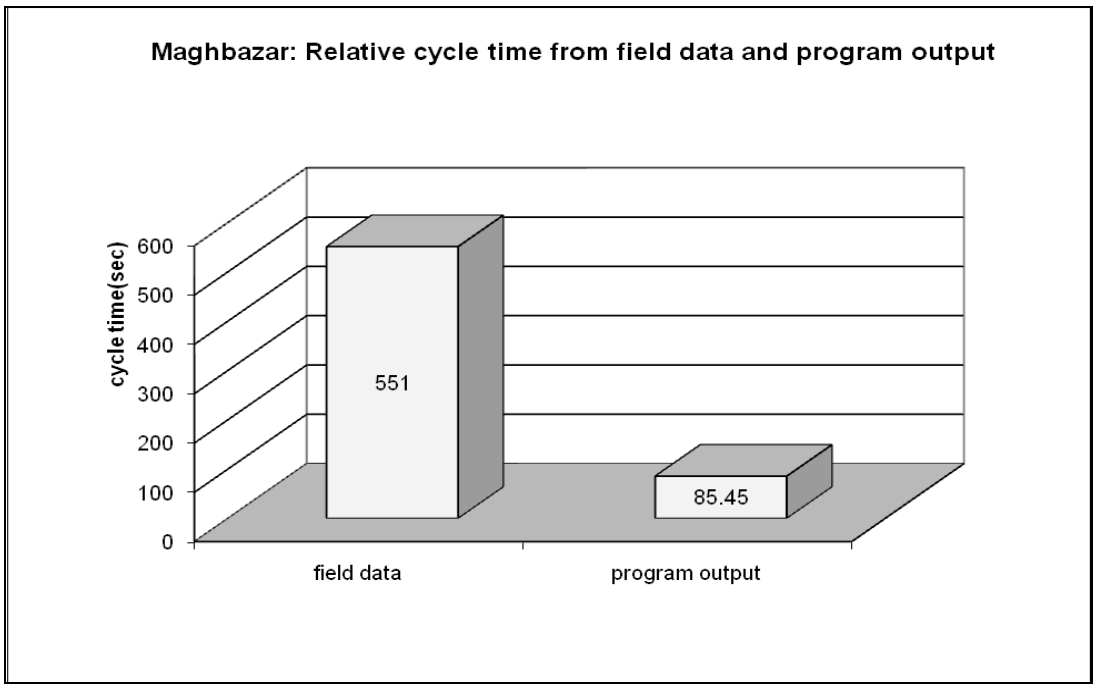


Figure 5: Cycle time in Moghbazar intersection

From Figure 5 it is observed that the cycle time was very high in the existing condition. So from the Figure 4 and 5 it can be conferred that if the cycle time is illogically high it will increase delay time. So the cycle time should be scientifically designed.

Banglamotor intersection: Similarly data collection and assessment for the Banglamotor intersection was also done. The collected data from existing conditions along with calculated results from Banglamotor intersection are shown in Table 5. The Banglamotor intersection is shown in Figure 6.

Table 5: Cycle time by traffic police (Manual) at Banglamotor Intersection (Two phase)

Observation no.	DIRECTION 1		DIRECION 4				
	Green(h:m:s)	Red(h:m:s)	Green	Red	Cycle time	Total	Avg. Cycle Time
1	0:01:30	0:10:55	0:10:55	0:01:30	0:12:25		
2	0:01:25	0:10:10	0:10:10	0:01:25	0:11:35		
3	0:00:50	0:07:10	0:07:10	0:00:50	0:08:00		
4	0:01:40	0:09:30	0:09:30	0:01:40	0:11:10	1:10:15	0:11:42
5	0:01:20	0:12:50	0:12:50	0:01:20	0:14:10		
6	0:01:45	0:11:10	0:11:10	0:01:45	0:12:55		

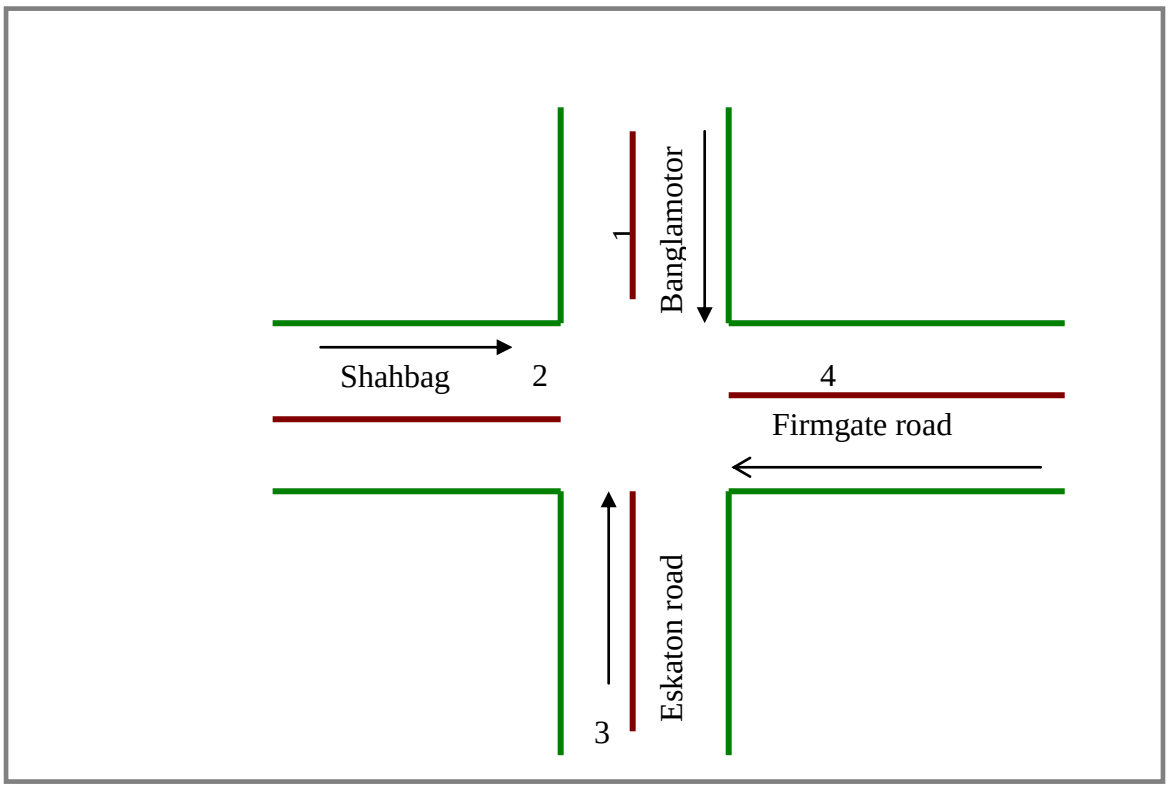
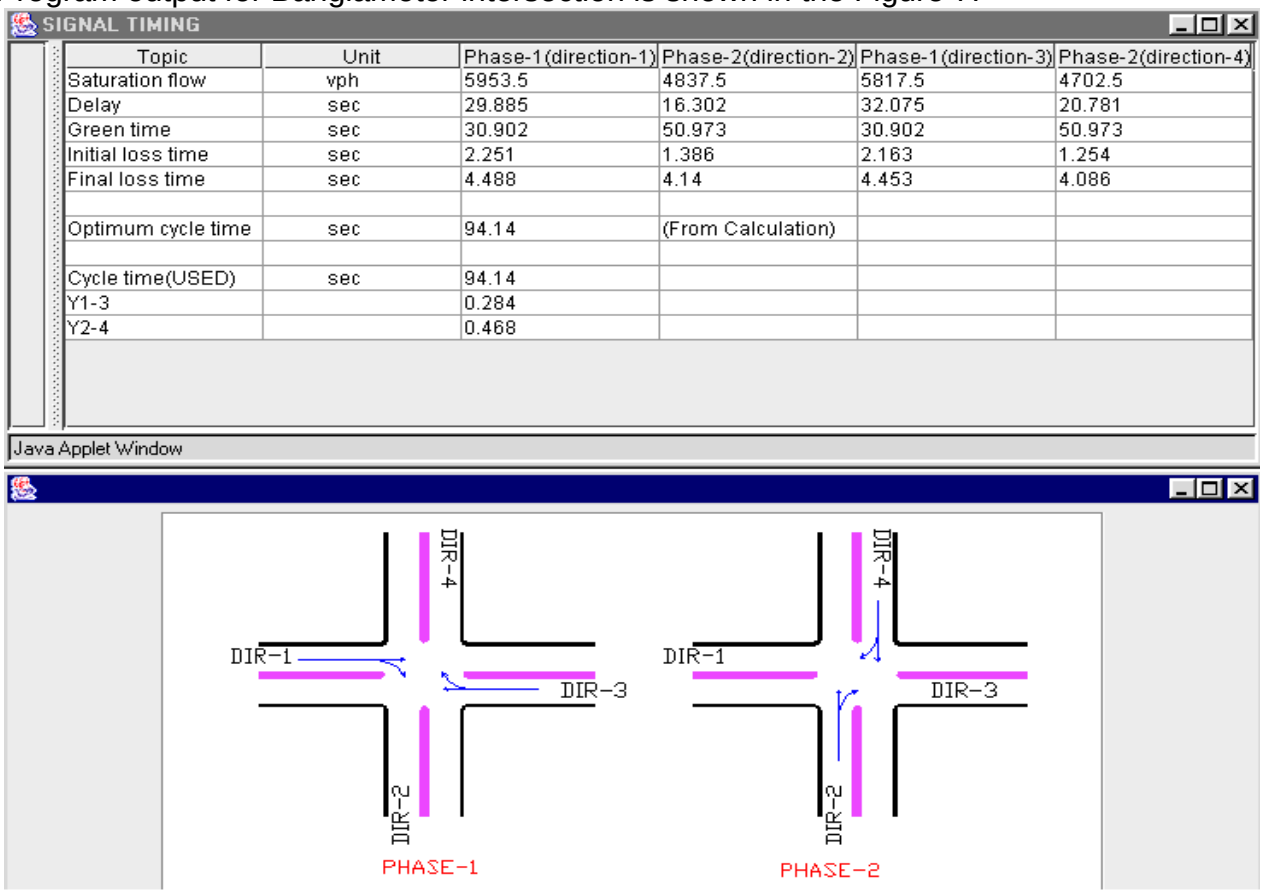


Figure 6: Banglamotor intersection

Program output for Banglamotor intersection is shown in the Figure 7.



Topic	Unit	Phase-1(direction-1)	Phase-2(direction-2)	Phase-1(direction-3)	Phase-2(direction-4)
Saturation flow	vph	5953.5	4837.5	5817.5	4702.5
Delay	sec	29.885	16.302	32.075	20.781
Green time	sec	30.902	50.973	30.902	50.973
Initial loss time	sec	2.251	1.386	2.163	1.254
Final loss time	sec	4.488	4.14	4.453	4.086
Optimum cycle time	sec	94.14	(From Calculation)		
Cycle time(USED)	sec	94.14			
Y1-3		0.284			
Y2-4		0.468			

Figure 7: Output for Banglamotor intersection

From Figure 8 and 9 it is also observed that delay time calculated from program is very small. So also in this case, it is found from the results that a scientific traffic signal system can reduce the delay time.

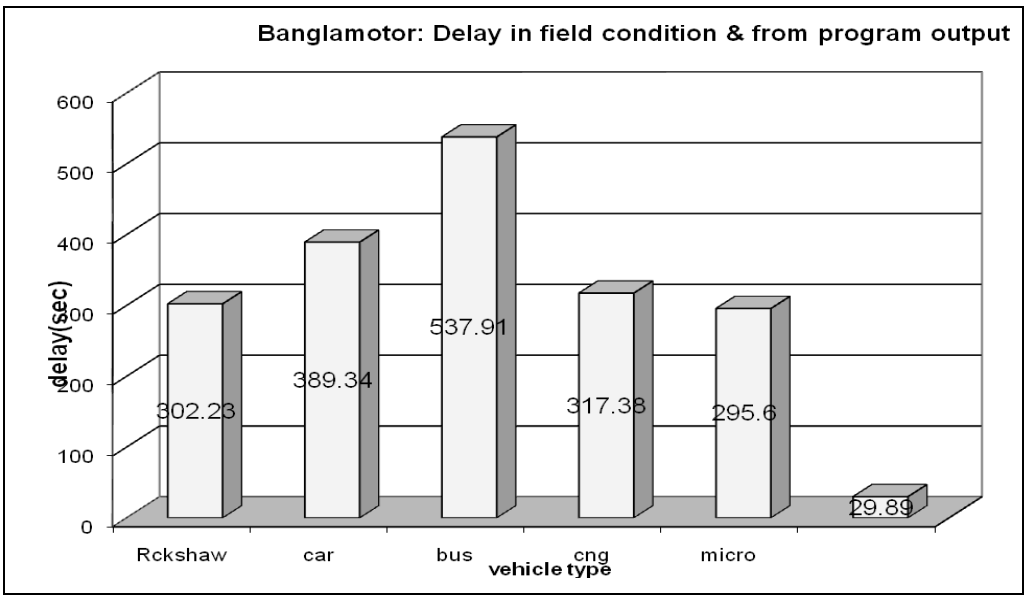


Figure 8: Delay for different vehicles & program output in Banglamotor intersection

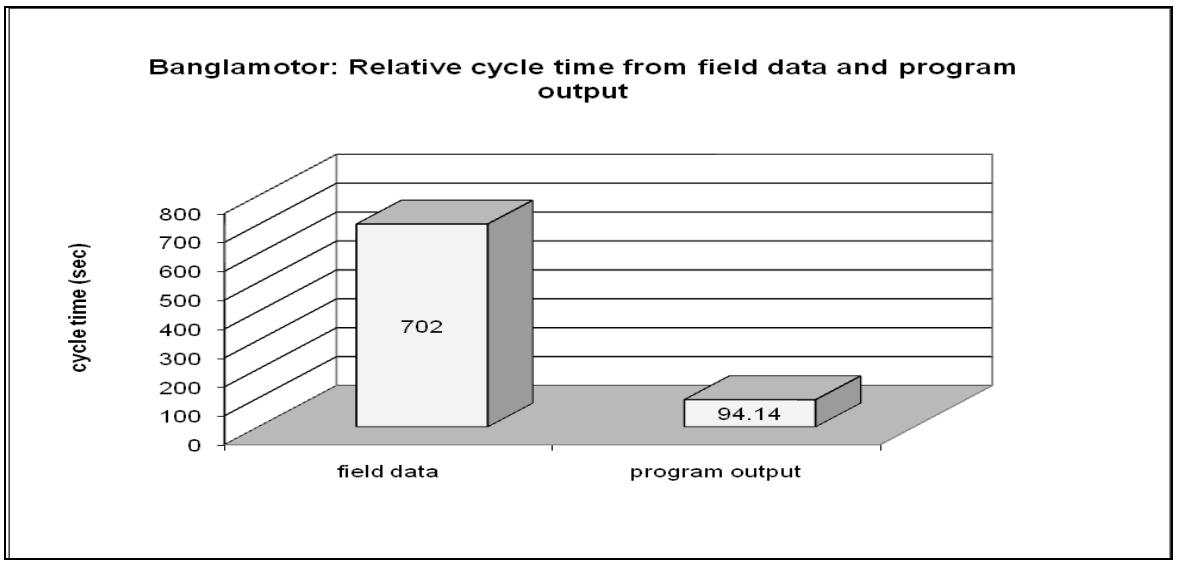


Figure 9: Cycle time in Banglamotor intersection

5. Conclusion and Recommendations

The aim of this study was to investigate the traffic signal performance of some intersection in the metropolitan city of Dhaka. This is also aimed at looking into other features regarding controlling and regulating the traffic and developing a computer program. Accordingly, the study involved the technique of collecting traffic data. Most of the data were collected by field investigation.

Traffic in Bangladesh consists of two distinct categories of vehicles i.e. motorized and non-motorized vehicles. The characteristics of these vehicles differ widely even within the same class, though they all use the same right of way. Lack of lane discipline makes the traffic system mixed and heterogeneous in nature.

Before developing a systematic design method for the traffic signal a comprehensive literature review was performed. Based on the review signal design parameters and relationships were identified for customizing in local traffic environment. Finally a user friendly computer program was developed using different signal design parameters for the local condition. Data of the surveyed intersections were used as inputs for the computer program and values of cycle time, signal timing and delay were found from the program. The calculated values from the program were less than the values found by field observation.

The study results showed that a scientific and systematic traffic signal system can reduce the delay time and thus can reduce traffic congestion. This kind of programs can also be used for estimating the signal timing in different intersections.

The study infers that the traffic control devices should be set on proper traffic engineering ground to achieve an effective traffic control system.

The following recommendations are made based on the findings of the study:

i. Relationship showing the variations of flow with cycle time can be developed for this country for better signal design and planning.
ii. Cycle time vs. delay relationships should be established for optimum signal setting for local condition.

iii. The variations of delay with major or minor flow should be established in the context of Bangladesh.
iv. Data can be collected more correctly than that conducted in this study. Such as video technique, and other developed techniques.
v. A pedestrian phase can be added to the computer program.
vi. The program can be upgraded from isolated system to interconnected signal system.

References

Flaherty, C.A.O., "*HIGHWAYS Volume 1 Highways and Traffic",* London: Edward Arnold, 1974.

Hossain, M., "*Estimation of saturation flow at signalized intersections of developing cities*": A micro-simulation modeling approach, the International journal of Transportation Research Part A, Elsvier Science Ltd., Vol.35/2, pp.123-141, 2001.

Matson, T. M., Smith, W.S. & Hurd, F.W., "*Traffic Engineering",* USA: McGraw-Hill, 1955.

Nag, B.*, "Traffic signal design of isolated intersection for mixed traffic operation", a thesis* performed for partial fulfillment of Bachelor of Science in civil engineering, BUET, Dhaka, 2002.

Ogden and Bennet D.W., "*Traffic Engineering Practice",* Monash University Victoria, 1981.

Pignataro, Louis J., "*Traffic Engineering theory and practice",* New Jersey: Prentice-Hall, Inc.,Englewood Cliffs, N.J., 1973.

Sharma, S. K., "*Principles Practice and Design of Highway Engineering",* Standard Publishers Distributors, Delhi, India, 1985.

Webster, F.W., "*Traffic Signal Settings Dept. of Scientific and Industrial Research, Road Research Laboratory",* Road Research Technical Paper No.39, H.M.S.O., U.K, 1961.

Webster, F.W. & Cobbe, B.M., "*Traffic Signals",* Road Research Technical Paper No. 56 U.K., 1966.