is detected by a receiving antenna. The depth to the reflecting surface can be calculated from the elapsed time for the electromagnetic wave to travel from and back to the surface. As the antenna is moved along a line, utilities underneath that line up to depths of around 2 meters can be mapped.

In order to obtain high resolution, pulse width of a transmitted electromagnetic wave needs to be very short, as short as few nanoseconds. The process under which the subsurface detector operates is schematically shown in Figure T-2.3.1.

The Subsurface Radar can be used effectively up to a depth of 2 meters under favorable conditions and the surrounding soil layers need to be electrically homogeneous. Since electromagnetic wave is attenuated by induced eddy current in medium, detection depth becomes shallower in the more conductive soils, such as beach soil which is filled with brine.

The standard components of the Radar are listed in Table T-2.3.2 and its specifications are shown in Table T-2.3.3.

(2) Execution

On the basis of the Interview Survey results, survey lines were set across the road where the flyover was likely to be constructed at 20m or 40m intervals for a distance of 160 meters from the intersection in each direction (as shown in Figure T-2.3.2). Subsurface Radar Survey was carried out during the night and early morning hours from early November up to the first week of December, 1991. At the Study intersections #3 and #5, the subsurface radar survey was carried out along both intersecting roads as the direction of the flyover was not yet determined.

Survey results were recorded on magnetic cassette tape and survey was carried out continuously. Color printouts were also produced at the time of survey as necessary.

Figure T-2.3.1 Schematic Presentation of Subsurface Detector Process

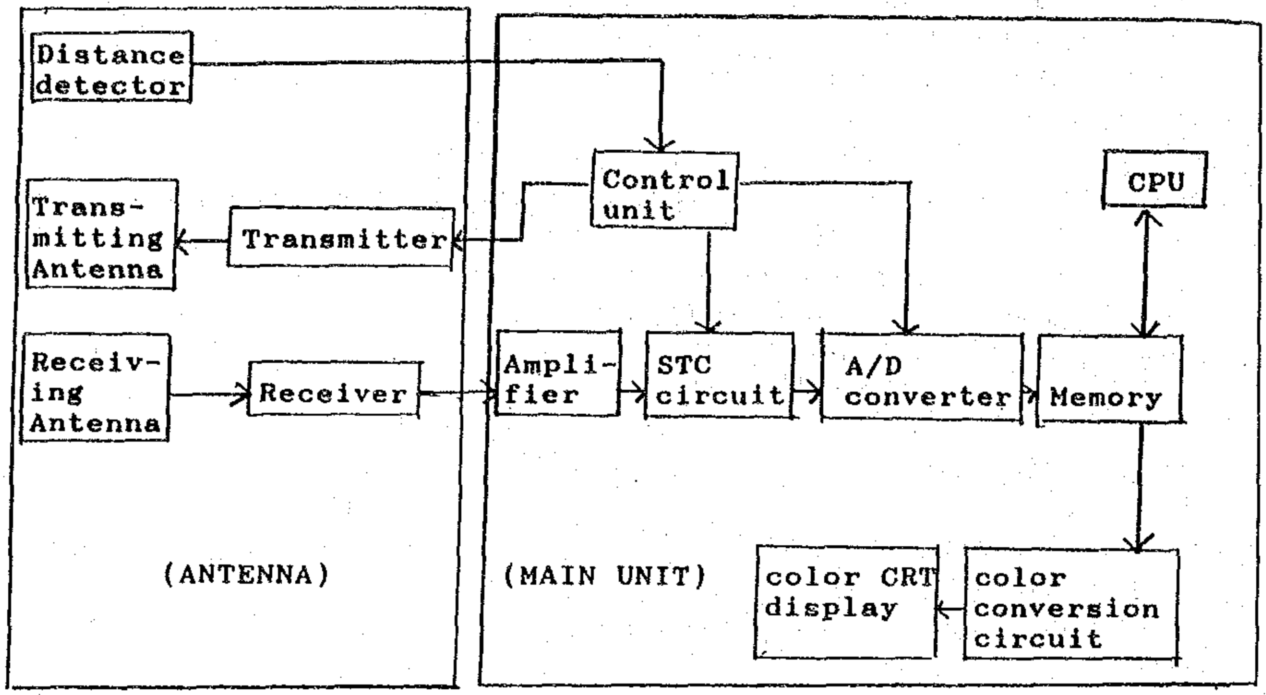


Table T-2.3.2 Standard Components of the Radar

Component	Model	Quantity
Main Unit	NJJ-28E	1
Antenna	NJJ-34E	1
Connecting Cable	CFQ2332	1
Marker Unit	CCK-481	1
Color Printer	CHC-135	1
Data Recorder	R-61	1

Table T-2.3.3 Specifications of the Radar

Item	Remarks
System	Impulse system
Signal duration	Approximately 2ns
Recording range	0 to 20 ns, 0 to 40 ns, 0 to 60 ns, 0 to 100 ns, 0 to 200 ns
Display modes	A mode: display reflected signal. B mode: display vertical section. C mode: display horizontal section.
Signal processing	Differential, product, differential/ product, and space filtering
Display	8-inch, 8-color CRT display
Depth	Converted depth by dielectric constant setting.
Horizontal distance	Integrated up to 999 m
Internal memory	28 m in 4 cm measuring interval. Instantaneous play back.
Antenna speed	1.6 m/sec or less in 4cm interval. Speeding alarm function.
Output	Close-up camera unit Color hard copy with instant film. Color hard copy with 35 mm film. Color printer. RS 232 (optional)
Power supply	100 VAC, 50/60 Hz
Power Consumption	Approximately 130 VA

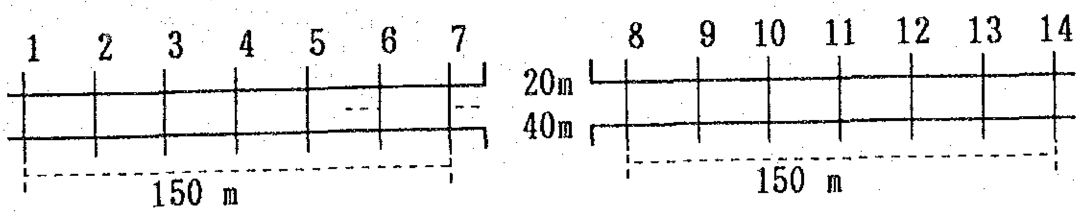
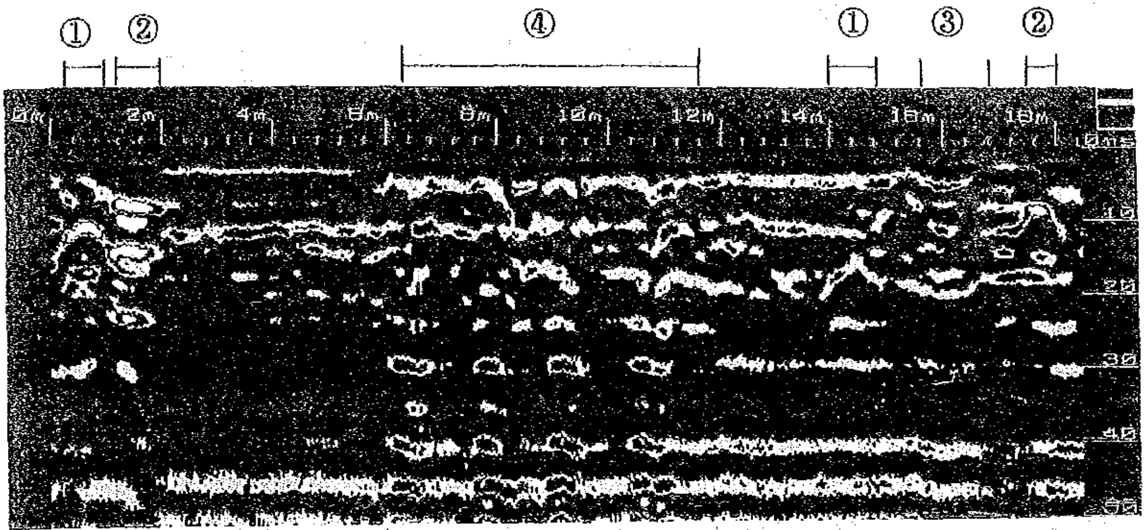


Figure T-2.3.2 Intervals of Surveyed Cross Sections

(3) Analysis

Recorded survey results were played back at the office and color hard copies of each survey lines were made. The example of a color printout is shown on Figure T-2.3.3.



(1) Cylindrical Pipe (3) Discontinuity near the surface
(2) Square Box (4) Multiple reflection of tram rail

Figure T-2.3.3 Example of Colour Printout of Underground Section along Survey Line

(4) Results

At both edges of the roads, strong reflecting bodies were largely detected near the ground surface. Buried objects were both cylindrical and square shaped. Buried pipes of diameters over 50 cm were easily detected by the Radar.

Many discontinuous reflecting bodies were detected as artificially filled earth, but some could not be identified as buried pipes in brick fragments filled earth. Utilities buried near tram rails and manholes could not be easily detected because of the strong reflection of the electromagnetic waves by the rails and manholes.

2.3.5 Verification by Excavation Survey

(1) Objective

Pits were excavated at the ten Study intersections to verify the results obtained in both the interview survey and subsurface radar survey.

(2) Methodology

The Study Team selected the verification pit locations at each of the ten locations, and excavation was carried out during the night, with reinstatement completed by early morning of the following day.

Pits of dimensions 1.5m x 1.5m with a depth of 2.0m were manually excavated to avoid any damage to existing pipes.

(3) Results

Sketches were made on site with measurements surveyed identifying the positions of any uncovered utilities and their depth from ground level. Drawings were then prepared in the office and shown on the topographic maps for each respective intersection. Tab. T-2.3.4 sums up the results of this survey.

2.3.6 Integration of Results of the Three Surveys

The results of the three surveys at Intersection #10 are integrated in one drawing as shown in Fig. T-2.3.4. In general the following information was provided from the three surveys.

(1) Interview Survey

a. Most telephone cables are buried along the sidewalks and cross roads near the intersections. In recent practice, telephone cables are laid in vinyl chloride pipes under sidewalks and in steel pipes under driveways.

Table T-2.3.4 Verification Excavation Survey Results

No.	Water Line Cross (C)	Sewer Line	Gas Line	Electricity Line	Telephone Line
1	φ75 mm h = 0.60 m (C)	φ1830 mm h = 1.75 m		φ500 mm h = 1.45 m	
2	φ457 mm h = 1.60 m				
3	Fragments of Bricks				
4				750×100 mm h = 1.85 m ? (Masonary Box)	
5	φ150 mm h = 1.75 m			φ75 mm(L) h = 1.45 m φ75 mm(L) h = 1.45 m φ150 mm(L) h = 0.75 m (covered with Tiles)	
6				φ25 mm(L) h = 0.75 m φ75 mm(L) h = 1.10 m φ75 mm(L) h = 1.10 m φ75 mm(L) h = 1.10 m	
7	φ457 mm h = 0.75 m			600×100 mm h = 1.75 m ? (Masonary Box)	
8	Fragments of Bricks				
9	φ457 mm h = 1.50 m		φ305 mm h = 0.90 m	φ25 mm(L) h = 1.60 m φ25 mm(L) h = 1.60 m φ25 mm(L) h = 1.60 m φ25 mm(L) h = 1.60 m φ25 mm(L) h = 1.60 m (L.T.Cable)	600×300 mm h = 1.15 m ? (Masonary Box)
10	φ457 mm h = 1.20 m (C)	φ1829 mm h = 1.90 m	1000×450 mm h = 0.00 m (Masonary Box)		

Names of Crossings
1. A.P.C Roy Road and Lenin Sarani Crossing (Moulali)
2. Chowringhee Road and Lenin Sarani Crossing
3. Gariahat Intersection on Rash Bihari Avenue
4. A.P.C Roy Road at Shyambazar Crossing
5. A.J.C Bose Road and Chowringhee Road Croosing
6. A.J.C Bose Road at Ballygynge Circular Road Crossing
A.J.C BOSE Road at Sarat Bose Road Crossing
7. A.P.C Roy Road at Maniktala Crossing
8. Park Street and Chowringhee Road Crossing
9. Lock Gate Road Flyover on the railway lines
10. A.J.C Bose Road and Park Street Crossig

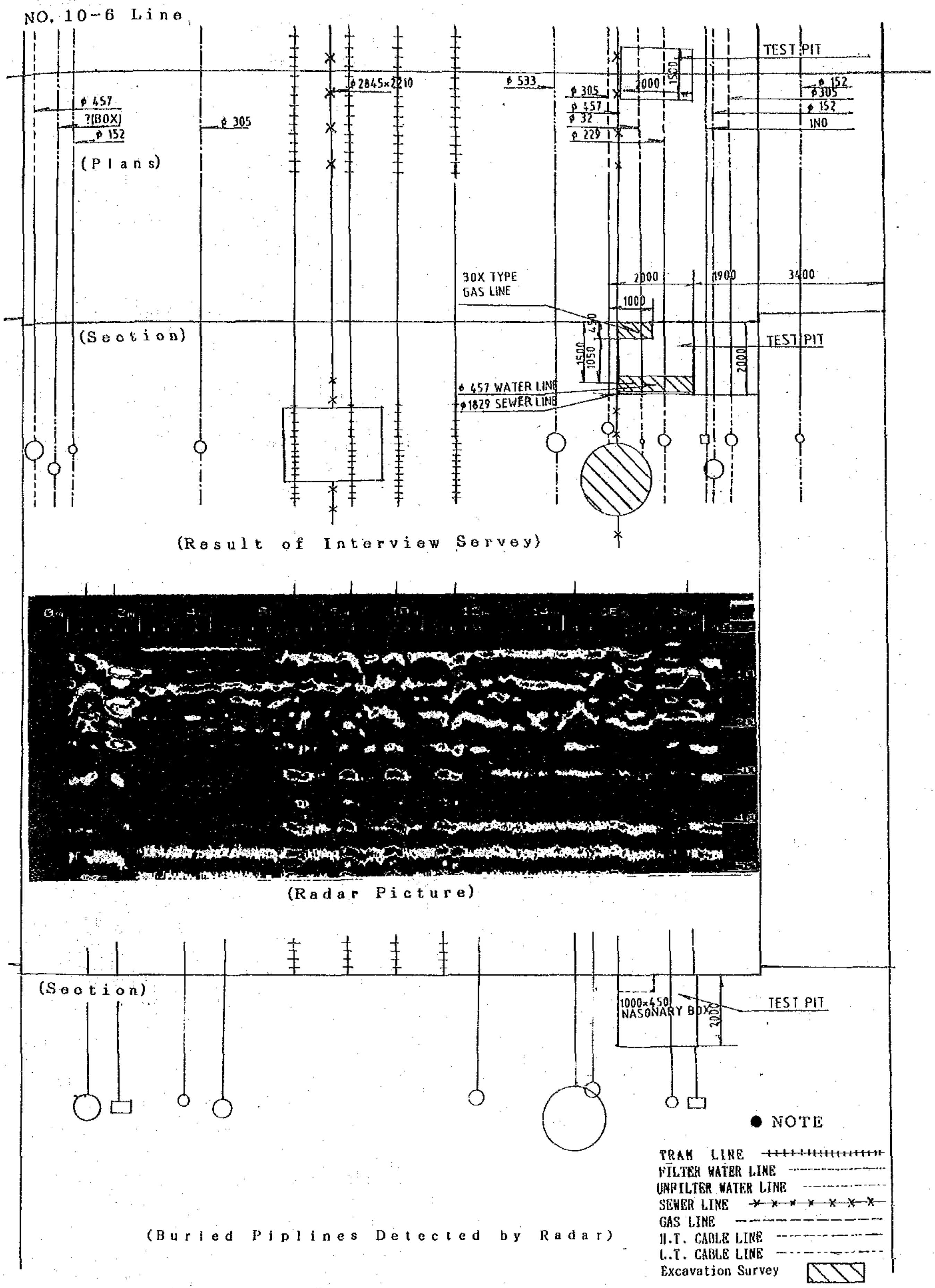


Figure T-2.3.4 Results (No.10-6 Line)

b. The locations of buried utilities given by concerned authorities did not often match with the actual locations revealed by the Verification Excavation Survey.

c. Locations of some of the buried pipes could not be clarified by the interview survey, especially for electricity cables and telephone cables.

d. Some sewage pipes were not recorded on available drawings although their surface outlets, manholes, exist.

(2) Subsurface Radar Survey

a. Radar photographs clearly show cylindrical or square pipes of dimension over 50 cm.

b. Buried materials of dimensions under 30 cm cannot easily be detected.

c. Subsurface Radar detection depth was in the range of about 1.5 to 2 m from the ground level at the Study intersections.

d. It is not easy to detect the presence of buried pipes when they are surrounded by fragments of bricks as fill.

e. Radar cannot detect under strong reflecting materials, such as metals.

(3) Verification Excavation Survey

This survey verified that the findings of the radar survey to a very large extent coincided with the actual site conditions.

CHAPTER 3

SIMULATION OF TRAFFIC FLOW

CHAPTER 3 SIMULATION OF TRAFFIC FLOW

3.1 Introduction

This working paper contains description of works carried out leading to the running of traffic flow simulation for the feasibility study on transport infrastructure improvement project in Calcutta. The main component of the improvement measure in question is the construction of flyovers at 10 locations being studied in this project.

Section 3.2 of this paper outlines the objectives of conducting a traffic flow simulation to assess the impact of infrastructure improvement in Calcutta.

Section 3.3 describes the procedure used in the simulation of traffic flow while Section 3.4 discusses the basic principle of traffic flow modelling.

Perhaps one of the most important aspects of traffic simulation is the preparation of input data, most of the times in specific format required by the type of model selected. The input data used in this study for traffic simulation are discussed in length in Section 3.5 of this paper. The travel routes containing the study intersections and used in the simulation are also discussed in this section.

Section 3.6 of this paper describes the verification of the selected model. This verification is done by 're-create' the existing traffic flow situations using the model and compare the simulated results to actual site survey data, thus verifying the ability of the computer model in predicting accurately actual traffic situations.

Section 3.7 outlines the results of simulation under the 'do-nothing' case with projected future traffic demand in 1998. This is followed by a discussion of the implications of the simulation results on future traffic flow conditions in the city.

Alternative cases for simulating future traffic flow are set up in Section 3.8. Different combinations in terms of locations or structural type of flyovers are considered. The alternatives devised for the tests are grouped by routes.

Lastly, Section 3.9 discusses the results of traffic simulation for the various alternative cases set up in Section 3.8. A comparative analysis of the traffic impact performance of the different alternative cases is also included here. The best plan, from the traffic impact viewpoint by route, is therefore elucidated here.

The end results of traffic simulation provide the basis for selecting the most effective intersection improvement alternative plan for the city of Calcutta.

3.2 Objectives of Traffic Simulation

The objectives of doing traffic flow simulation in this Study is of two folds.

(1) To examine the future traffic flow conditions along the study corridors with the present transport infrastructure, and

(2) To predict the future traffic conditions along the study corridor where alternative transport infrastructure improvements are proposed, thus assessing the traffic impacts of these alternative plans.

Traffic simulation in this Study is an attempt to use computer simulation model to measure the impacts on traffic flow of constructing flyovers at selected intersections. However, the selected intersection cannot be treated in isolation. The simulation is to be done for a series of intersections along a particular route or corridor. This is because improvement efforts in a downstream intersection would also affect traffic flow at an upstream intersection.

The traffic simulation model in this Study is also used to assess the advantages of having continuous flyover bridges across two intersections for instance as compared to having individual flyovers. This is because traffic interference from minor intersections between two major intersections can often negate the benefits of grade separations at the major intersections.

Results of the traffic simulation such as total delay time, total vehicle.km travelled, total vehicle.hour required by each alternative plan are essential for the computation of benefits of these plans. Savings in delay time for example are converted into quantifiable form using the average time value of an average worker in Calcutta. Infrastructure improvements that resulted in an increase of travel speed would therefore result in energy savings. Fuel savings are therefore computed using fuel consumption rate at different level of travel speed in India.

These computation of benefits thus provide one of the major input for carrying out an economic evaluation of the alternative plans.

3.3 Procedure for Traffic Simulation

The procedure undertaken in this Study to simulate the future traffic conditions under both the existing and future transport infrastructure scenarios is illustrated in Fig. T-3.3.1. There are basically four major tasks in this procedure.

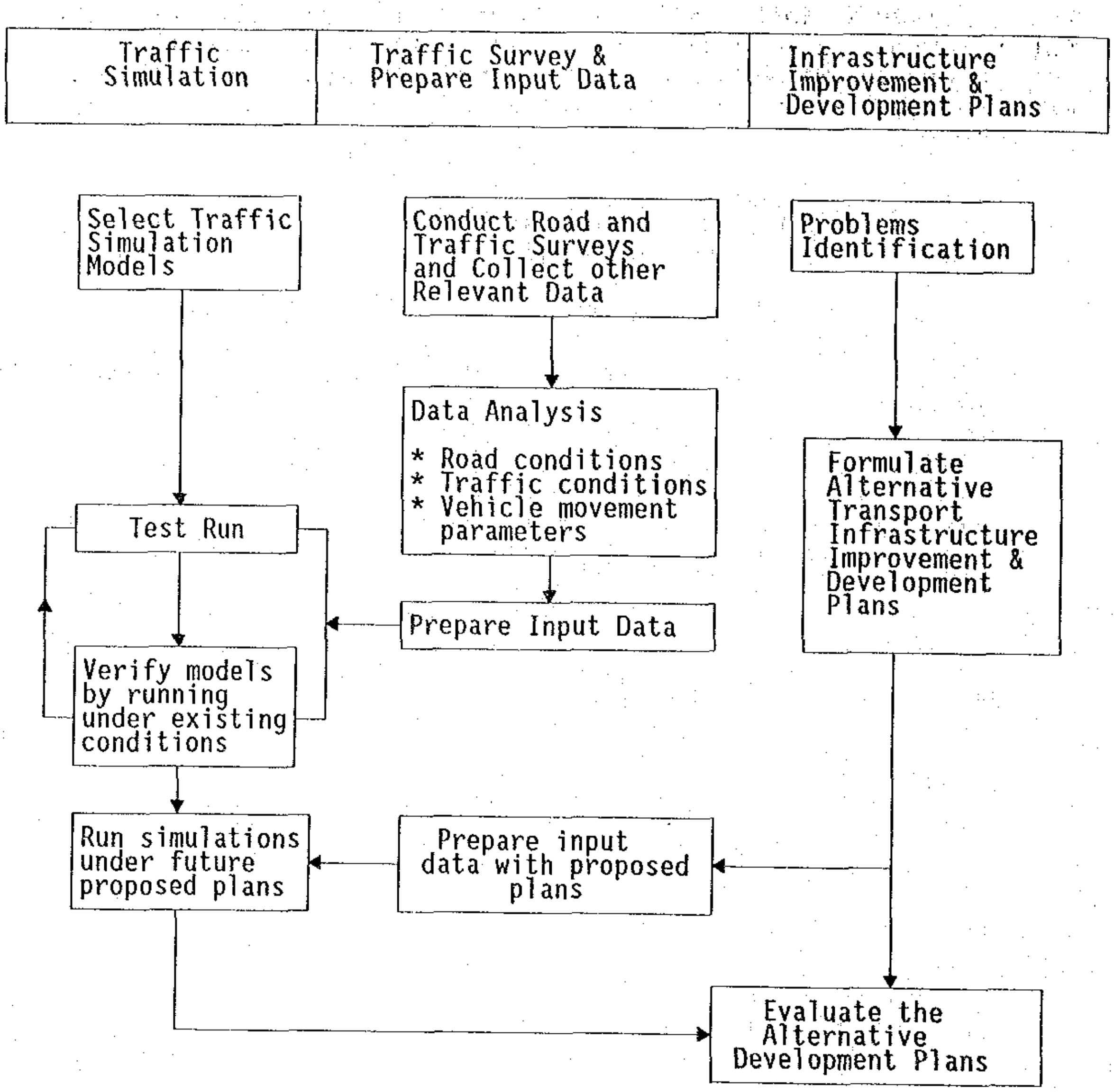
(1) The formulation of a number of alternative transport infrastructure improvement and development plans,

(2) The selection of suitable simulation model types and adopting them to simulate the traffic conditions under the alternative transport infrastructure improvement and development plans,

(3) The preparation of input data for simulating the existing traffic conditions as well as future traffic conditions with implementation of the alternative infrastructure improvement and development plans,

(4) The analysis of the traffic simulation results and hence the evaluation of the alternative transport infra-structure improvement and development plans.

Figure T-3.3.1 Procedure For Traffic Flow Simulation



3.4 Traffic Simulation Models and Type of Outputs

(1) Traffic Simulation Models

There are two candidate traffic simulation models that may be used for the purpose of this Study. One is the Input-Output Model (I/O model in short) developed by the Tokyo Metropolitan Expressway Public Corporation. The other is the NETSIM Model developed by the US Federal Highway Administration (FHWA).

These two traffic simulation models are briefly discussed below:

(a) Input-Output Model

The original input-output model was first developed by the Tokyo Metropolitan Expressway Public Corporation (TMEPC) for simulating expressway traffic operation. It was later modified to simulate ordinary street traffic operation using the same principle and logic.

The I/O Model basically simulates traffic streams as liquid flows in a given network of channels with a time interval scanning function. During an interval scanning, excess demand at any bottleneck is restrained by the capacity of the bottleneck. This excess demand has to wait for the next scanning in order to clear the bottleneck. In our case here, the bottlenecks are intersections on street routes. The model thus simulates traffic flows through traffic intersections in a road network and the excess demands restrained by the capacity of the intersection are in fact vehicle queues waiting to cross the intersections.

The queue length at a bottleneck is calculated directly from the number of the excess traffic demand. Since the model simulates traffic streams as liquid flows, any queue from a bottleneck that reaches an upstream bottleneck will produce a backup effect and reduces the capacity of the upstream intersection.

The procedure of clearing and restraining demand is done on all the links of the entire network during each interval scanning which is usually set at 5-15 minutes.

The applicability of traffic flow simulation models such as the I/O model hinges on the presumptions that future traffic volume as predicted by future traffic forecasting model within the larger planning road network in Calcutta is accurate and that social conditions such as drivers behaviour remain unchanged. The results of traffic flow simulation therefore must be read with these presumptions in mind.

The advantages of an I/O model are:

a. the ability to simulate traffic conditions on different sections of a long street route.

b. the ability to simulate at high speed.

c. the ability to simulate for a continuous 24-hour traffic condition.

(b) NETSIM Model

This model also adopts the interval scanning technique to represent traffic conditions. The traffic stream is modelled explicitly with each vehicle on the network treated as an identifiable entity.

In an interval scanning simulation model, each vehicle is moved every second according to the car-following logic and in response to traffic control devices and other conditions which influence vehicle behaviour.

Each vehicle's position (both lateral and longitudinal) on a network link is determined, as well as its relationship with other vehicles nearby. Its speed, acceleration and status are also defined in the model.

This model has a number of advantages. It provides a means for reviewing the input data and results of the simulation pictorially. It also allows the user to analyze the outputs through colour displays which provide sufficient details of intersection geometrics or highlighting of potential 'hotspots' or problem areas in the network. The user can also request an animated display of the simulated traffic flow on the screen.

However, the model also has its own limitations. Because of its detailed analytical ability, the network to be simulated in any particular case is not large. Using a personal computer, this would only amount to one flyover with a few intersections nearby. Moreover, very detailed data are required to run this model.

This model also has a prerequisite condition that the total number of vehicles in the modeled network should not exceed 1500 vehicles at any one time. This condition means that it can only simulate a road section of 1.5 kilometer if it is a six lane road and assuming it is congested.

In each simulation case, therefore, only one intersection with the proposed flyover can be represented on the network.

(2) Selection of Model for This Study

As discussed in the above sections, NETSIM model cannot simulated multiple intersections like the I/O model. Moreover, data required for running the NETSIM model are more and have to be more detail than those required for I/O models.

For this study, where a total of 10 intersections are to be studied along specific arterial routes, simulation should preferably be run for a number of connected intersections along a particular route. This is especially important in our case here as some of the study intersections are located very close to each other (e.g. No.5,6 and 10) such that traffic flow condition at one intersection will greatly affect the flow at the other nearby intersections.

For these two main reasons, the I/O model is selected for simulating the study intersections along the major corridors in this Study.

(3) Outputs From the Simulation

The expected outputs or results from the traffic simulations are to act as key indicators of traffic conditions. These will be used to evaluate the merits and strengths of the various alternative plans.

The I/O simulation model will generate the following results for each of the alternative plans:

(a) Entering volume at each intersection,
(b) Intersection traffic flow in vehicle unit over the simulation period eg.12 hours,
(c) Total delay at intersections in veh.hours,
(d) Average delay in minutes,
(e) Queue length in km,
(f) Total vehicle travel distance in veh.km,
(g) Total vehicle travel time in veh.hour,
(h) Average travel speed.

For the purpose of economic evaluation of alternative plans, total delay time, travel speed and total vehicle.km are by far the most important indicators. Savings in delay time and increase in travel speed for the total vehicle.km travelled can be converted into savings of both productive time and fuel consumption. These two are used to compute the benefits of the alternative plans.

The queue lengths at each of the intersections along the simulated routes are useful for graphically displaying the predicted traffic conditions on the road, indicating where are the worst congestions along the route.

3.5 Road Network for Traffic Simulation and Input Data

(1) Simulation Routes

The road network to be covered by the I/O model in any simulation case is set with a road distance of not more than 10 km for the convenience of preparing the input data and analyzing the results.

To cover the proposed flyovers within the study area, the corridors have to be sub-divided into three sections or routes. This is illustrated in Figures T-3.5.1 to T-3.5.3.

Route 1: along AJC Bose Road from Khidirpur Road to M.G Road,

Route 1 encompasses 4 intersections, namely intersection No.5,6, 10 and 1.

Route 2: along AJC Bose Road from M.G.Road to Paikpara Road,

Route 2 encompasses 2 study intersections, namely intersection no.4 and 7. In the simulation process, intersection no. 1 is also included in Route 2.

Route 3: Chowringhee Road from Paddapukur Road to M.G. Road.

This route encompasses 2 study intersections, namely intersection no. 2 and 8. No.5 is also included in Route 3 during simulation.

There are two other intersections with proposed flyovers not within the coverages of the defined three routes above. These are:

* Intersection No.3 of Gariahat Road/Rash Behari Avenue and

* Intersection No.9 of Look Gate Road/Railway Crossing. However, the location of this intersection is peculiar and such that any improvement to this intersection would greatly affect traffic flow at intersections no. 4 and 7. For this reason, this intersection is included in Route 2 during simulation.

Figure T-3.5.1 Route 1 for the Traffic Simulation

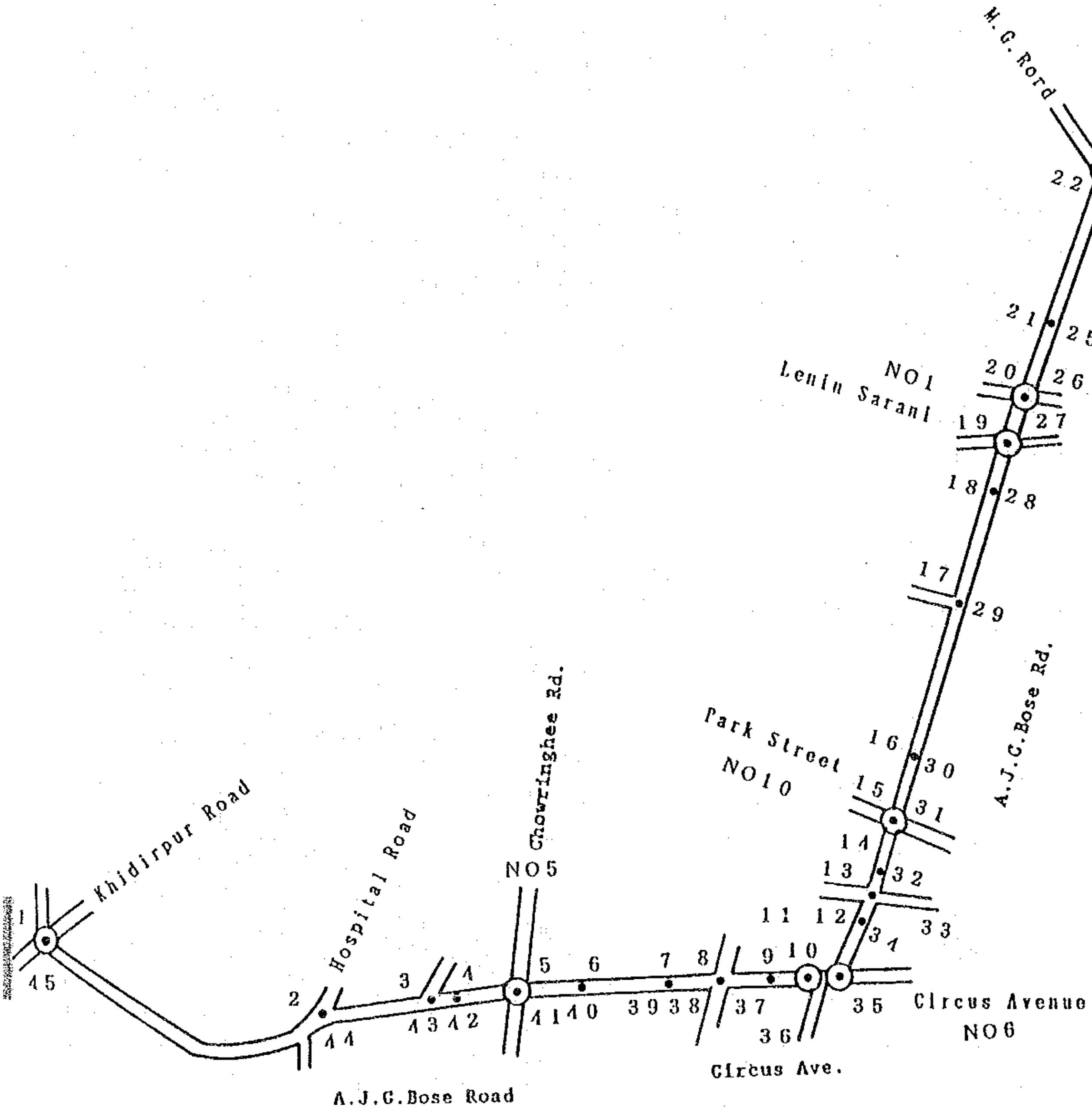


Figure T-3.5.2 Route 2 for the Traffic Simulation

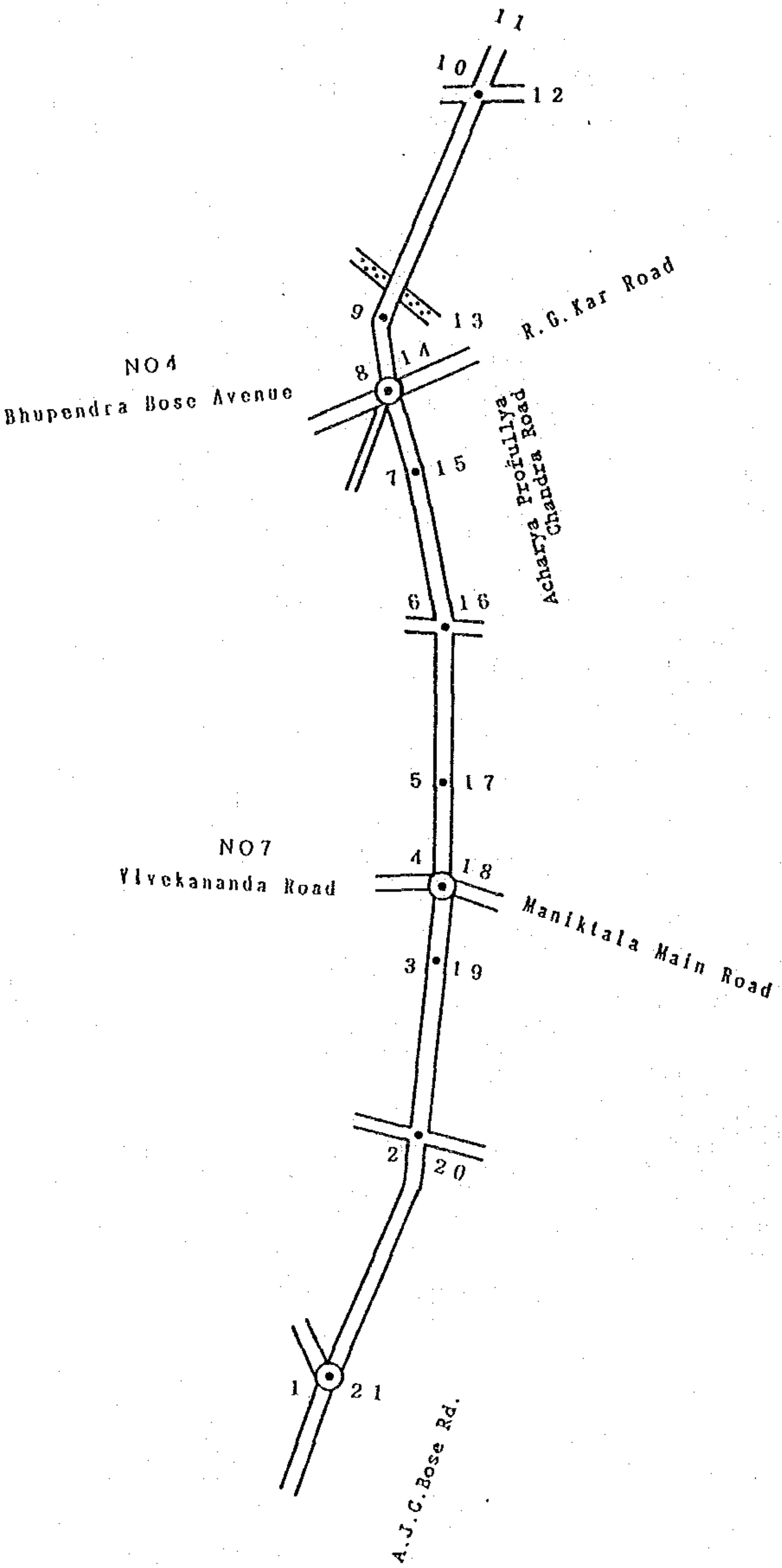
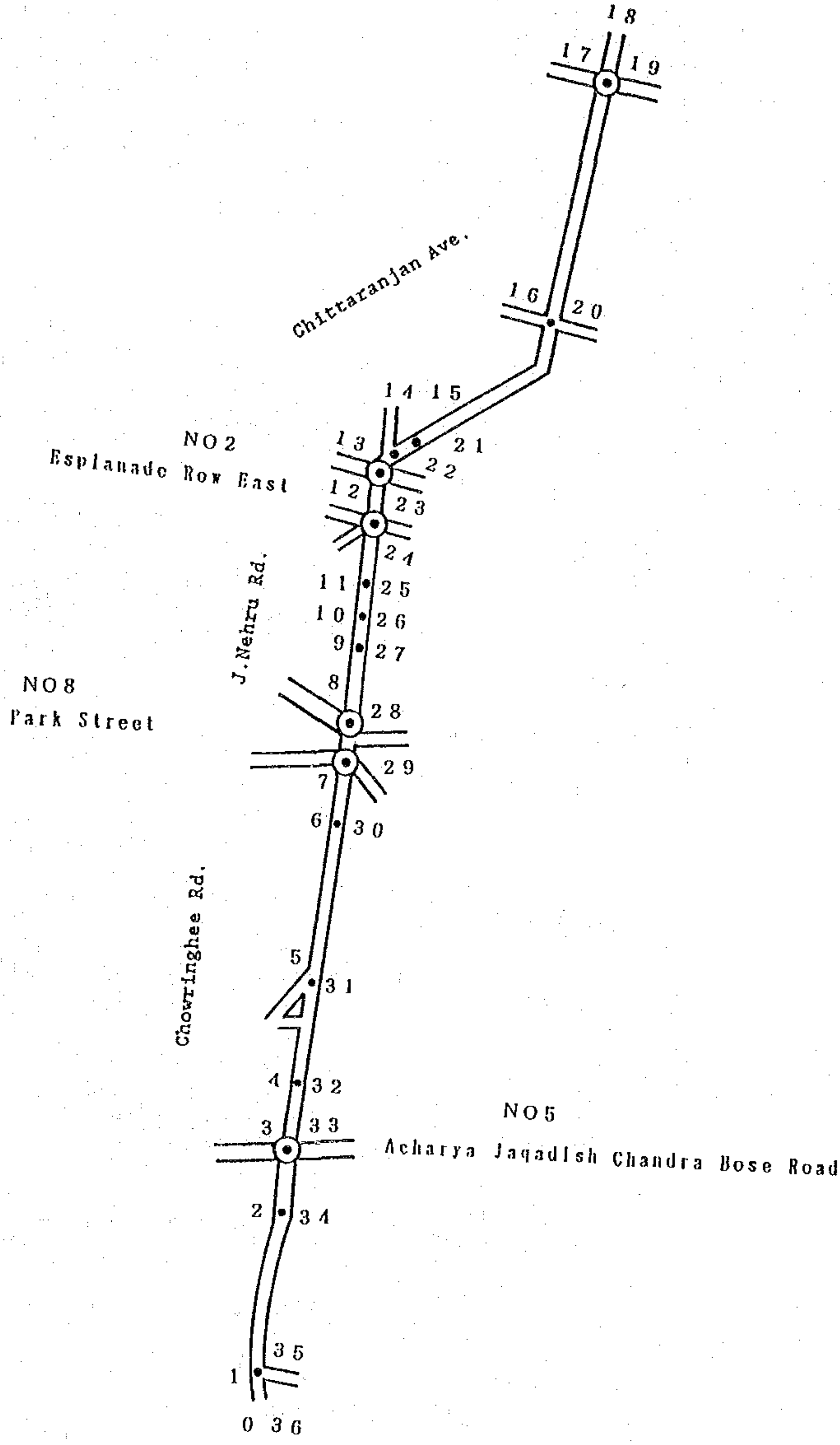


Figure T-3.5.3 Route 3 for the Traffic Simulation



(2) Simulation Time Period

The I/O model can simulated a 24 hour traffic flow. In this Study, however, the model will only simulate continuously a 12 hours traffic conditions as the traffic data surveyed by the Study for the simulation is 12 hours data. The model is also used to simulated traffic conditions during peak hours 8:00-12:00 and 16:00-20:00, where existing observed data are also available for simulation and comparison.

(3) Input Data

There are two types of input data required for the running of the I/O traffic simulation model. One is the basic data, reflecting the local conditions and the other is data specifically required by the I/O model. Specific items of the basic data are listed below.

Most of the input data required by the I/O model can be gathered for the given road sections in this Study. While most of the basic data are gathered through the traffic surveys, some of the specified data are assumed based on the study team's observations and judgement or utilize the default values as given in the model.

(a) Basic Data

Road Condition Data

a. Road Network (or link connection)
b. Length of the links (in meter)
c. Number of lanes servicing the moving traffic

Traffic Condition Data

a. Intersection turning movements
b. Entry link traffic volumes (existing and future)

Traffic Characteristics Data

a. Mean value of the start-up lost time
b. Mean value of discharged headway (or saturation flow)
c. Free flow speed
d. Mean value of headway distance during stopping caused by congestion (or jam density)

Traffic Operation Data

a. One-way traffic operation
b. Signal (or policeman) control timing

A number of on-site traffic surveys and observations were conducted by the Study to gather actual traffic and road conditions for the simulation exercise. Useful data for the simulation are obtained by the following type of surveys:

	Type of Survey		Type of Data Gathered
(i)	Intersection Geometric Survey	-	Road Condition Data
(ii)	Intersection Turning Movement Survey	-	Traffic Condition Data
(iii)	Free Flow Speed Survey	-	Traffic Condition Data
(iv)	Saturation Flow Survey	-	Traffic Condition Data
(v)	Policeman Traffic Control Timing Survey	-	Traffic Operation Data

These surveys and the data collected are explained below:

(i) Intersection Geometrics

The road geometric data were obtained from a site survey. These data, such as carriageway width, lane width, etc, are some of the basic data needed for the traffic simulation.

(ii) Intersection Turning Movements

The intersection turning movements required for the simulation are also surveyed and recorded.

(iii) Free-flow Speed

A free-flow spot speed survey was conducted on December 20, 1991 (Friday) using the video recording method along a selected section of Chowringhee Road. The travel times for a distance of 40 meters were timed and the speed computed.

The results of this survey are:

* Mean speed - 37.5 km/hr
* Standard deviation - 6.7 km/hr
* Sampling number - 120 vehicles

The distribution of the speed is shown in Figure T-3.5.4 below:

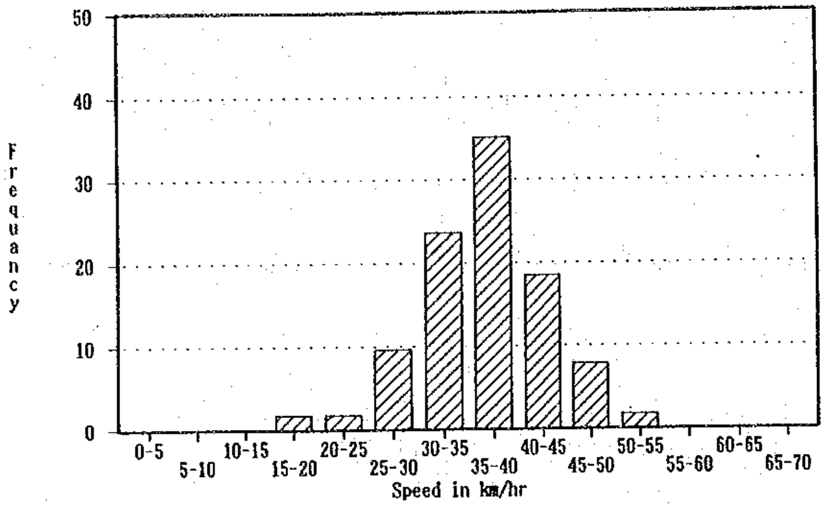


Figure T-3.5.4 Distribution of Free Flow Speed

(iv) Saturation Flow at Intersection Approach

Another survey using video recording was conducted on the same day, December 20, 1991 at the intersection of Chowringhee Road/AJC Bose Road to obtain the capacity of an intersection approach.

The subject approach is the direction from west to east on AJC Bose Road. This is a 2 lane, 6.5 meter wide approach with a 'No Right Turn' prohibition, although it is observed that at times, three passenger cars may travel abreast.

Results of analysis of this survey are summarized below:

a. Composition of bus

Within the survey period, the buses passing through the approach are found to be 9.5 percent of the traffic stream.

b. Traffic Flow Rate in 10 Seconds

Fig. T-3.5.5 shows the average traffic flow rate in 10 seconds interval from a time when the first car passes the corner of the intersection after it was given the right of way. From this figure, the average rates are 6.1 vehicles/10 seconds in the first 30 seconds and 5.9 vehicles/10 seconds in 60 seconds. These rates could be converted to 2,202 veh/hour/two lane and 2,128 veh/hour/two lane respectively.

However, the above rates might have been under the effects of short demand during the given right of way period, and the blocking effect at the intersection by some down-stream obstacles.

To exclude these effects, it is assumed that traffic flow with less than 6 vehicles/10 seconds is not passing in a condition of saturation flow.

Fig.T-3.5.6 shows the revised average flow rate in 10 second intervals after those samples with a rate less than 6 vehicles/10 seconds are taken out. The figure displays an average traffic flow rate of 7.9 vehicle/10 seconds in the first 30 seconds as well as 60 seconds.

The converted flow in veh/hour (saturation flow) is 2,844 vehicle/hour/2 lanes and 1,422 vehicles/hour/lane. Thus the saturation flow would be taken to be approximately 1,400 vehicles/hour/lane at this approach (in the case that 10 percent of the traffic volume are buses of course).

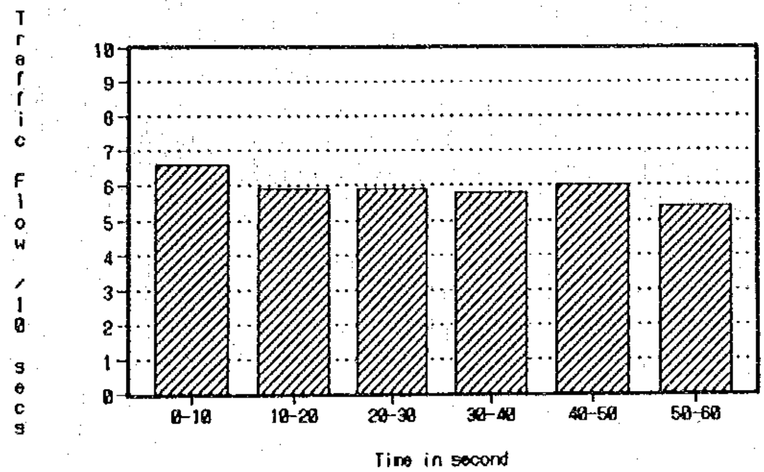


Figure T-3.5.5 Average Traffic Flow Rate in 10 Seconds Intervals

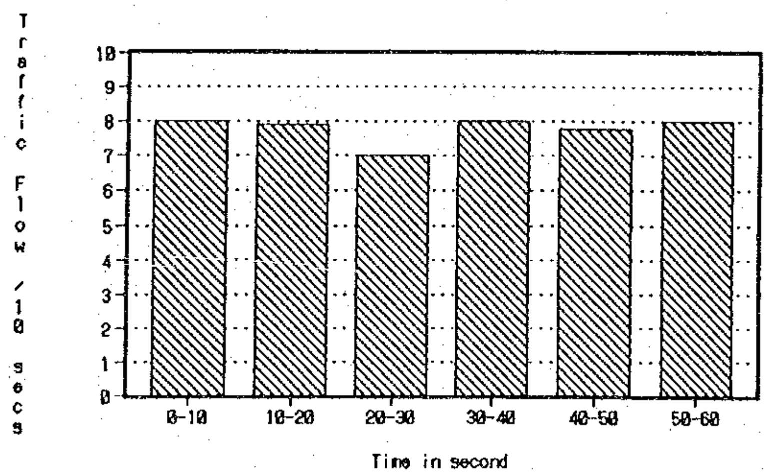


Figure T-3.5.6 Traffic Flow Rate For Samples >6 veh/10 sec.

(v) Policeman Control Timing

The timings for the assignment of right of way and cycle controlled by policeman have been measured on site during the morning and evening peak hours at the following intersections:

i. Intersection No.5: AJC Bose Road/Chowringhee Road
ii. Intersection No.8: Chowringhee Road/Park St./ Outram Road
iii. Intersection of AJC Bose Road/Laudon Road/Sarat Bose Road
iv. Intersection of M.G.Road/Central Avenue
v. Intersection of Government Place East/B.B.D.Bag
vi. Intersection of AJC Bose Road/M.G.Road

Tab.T-3.5.1 shows the average assigned time and the average minimum and maximum cycle time at each intersection. Fig.T-3.5.7 shows the cycle time distributions at three of these intersections.

Table T-3.5.1 Surveyed Cycle Times and Right-of-Way Timings

Location			Ave. Phase Timing (in seconds)				Cycle Time (in min.sec)		
			Ph-1	Ph-2	Ph-3	Ph-4	Ave.	Max.	Min.
Int.No.5 :			E=W	S=N					
AJC Bose Road/	Morning	53	49				1.42	2.32	1.09
Chowringhee RD	Evening	57	66				2.02	3.15	0.52
Int.No.8:			E=W	S=N					
Chowringhee Rd/	Morning	97	146				4.03	8.20	2.31
Park St.	Evening	122	243				6.05	7.58	4.12
Int.No.20:			E=W	W-E	N-E	S-W			
AJC Bose Road/				W-S	N-W	S-N			
Laudon Road/					N-S	S-E			
Sarat Bose Road	Morning	132	64	87	61		5.44	9.38	3.40
	Evening	94	44	52	62		4.11	5.49	2.29
Int.No.21:			E=W	S=N					
M.G.Road/Central	Morning	69	135				3.24	4.41	2.31
Avenue	Evening	53	85				2.18	3.01	1.47
Int.No.22:			E=W	S=N					
Govt.Place East/	Morning	102	60				2.02	2.42	1.27
B.B.D.Bag	Evening	44	49				1.33	2.08	0.31
Int.No.23:			W-S	S=N	N=W				
AJC Bose Road/			W-N						
M.G.Road	Morning	61	107	30			3.03	3.56	1.48
	Evening	26	52	7			1.21	1.31	1.08

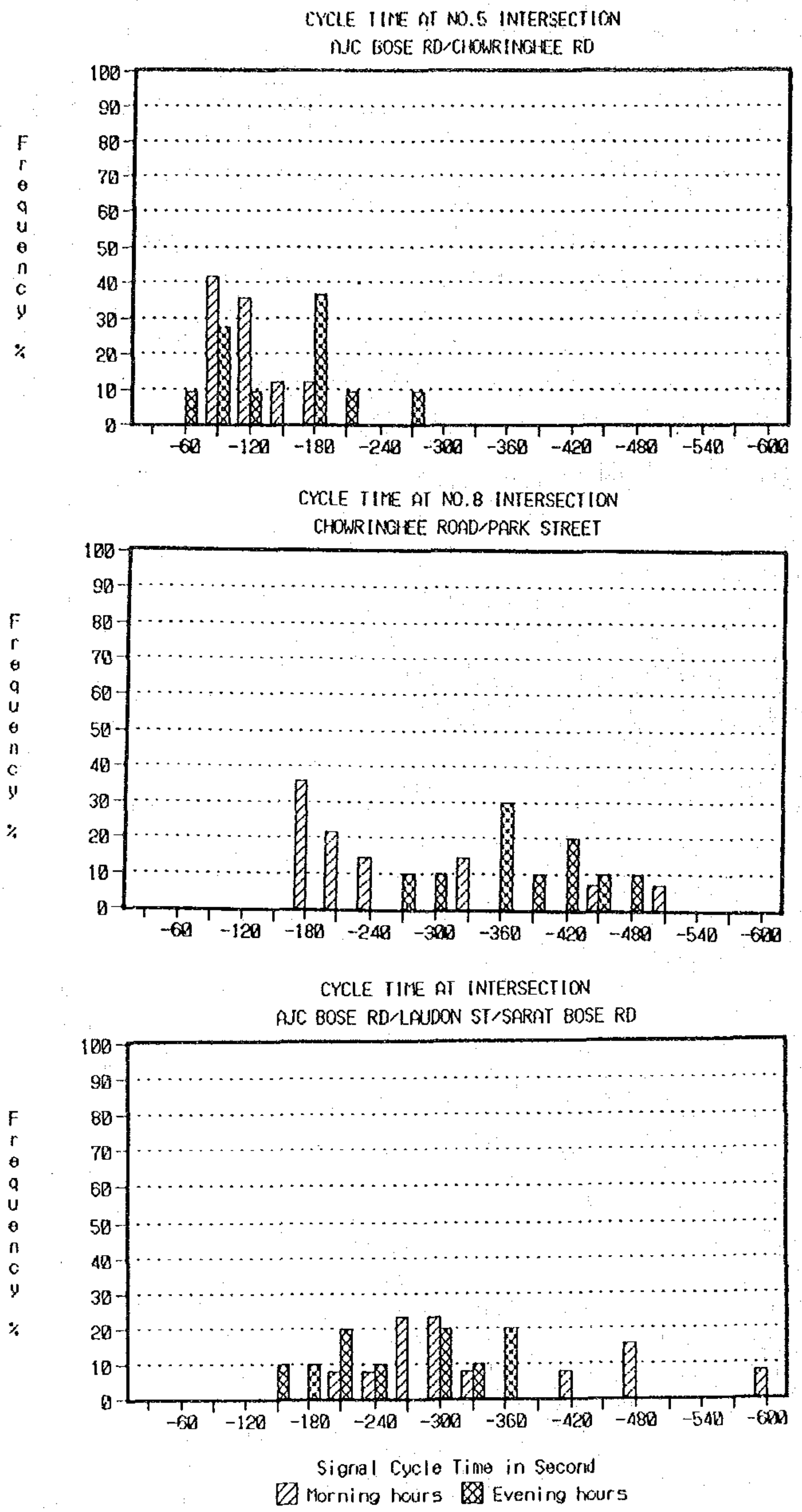


Figure T-3.5.7 Cycle Time Distribution of Three Intersections

The assigned times are not constant as the policeman varies them according to his judgement on the current traffic conditions. In general however, congested intersections are observed to have longer assignment and cycle times, for example the intersection at Chowringhee Road and Park Street is observed to have an average cycle times of 6 minutes 5 seconds and a maximum of 7 minutes 58 seconds in the evening hours.

(4) Input and Output Format

The format by which various data are input into the computer for the simulation is given in the appendix.

A set of the simulation outputs by route are also given in the appendix together with figures showing the link numbers.

3.6 Verification of Model

(1) Indicators

Before the selected simulation model can be used to simulate future traffic conditions to enable the evaluation of alternative plans, they have to be verified for their applicability and accuracy. This is done by simulating the existing traffic conditions and comparing the simulation results with the actual observed traffic conditions on site.

The following items are used for this comparative analysis:

a. Traffic volumes at intersections,
b. Average hourly delay in veh.hour at intersections.

Traffic volumes at the study intersections have been surveyed on site. Delay at intersections are derived based on data gathered from the traffic volume and travel speed surveys.

(2) Measurement of Delay

Delay at an intersection approach is defined as the traffic volume at that approach multiply by the difference in travel time at the observed speed and at free speed.

The computational equation used is:

$$D = V \times (T_t - T_f)$$

where,

D : Delay of an intersection approach in veh.hours
V : Traffic volume of the approach
T_t : Travel Time measured on link
T_f : Travel Time at free speed on the link

The free speed in this computation is taken as 36.7 kph, results of the actual site observation survey described in Section 3.5. The total delay at an intersection is thus the sum of all the delays at its approaches.

The average hourly delay in the morning and evening peak hours at the study intersections are computed and shown in Table T-3.6.1.

Table T-3.6.1 Average Hourly Delay at Intersections

Intersection	Morning Peak	Evening Peak	Total 8 Hours
#1:Moulali	397	451	3,392
#2:Esplanade	237	957	4,776
#3:Gariahat*	80	137	868
#4:Shyambazar*	224	307	2,214
#5:Rabindra Sadan	305	199	2,016
#6:Beck Bagan	209	263	1,888
#7:Maniktala	230	159	1,556
#8:Park Street	474	572	4,184
#9:Lock Gate**	0	0	0
#10:Mullik Bazar	29	74	412
Total	2,185	3,119	21,216

*: Total does not include all approaches
**:Survey data not available
Morning: 8:00-12:00 Hrs
Evening:16:00-20:00 Hrs

Figs. T-3.6.1 and T-3.6.2 show the average hourly delay in vehicle.hours for each of the intersection approaches of the study intersections during morning and evening peak hours.

Figure T-3.6.1 Average Hourly Delay During Morning Hours

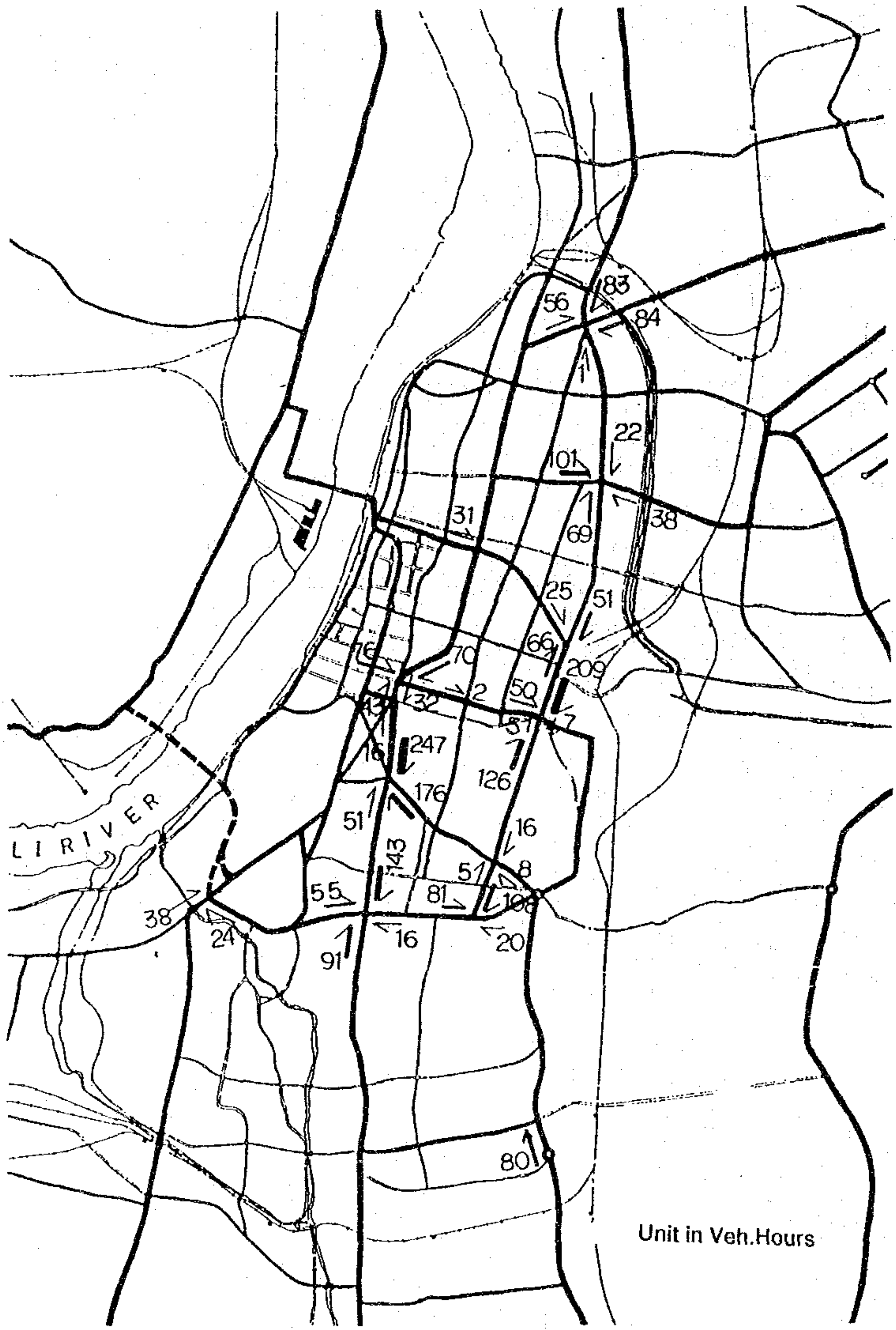
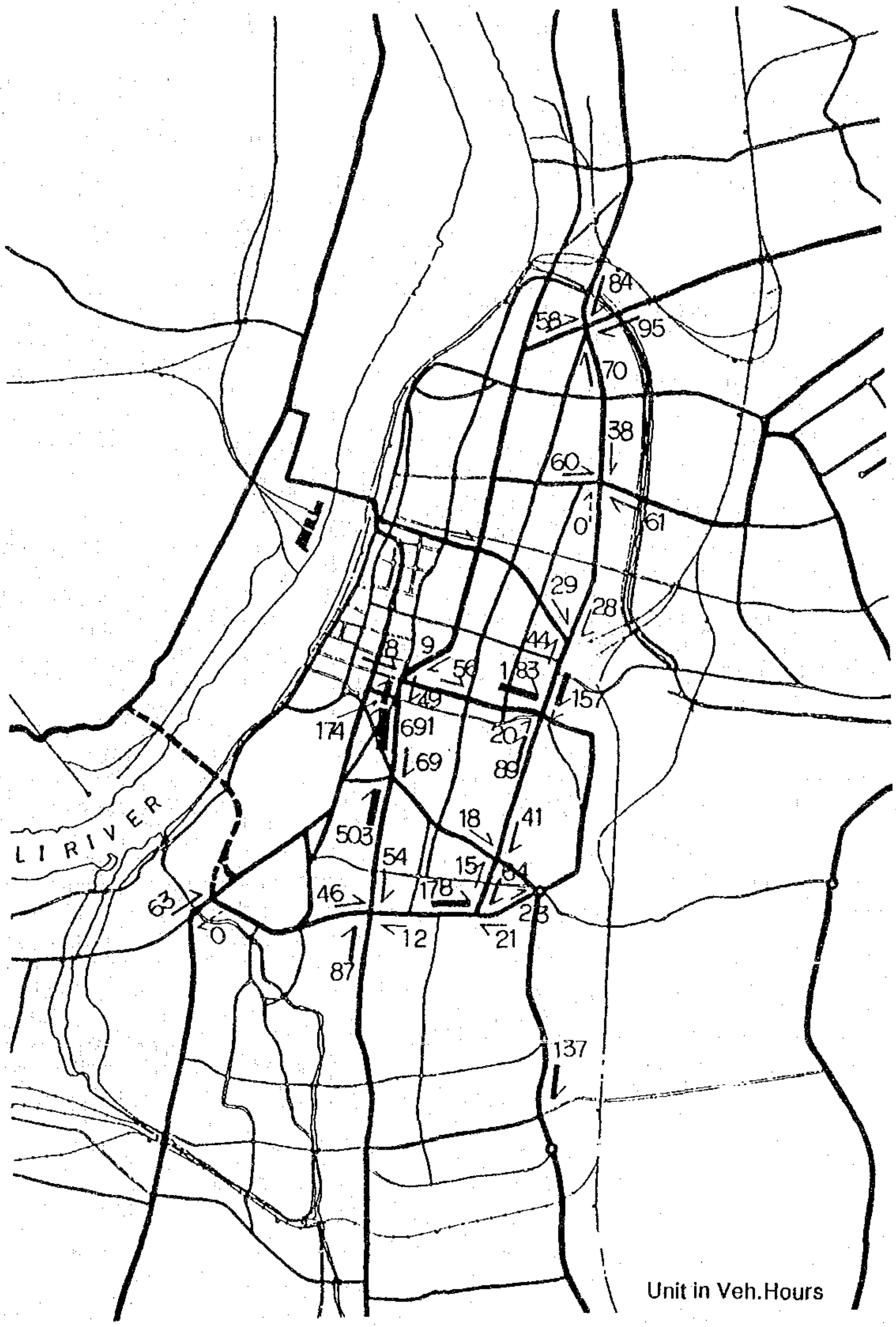


Figure T-3.6.2 Average Hourly Delay During Evening Hours



(3) Model Verification

A number of runs were executed under the existing traffic conditions and the results compared to the observed traffic volume data and average hourly delays computed above.

The issue however is how to set an acceptable level for the simulation results since they cannot be expected to fit exactly with the actual observed values.

This is due to the following reasons:

a. Shortage of basic data on traffic characteristics,

b. Complexity of road network, such as presence of intersections nearby and multi-leg intersections,

c. Existence of tram operation that disrupt road traffic operation,

d. Usage of road carriageway by a myriad of different traffic as well as street vendors and others.

Taking everything into considerations, it is taken that a deviation of up to 5-10% of the traffic volume at each approach of the intersections should be acceptable. For the average hourly delay which is more difficult to simulate due to the complex users behaviour and ever changing road conditions, comparable order of delays by each approach should be acceptable.

After several runs and trials, the model is fine-tuned to best re-recreate the existing traffic conditions. The results of this verification exercise are shown in the form of figures by the three simulation routes discussed before.

Tab.T-3.6.2 shows the comparison of traffic flow volumes by approach and intersection from simulation to those by site surveys. The ratios of simulated traffic volume to observed values for all approaches vary from 0.95 - 1.02 among the 8 intersections. The I/O model adopted shows a high degree of accuracy in simulating the traffic flow at the study intersections. (Note: comparison for intersections no.3 and 9 is not possible because traffic volume survey was not conducted at these two intersections).

Table T-3.6.2 Comparison of Simulated Traffic Volume at Study Intersections with Observed Values

Unit: Vehicle

Intersection	Approach 1		Approach 2		Approach 3		Approach 4		All Approaches	
Number	Observed	Simulated	Observed	Simulated	Observed	Simulated	Observed	Simulated	Observed	Simulated
#1	17266	17213	4790	4789	13428	13642	0	0	35484	35644
*		1.00		1.00		1.02		–		1.00
#2	9171	9256	0	0	17656	15932	10623	10622	37450	35810
*		1.01		–		0.90		1.00		0.96
#4	8854	8859	3313	3295	10021	10732	9779	9779	31967	32665
*		1.00		0.99		1.07		1.00		1.02
#5	13423	13423	14669	14216	14828	14827	12922	13014	55842	55480
*		1.00		0.97		1.00		1.01		0.99
#6	15138	13488	22241	21046	14876	14876	22608	23320	74863	72730
*		0.89		0.95		1.00		1.03		0.97
#7	11694	11735	7500	7413	10328	10397	11440	11440	40962	40985
*		1.00		0.99		1.01		1.00		1.00
#8	26894	27476	15769	13583	22278	20346	12184	12179	77125	73584
*		1.02		0.86		0.91		1.00		0.95
#10	17050	17025	10860	10860	12703	12975	8766	8765	49379	49625
*		1.00		1.00		1.02		1.00		1.00

* : Ratio of Simulated Values to Observed Values

Approach 1: N–S, Approach 2: E–W, Approach 3:S–N, Approach 4: W–E

Simulating the traffic volume by approaches for intersections no.1,5,7 and 10 are most satisfactory, with the overall ratios at or near to 1.0.

Fig.T-3.6.3 shows the comparison of simulated traffic flow volumes by approach along Route 1 to those obtained from site surveys. The simulated traffic volume at some approaches was found to be exactly equal to the observed values. Similarly, results of traffic flow simulation compared to observed values along Route 2 and 3 are given in Figures T-3.6.4 and T-3.6.5.

Fig. T-3.6.6 on the other hand shows the comparison of average hourly delay in the morning and evening peak hours along Route 1 as generated by the simulation model to those computed using survey data. The results show that the model is able to predict such delays with acceptable degree of accuracy, that is within the order of the observed values. Similarly, for Route 2 and 3, the comparative analysis results are given in Figures T-3.6.7 and T-3.6.8.

Queue length in km at the study intersections along Routes 1,2 and 3 from 9:00 to 20:00 hours are illustrated in Figures T-3.6.9 through T-3.6.11.

As shown in Fig. T-3.6.9, for instance, queues are particularly conspicuous at intersection No.1 (SN.Banerjee/Lenin St.) on AJC Bose Road. This queue gradually builds up from morning and peaks at around 14:00 hours, extending to about 1.3 km downstream to Alimuddinst Intersection and beyond for the north bound traffic stream.

Queue length for the south bound traffic stream at Intersection No.6 during peak hours is also excessive, and it would extend up to Park Street and beyond for a distance of about 900 meters. Queue lengths during off peak hours at this intersection are however not serious.

Queue length at Intersection No.5 (Chowringhee Road) is fair with the existing conditions, having a queue length of only 400 meters or less for most of the hours. Queue lengths at Intersection No.10 are comparatively small under the present conditions.

Figure T-3.6.3 Simulated and Observed Traffic Volume by Approach at Study Intersections on Route 1

Note:

Upper Figure : Actual Observed Volumes
(Lower Figure): Simulated Volumes

Volumes in Vehicles

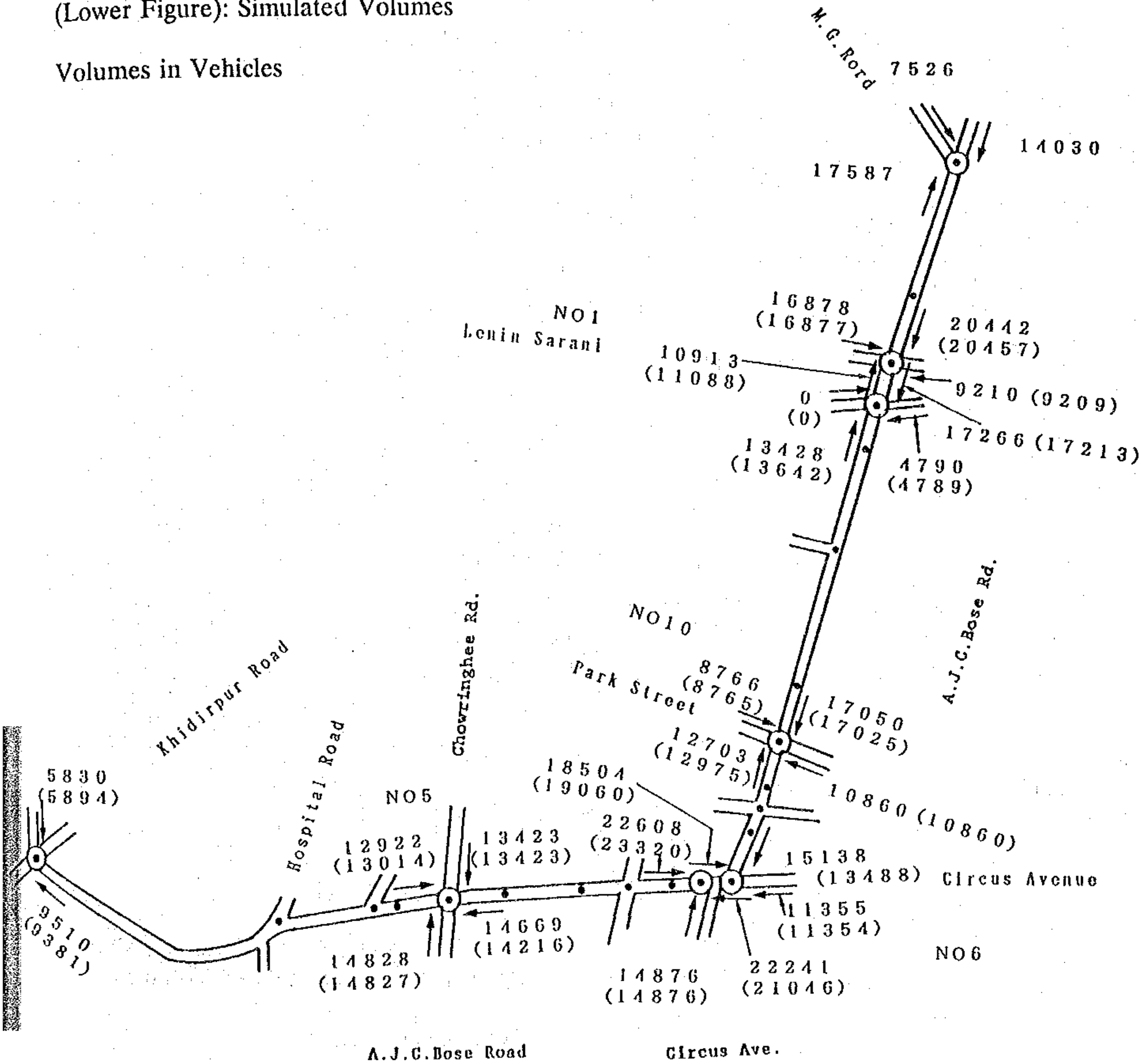
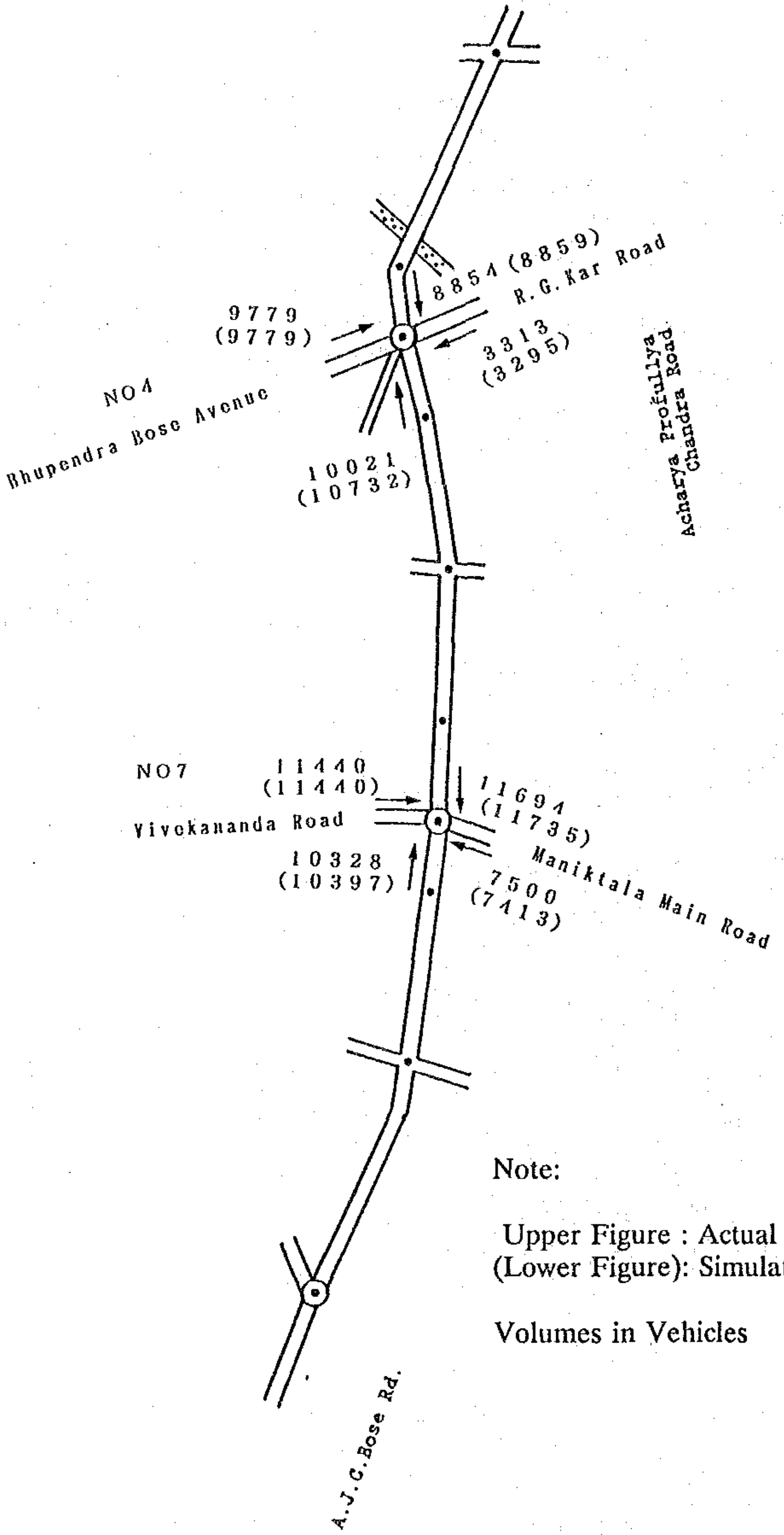


Figure T-3.6.4 Simulated and Observed Traffic Volume by Approach at Study Intersections on Route 2



Note:

Upper Figure : Actual Observed Volumes
(Lower Figure): Simulated Volumes

Volumes in Vehicles

Figure T-3.6.5 Simulated and Observed Traffic Volume by Approach at Study Intersections on Route 3

Note:

Upper Figure : Actual Observed Volumes
(Lower Figure): Simulated Volumes

Volumes in Vehicles

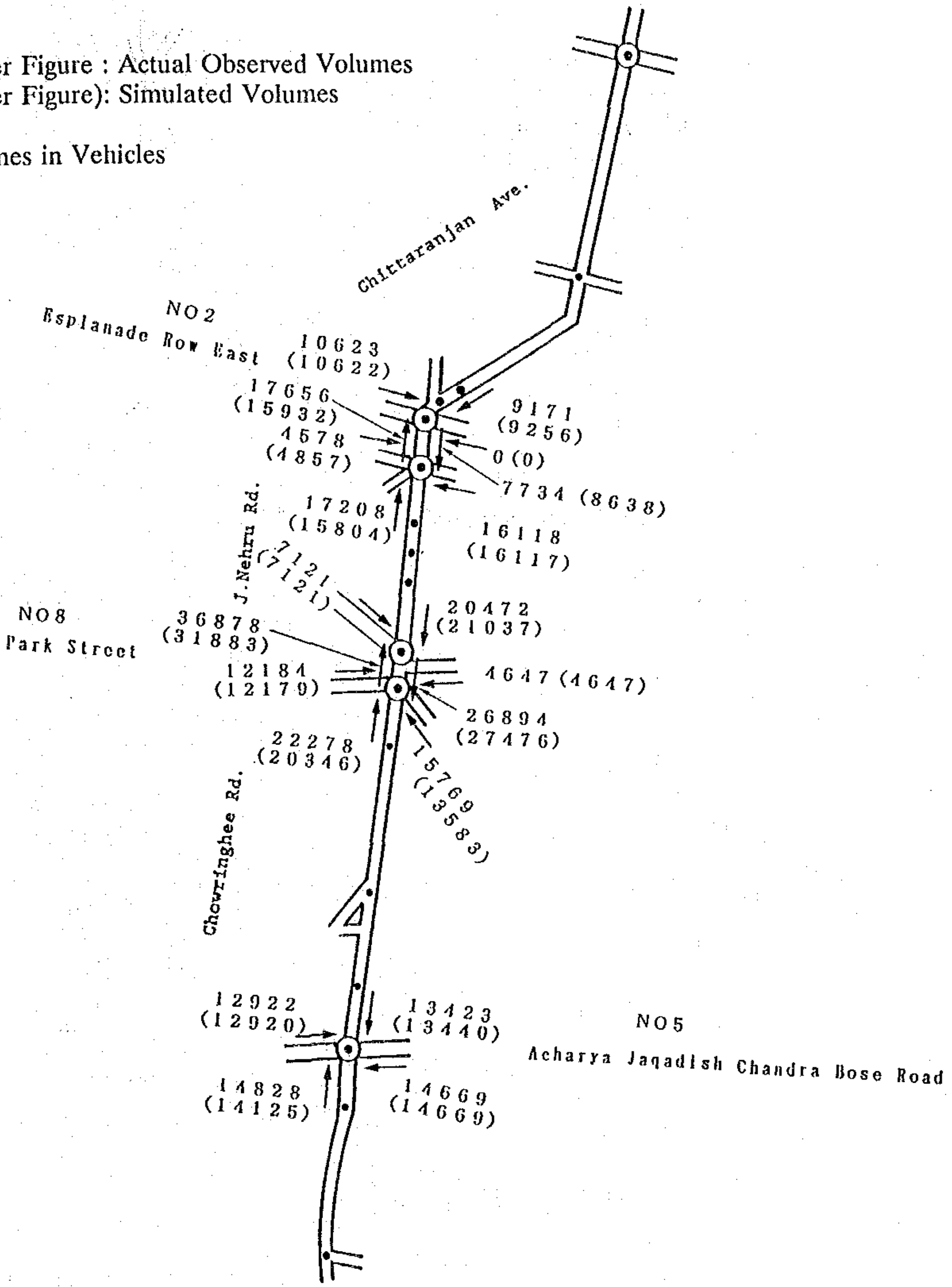
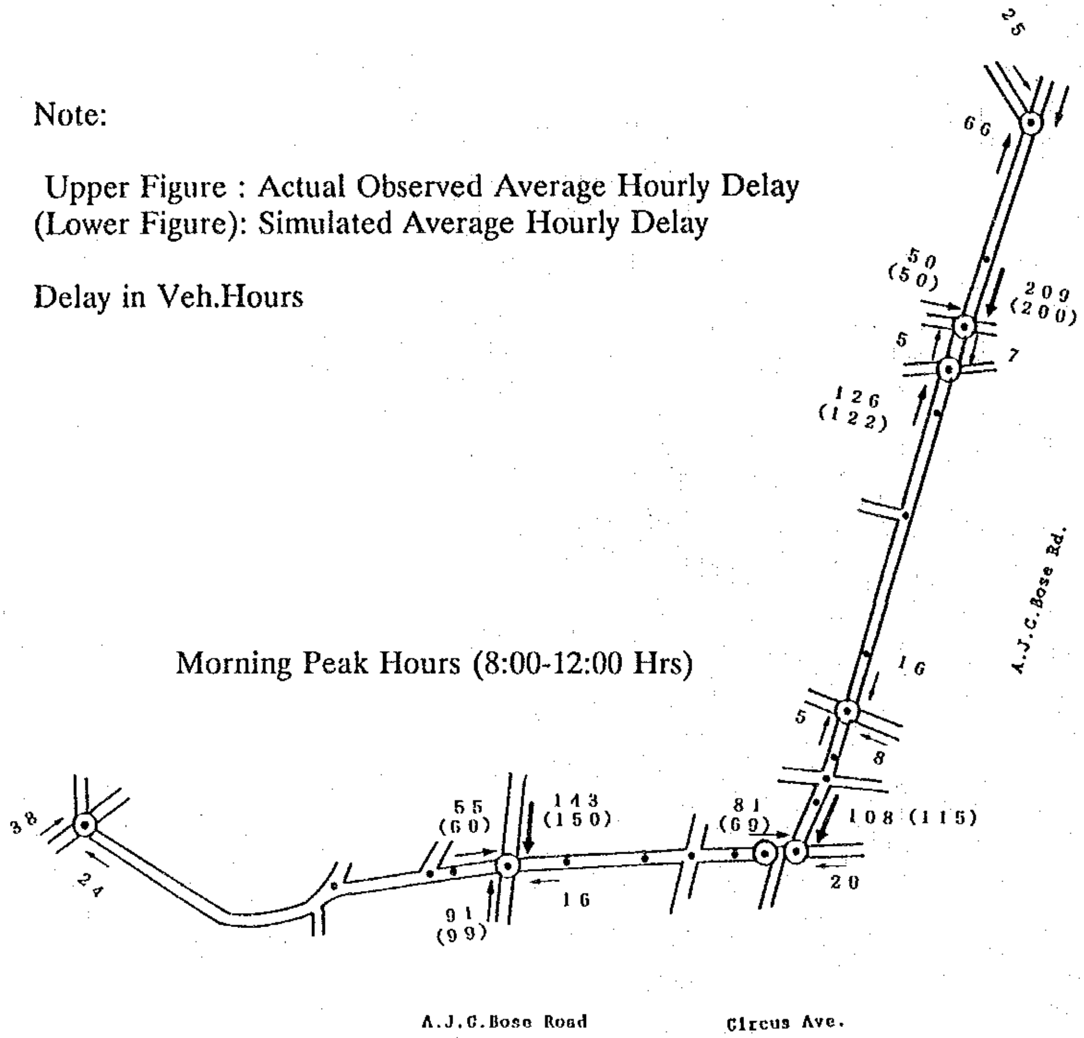


Figure T-3.6.6 Simulated and Observed Average Hourly Delay During Morning and Evening Peak Periods by Approach at Study Intersections on Route 1

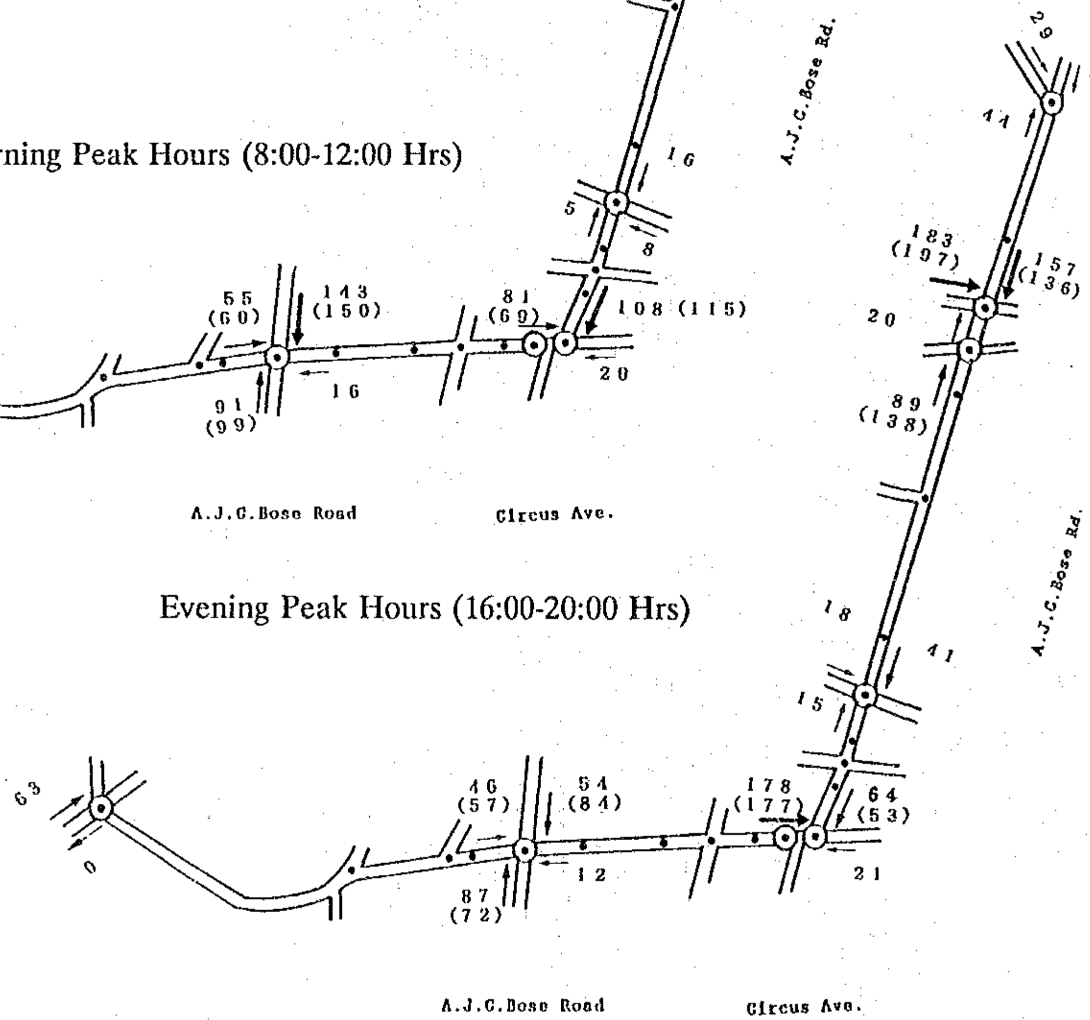
Note:

Upper Figure : Actual Observed Average Hourly Delay
(Lower Figure): Simulated Average Hourly Delay

Delay in Veh.Hours



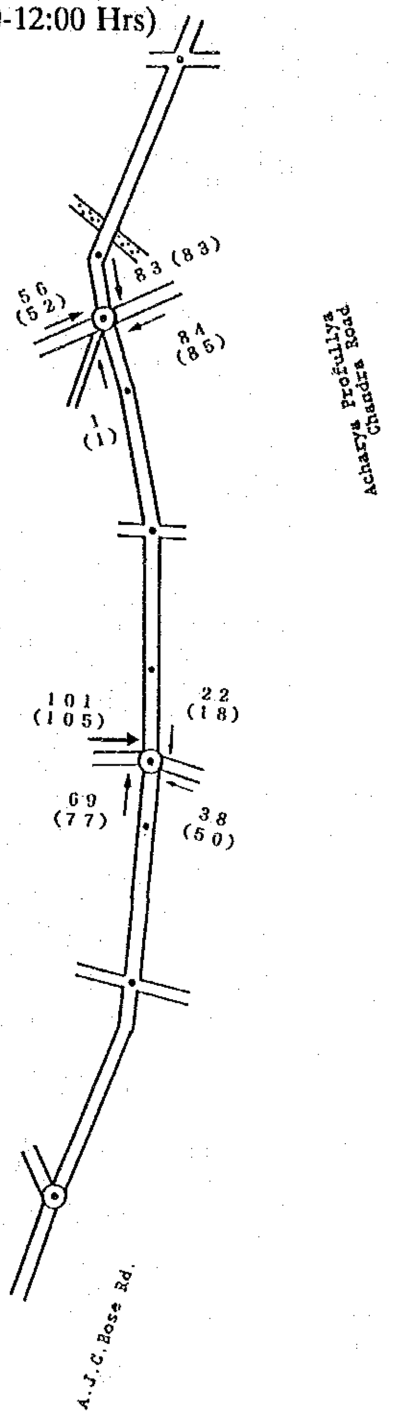
Morning Peak Hours (8:00-12:00 Hrs)



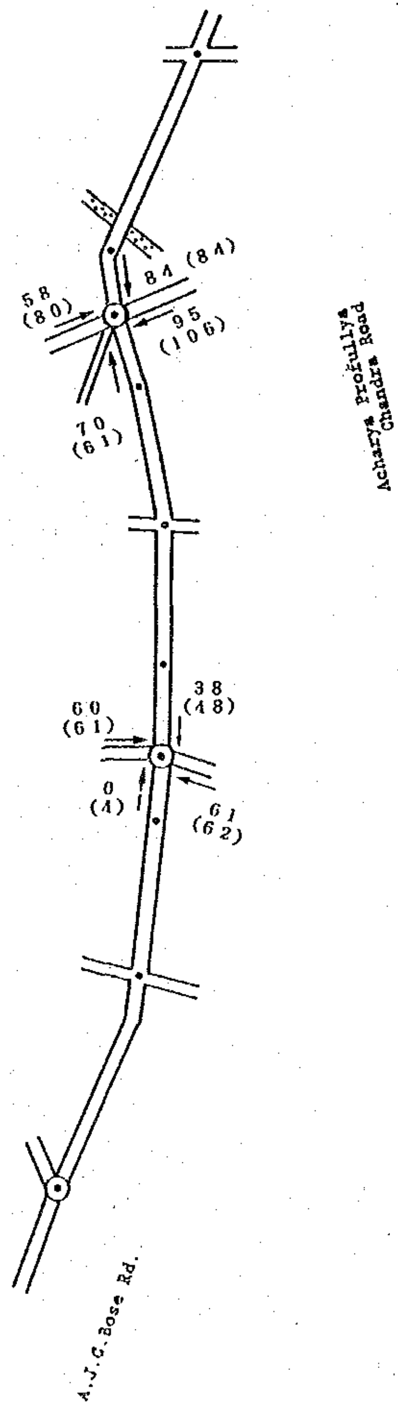
Evening Peak Hours (16:00-20:00 Hrs)

Figure T-3.6.7 Simulated and Observed Average Hourly Delay During Morning and Evening Peak Periods by Approach at Study Intersections on Route 2

Morning Peak Hours (8:00-12:00 Hrs)



Evening Peak Hours (16:00-20:00 Hrs)

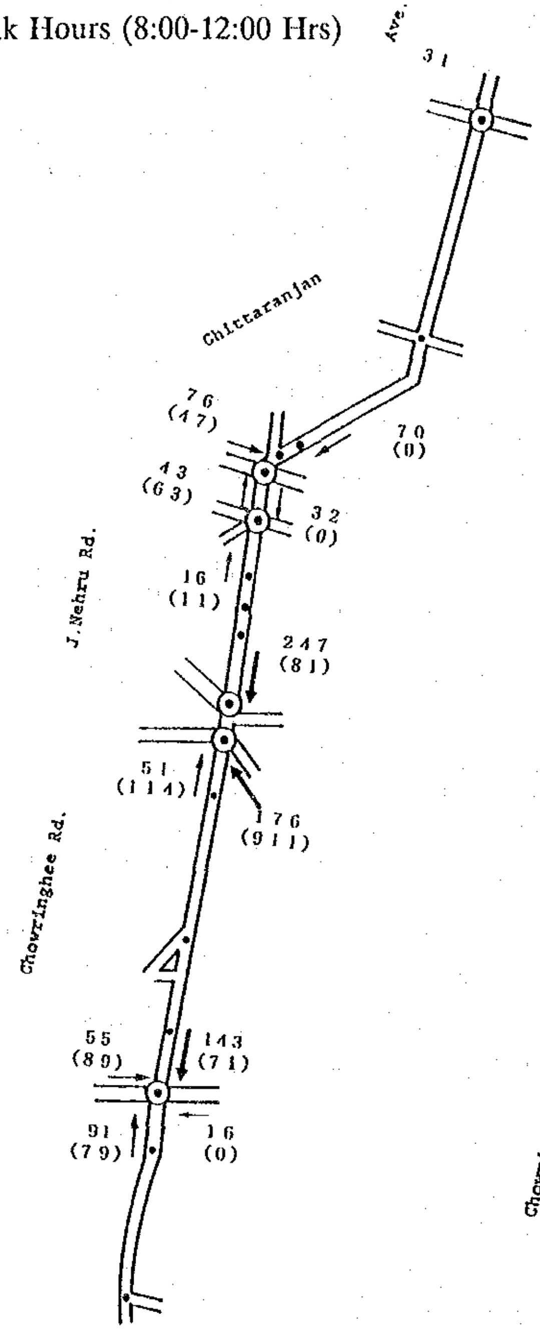


Note:

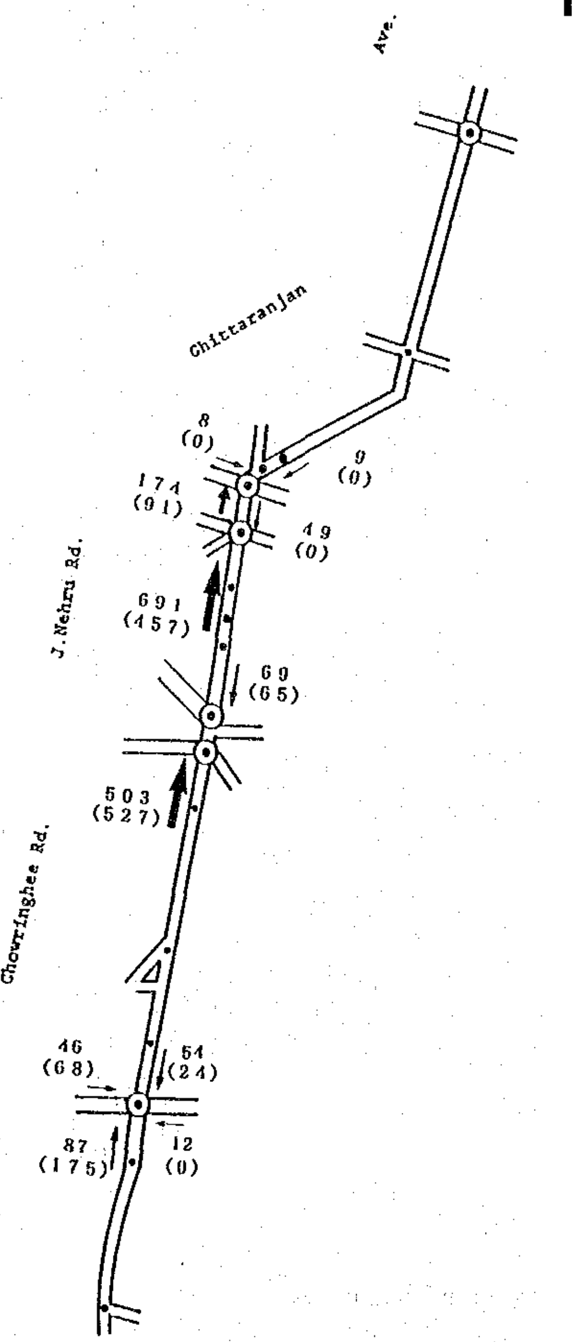
Upper Figure : Actual Observed Average Hourly Delay
(Lower Figure): Simulated Average Hourly Delay

Figure T-3.6.8 Simulated and Observed Average Hourly Delay During Morning and Evening Peak Periods by Approach at Study Intersections on Route 3

Morning Peak Hours (8:00-12:00 Hrs)



Evening Peak Hours (16:00-20:00 Hrs)



Note:

Upper Figure : Actual Observed Average Hourly Delay
(Lower Figure): Simulated Average Hourly Delay

Delay in Veh.Hours

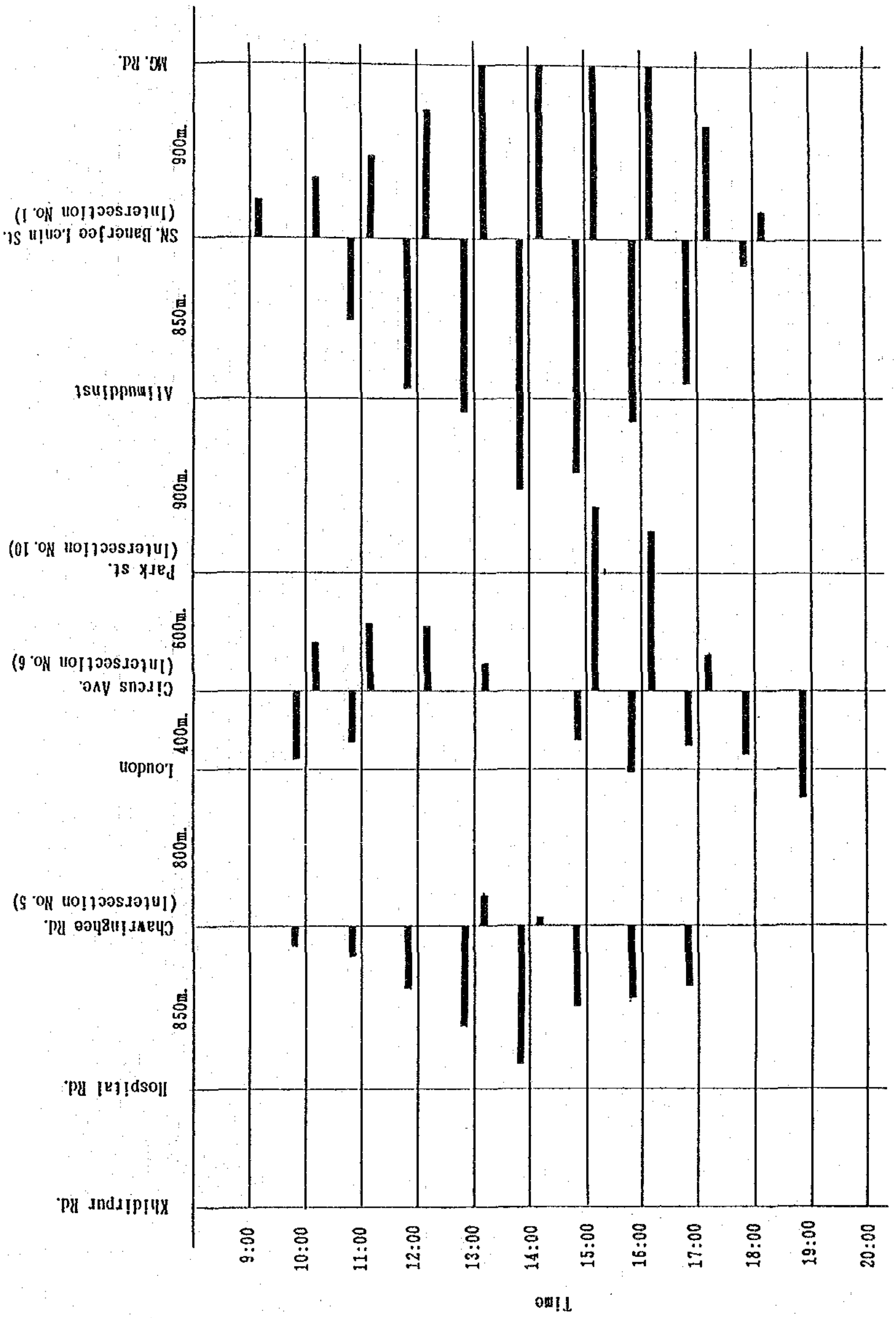


Figure T-3.6.9 Simulated Queue Lengths on Route 1 (AJC Bose Road) Under Existing Traffic Conditions

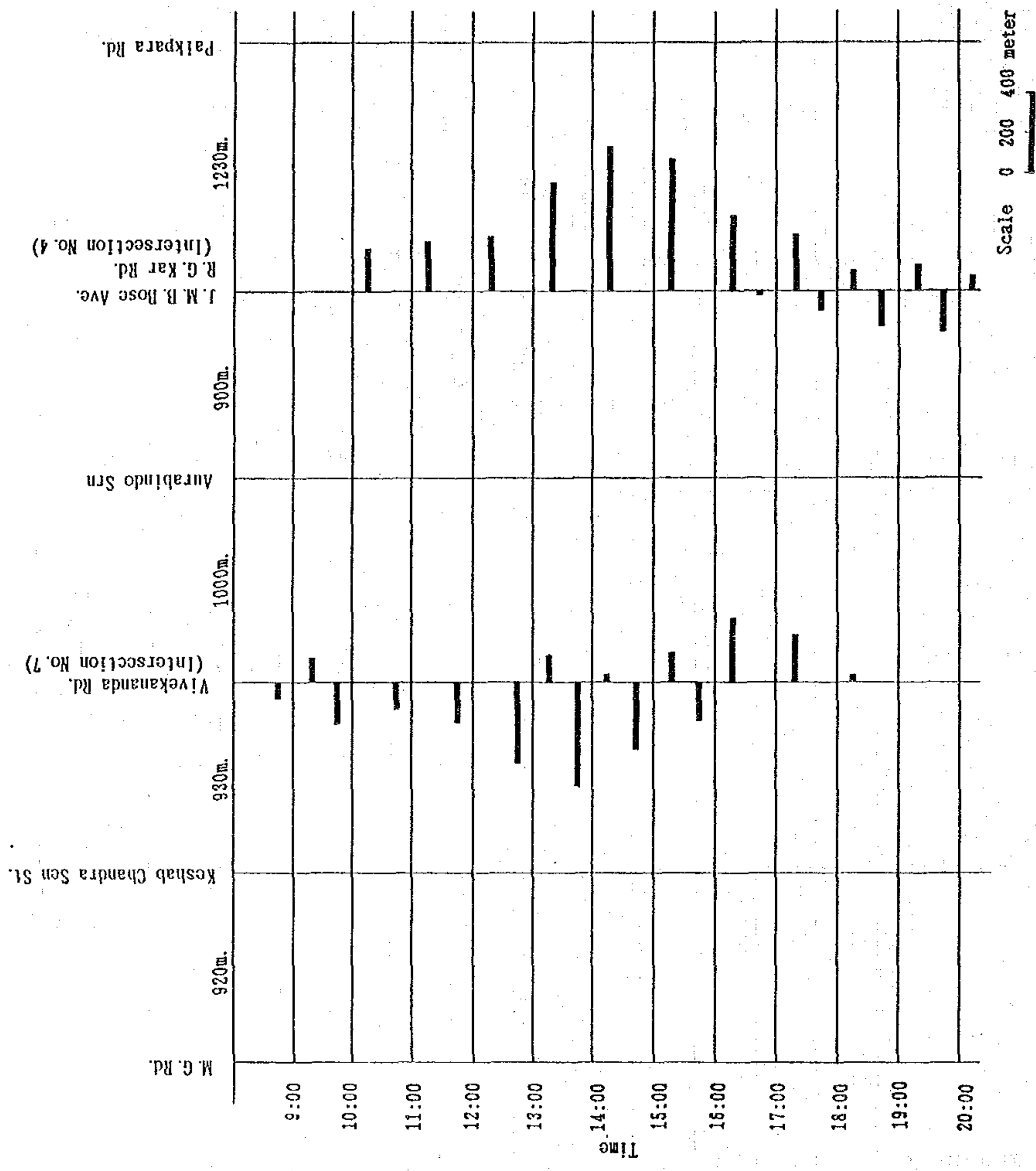


Figure T-3.6.10 Simulated Queue Lengths on Route 2 Under Existing Traffic Conditions

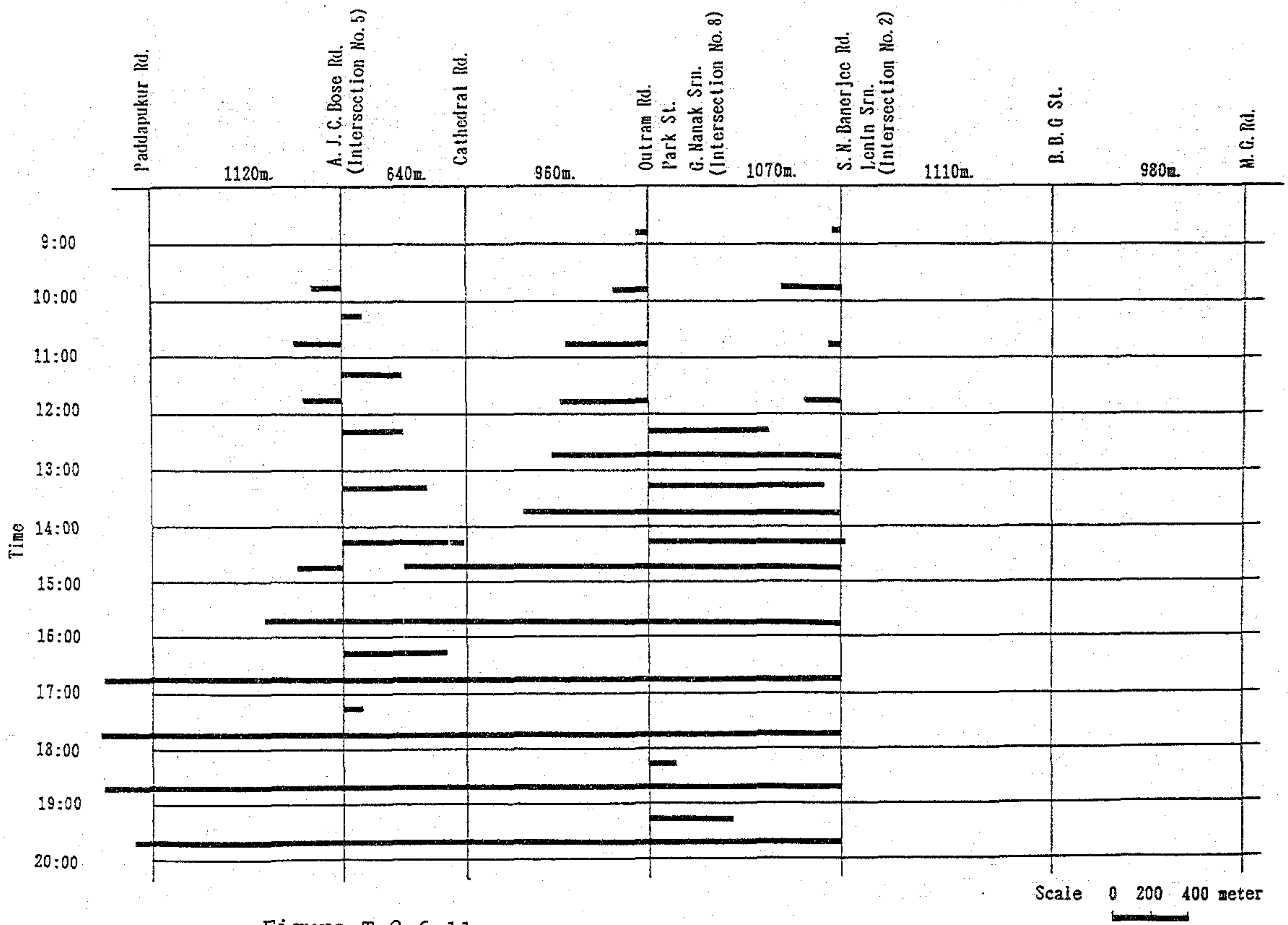


Figure T-3.6.11 Simulated Queue Lengths on Route 3 Under Existing Traffic Conditions

3.7 Simulation under the Do-Nothing Case (Base Case)

(1) Purpose

The I/O model has been verified for its ability to simulate traffic flow given the demand and intersection capacity conditions. The model now is ready for simulating FUTURE traffic conditions under various infrastructure scenarios or capacities. However, before the model is used to simulate future traffic conditions with flyover construction at selected intersections, it is necessary to first simulate 'future traffic conditions given that traffic demand has increased to the target year (1998) level but assuming that NO improvement whatsoever is being done to the existing road and intersection conditions'. This is so-called the "Do-Nothing Case" scenario.

The simulation of this scenario is important for two reasons:

a. The simulation results of this do-nothing scenario will show how the traffic conditions would deteriorate compared to the existing conditions, if the future demand is to increase at the predicted rate while no improvement to the present intersections is made.

b. The simulation results of the do-nothing case would provide a yardstick or baseline for assessing (by comparing) the performance of alternative flyover construction plan in reducing total delay, for instance.

(2) Future Traffic Conditions Under the 'Do-Nothing' Case

Simulation is therefore carried out for the three study routes under this do-nothing scenario and the results are given in Table T-3.7.1 below.

Future traffic conditions along the three study routes are expected to worsen as traffic demand increases by 1998. The study intersections on Route 1 for instance, are expected to handle an increase of 60% of traffic by 1998. With such an increase, the total delay in terms of total veh.hours, would increase by 7 folds from the existing 23,609 veh.hours to 164,229 veh.hours in 1998. The average travel speed is expected to fall to only one third of the existing level.

Table T-3.7.1 Traffic Conditions Under 'Do-Nothing' Case and Existing Conditions

Route	Case	Entering Volume (veh.)	Total Delay (veh.hr)	Average Delay (min)	Average Speed (kph)
1	Existing	154,518	23,609	1.7	9.1
	Future Do-Nothing	245,769	164,229	9.5	3.2
2	Existing	54,907	9,663	2.4	10.6
	Future Do-Nothing	87,726	32,491	6.2	7.8
3	Existing	143,587	37,171	3.4	5.9
	Future Do-Nothing	187,976	128,458	8.7	3.7
All	Existing	353,012	70,443	7.5	7.8
	Future Do-Nothing	521,471	325,178	24.4	3.9

Along Route 2, the study intersections face an increase in traffic demand of 87,730 compared with 54,900 at present. This increase in traffic would cause a total delay of 32,491 veh.hours, a 3.4 times increase from the existing level. The average travel speed would fall to 7.8 kph.

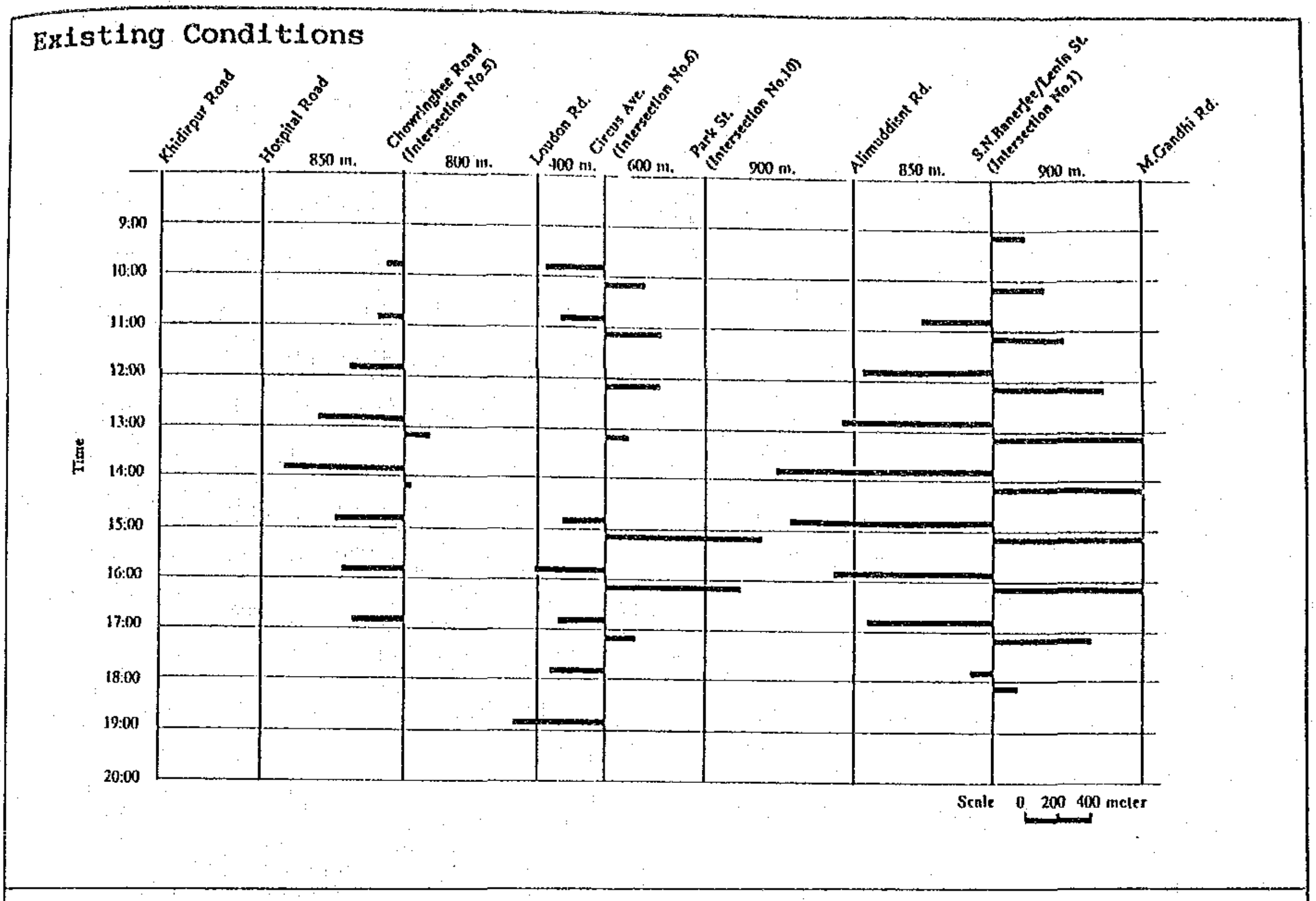
For Route 3, the total delay would increase by 3.5 times to 128,458 veh.hours under the do-nothing case. Among these three routes, Route 1 is expected to experience the worst deterioration of traffic conditions in future under the do-nothing case, followed by Route 3 and Route 2.

As shown in the table, the total delay for the three routes in future under the do-nothing case would increase by 4.6 times. This confirms the observation that the level of service of the major arterials of AJC Bose Road and Chowringhee-JL Nehru Road would deteriorate very quickly in the near future, unless something is done to improve the intersection capacity along these routes. Delays would be very excessive resulting in a great loss of productive times. Queues at the major intersections would extend to downstream intersections, creating a continuous queue extending for many kilometers. The slow speed would further reduce fuel efficiency, resulting in high cost of operation and increase air pollution.

The queue length along the three routes under the do-nothing scenario when compared to the existing condition can best represent the future state of the traffic congestion problems.

See Figures T-3.7.1 through T-3.7.3.

In Fig. T-3.7.1, for instance, queue lengths are excessively long at all the study intersections. Queue at intersection no.5 for the south bound traffic is as long as 3.2 km, extending up to beyond Alimuddinst Street. Comparing the two diagrams in this figure, queues also persist beyond 20:00 hrs in the do-nothing case. Under the existing traffic conditions, queues would disappear along this Route after 19:00 hrs.



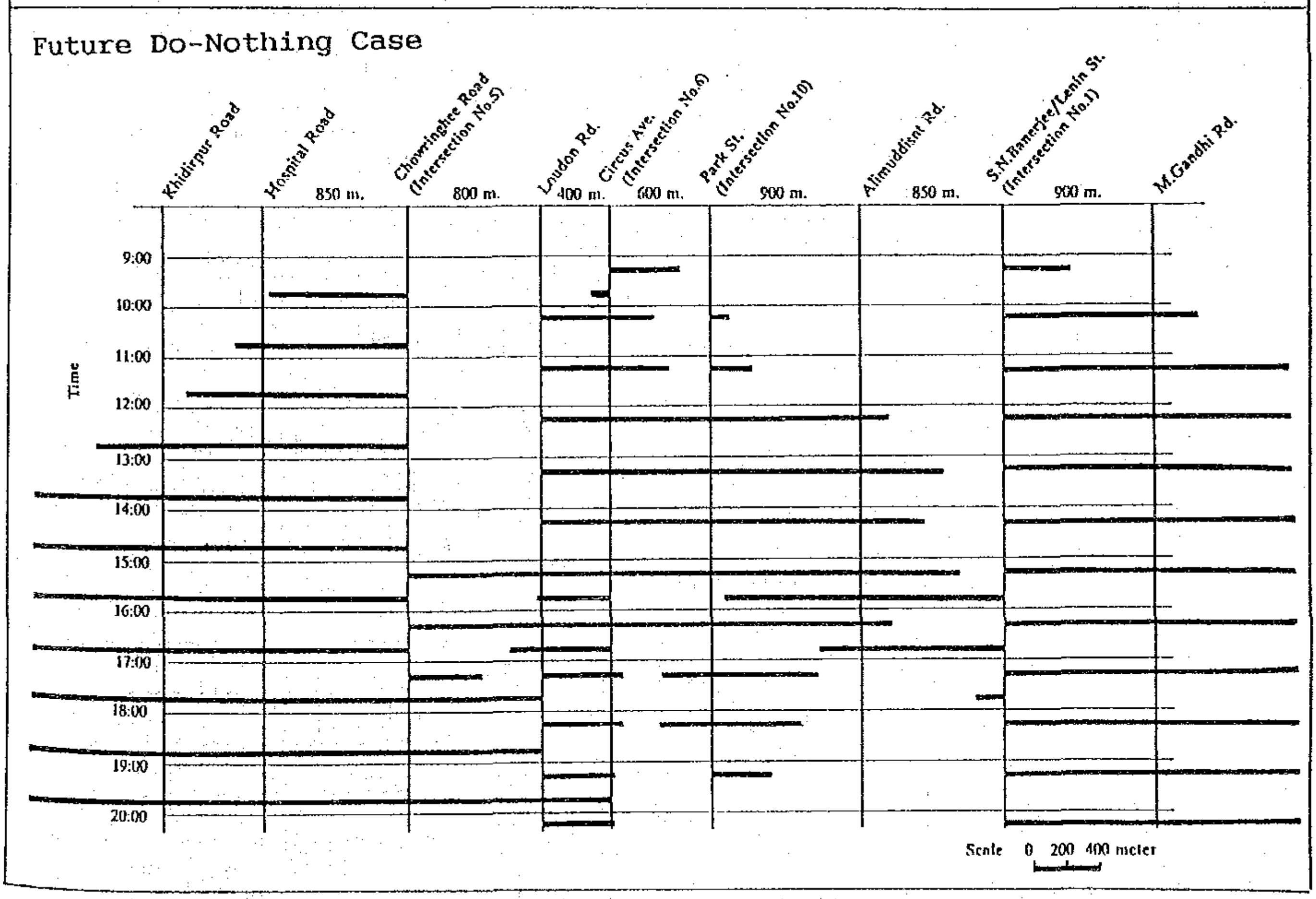


Figure T-3.7.1 Comparing Simulated Queue Lengths at Study Intersections on Route 1 Under Do-Nothing Case and Existing Traffic Conditions

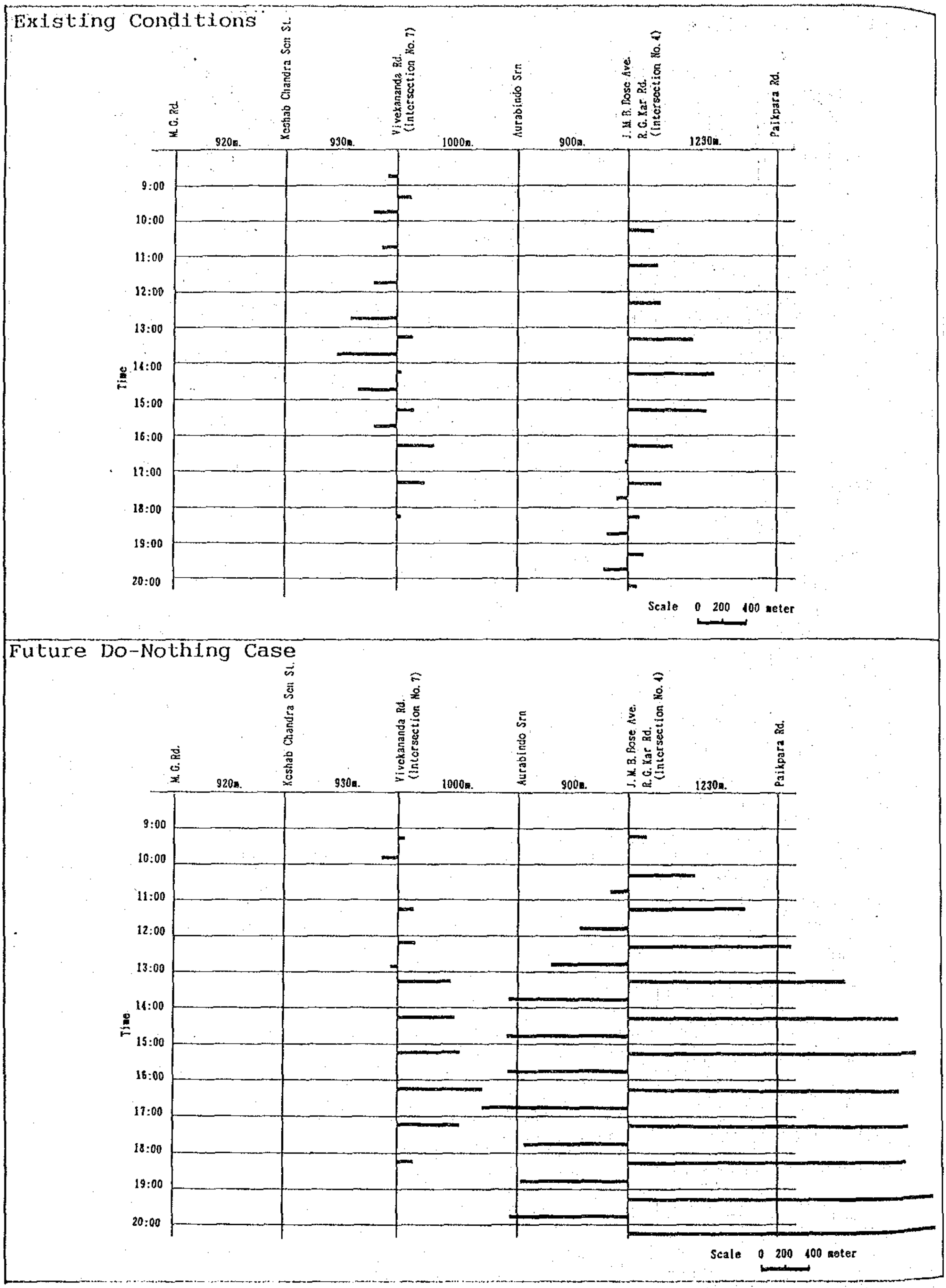


Figure T-3.7.2 Comparing Simulated Queue Lengths at Study Intersections on Route 2 Under Do-Nothing Case and Existing Traffic Conditions

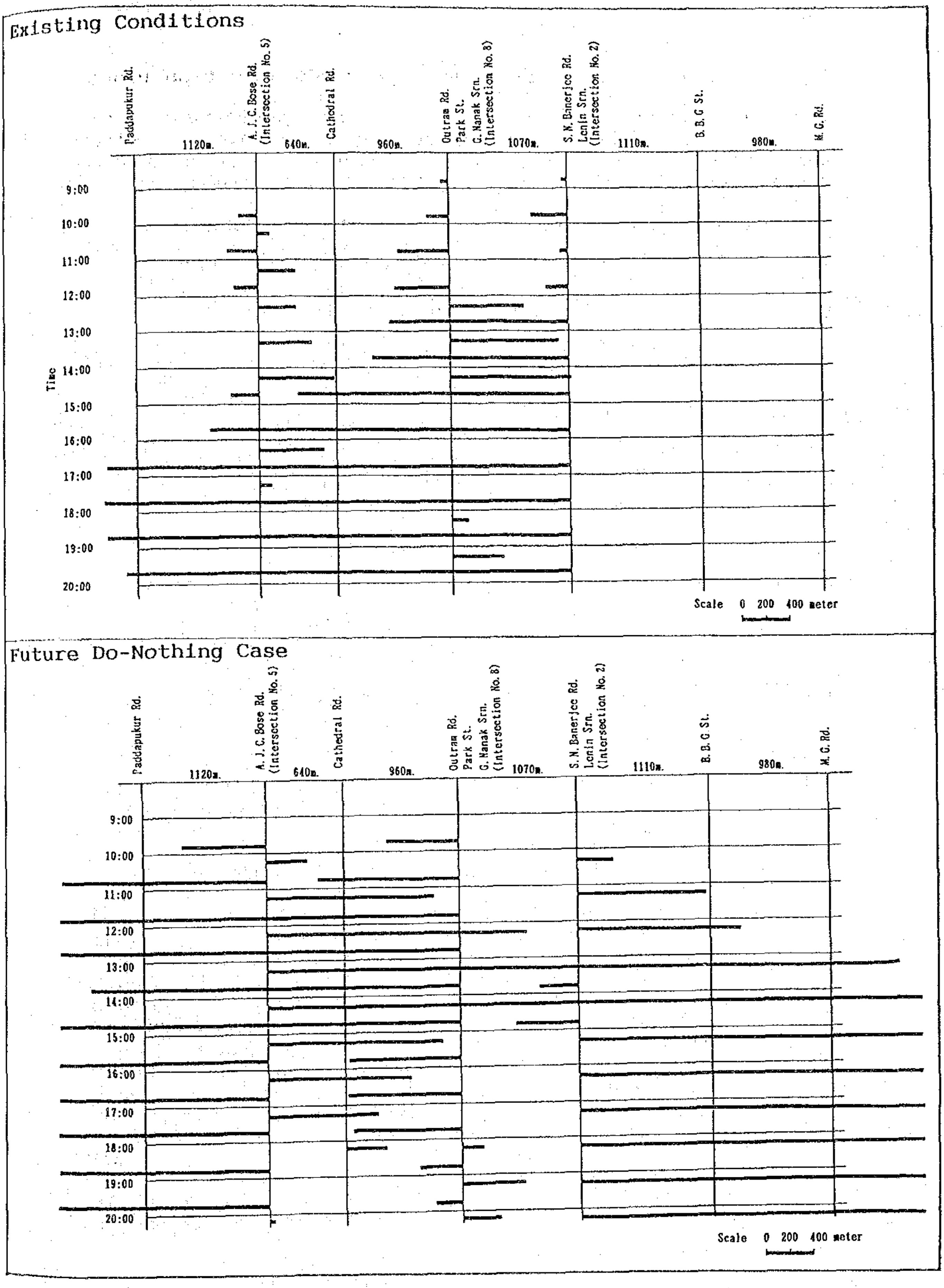


Figure T-3.7.3 Comparing Simulated Queue Lengths at Study Intersections on Route 3 Under Do-Nothing Case and Existing Traffic Conditions

3.8 Setting of Alternative Flyover Construction Plans

The next step is to simulate the performance of constructing flyovers at selected intersections. With three simulation routes and 9 intersections on these routes, a vast number of combinations are possible.

The following alternatives by each route are formulated.

Table T-3.8.1 List of Simulation Alternative Cases by Route

Route	Alternative Case	Proposed Flyovers
Route 1	1-1	(Do-Nothing Case)
	1-2	#1,#5,#6
	1-3	#1,#56
	1-4	#1,#5,#6,#10
	1-5	#1,#56,#10
Route 2	2-1	(Do-Nothing Case)
	2-2	#4,#7
	2-3	#9
	2-4	#4,#7,#9
Route 3	3-1	(Do-Nothing Case)
	3-2	#2,#8
	3-3	#8*
	3-4	#8,(#2-4Lane)
Isolated	4-1	(Do-Nothing Case)
	4-2	#3

Note:
#56: Continuous flyover bridge from intersection #5 to #6
* : Intersection #2 will be improved to 3-lane when the Metro construction is completed.

The above alternatives are set up with the aims of:

a. Comparing the simulation results of 1-2 and 1-3 would reveal the benefits if any of having a continuous flyover bridge from intersection no.5 to 6 as compared to having two individual flyovers at intersection no.5 and 6. The need to examine this scenario is because of the proximity of these two intersections. Moreover, it is observed that the three minor intersections between intersections no.5 and 6 would create further conflicts in movement to through traffic passing both intersections no.5 and 6. By having a continuous flyover, such conflicts would be removed.

b. The effect of having a flyover at intersection no.10 can be determined by comparing alternatives 1-2 and 1-4 or comparing 1-3 with 1-5.

c. For Route 2, alternatives are set up to test the effect of having a flyover at intersection no.9 against having two flyovers at no.4 and 7 - comparing simulation results of alternatives 2-2 and 2-3. The effects on traffic flow on Route 2 by having 3 flyovers can be obtained by either comparing the simulation results of 2-2 and 2-4 or 2-3 with 2.4.

d. For Route 3, the main concern is to test the extend of impact of having a flyover at intersection no.2 compared to having at-grade improvements. This is because of the foreseeable high cost of constructing a flyover at this location with the presence of the Metro structures underground. Comparing the simulation results of 3-2 and 3-3 would therefore provide some insights into this matter. Alternative 3-4 with a 4 lane at grade improvement to intersection no.2 is added to test if such a proposal would measure up to the effects of having a flyover.

3.9 Simulation Results of Alternative Flyover Plans

(1) Future Traffic Conditions by Alternative Plans

Tab. T-3.9.1 shows the final simulation results of all the alternative flyover plans set up above. The performances of each of these alternative plans are represented by their respective measures of effectiveness or MOE.

These MOE include:

- Total entering volumes,
- Traffic volume for 12 hours,
- Total delay in veh.hours
- Average delay in minutes
- Total veh.kms
- Total veh.hrs
- Average speed.

For assessing traffic impact, indicators such as average speed, total delay and total entering volume are the most appropriate.

For comparative analyses of their relative impacts on traffic flow along the study routes, the total delays in veh.hrs are represented as indices as shown in Tab. T-3.9.2.

An index of total delay of the alternative plans to that of the existing conditions is to present the extent of the delay in comparison to the delay as experienced in Calcutta along the three routes today.

A second index to indicate the reduction of total delay of the alternative plans from delays in the 'do-nothing' cases are also given.

Assessing the effectiveness in reducing total vehicle delays for Route 1, Plan 1-5 would be the best among the alternative plans. It is capable of improving the future traffic conditions to a level that is better than the existing conditions. This plan would reduce some 89% of the total delay in the 'Do-Nothing' Case.

A comparison of Plans 1-2 and 1-3 reveals that construction of a continuous flyover bridge from Intersection No.5 to 6 is far more superior than having two individual flyovers at Intersection no.5 and 6. The continuous bridge is able to achieve a reduction in the total vehicle delay by about 26,700 veh.hrs on the fact that most through traffic will be able to pass through the two intersections unhindered. For this reason, a continuous flyover from intersection no.5 to 6 is recommendable from the traffic impact viewpoint.

Table T-3.9.1 Simulation Results of Alternative Flyover Plans by Routes

Case			Entering Volume	Volume (12hrs)	Total Delay (Veh-hrs)	Avg.Delay (mins)	Vol*kms (vol-kms)	Vol*t.time (vol-hrs)	Avg.Seed (km/hr)
Route 1	1-0	Existing	154,518	820,853	23,609	1.72	283,890	31,057	9.14
	1-1	non	245,769	1,043,004	164,229	9.45	573,294	179,285	3.20
	1-2	#1,#5,#6	246,899	1,005,492	53,588	3.20	634,558	70,250	9.03
	1-3	#1,#56	245,111	964,755	26,890	1.67	636,074	43,590	14.59
	1-4	#1,#5,#6,#10	233,694	996,772	47,242	2.84	630,626	63,788	9.89
	1-5	#1,#56,#10	231,906	953,815	18,207	1.15	630,126	34,748	18.13
Route 2	2-0	Existing	54,907	243,554	9,663	2.38	141,622	13,378	10.59
	2-1	non	87,726	315,858	32,491	6.17	317,181	40,812	7.77
	2-2	#4,#7	87,726	312,925	1,472	0.28	332,266	10,177	32.65
	2-3	#9	76,976	225,414	1,228	0.33	214,348	6,846	31.31
	2-4	#4,#7,#9	76,976	213,851	1	0.00	214,273	5,616	38.15
Route 3	3-0	Existing	143,587	654,553	37,171	3.40	259,792	43,995	5.91
	3-1	non	187,976	889,799	128,458	8.66	528,079	142,323	3.71
	3-2	#2,#8	161,443	848,766	39,607	2.80	575,933	54,699	10.53
	3-3	#8,(#2,3Lane)	161,443	862,768	68,936	4.79	547,151	83,296	6.57
	3-4	#8,(#2,4Lane)	161,443	919,753	42,475	2.77	575,746	57,582	10.00
Route 4	4-0	Existing	39,778	141,632	0	0.00	95,251	2,494	38.19
	4-1	non	49,994	176,619	0	0.00	118,633	3,109	38.16
	4-2	#3	49,994	158,643	0	0.00	118,630	3,112	38.12

Table T-3.9.2 Comparative Indices of Total Delay of Alternative Plans

Route	Case	Flyovers	Entering Volume (Veh.)	Average Speed (Kph)	Total Delay (Veh.Hrs)	Total Delay Index*	Delay Reduction Ratio
Route 1	1-1	(Do-Nothing)	245,769	3.2	164,229	6.96	1.00
	1-2	#1,#5, #6	246,899	9.0	53,587	2.27	0.33
	1-3	#1,#56	245,111	14.6	26,890	1.14	0.16
	1-4	#1,#5,#6,#10	233,694	9.9	47,242	2.00	0.29
	1-5	#1,#56,#10	231,906	18.1	18,207	0.77	0.11
Route 2	2-1	(Do-Nothing)	87,726	7.8	32,491	3.36	1.00
	2-2	#4,#7	87,726	32.7	1,472	0.15	0.05
	2-3	#9	79,976	31.3	1,228	0.13	0.04
	2-4	#4,#7,#9	79,976	38.2	1	0.00	0.00
Route 3	3-1	(Do-Nothing)	187,976	3.7	128,458	3.46	1.00
	3-2	#2,#8	161,443	10.5	39,607	1.07	0.31
	3-3	#8	161,443	6.6	68,936	1.85	0.54
	3-4	#8,(#2,4Lane)	161,443	10.0	42,475	1.14	0.33
Isolated	4-1	(Do-Nothing)	49994	38.1	0	-	-
	4-2	#3	49994	38.2	0	-	-

Note: * Index with total delay under existing condition as 1.0

#56 : Continuous flyover bridge from Intersection No.5 to 6

Reduction in total delays from the 'Do-Nothing' case on Route 2 for Plans 2-2 and 2-3 are very close. 31,020 against 31,260 veh.hrs, indicating that effects of having two flyovers at intersection no.4 and 7 are about the same as having a flyover at intersection no.9. Having all the three flyovers, however, would further reduce delay but only by a negligible margin.

The construction of a flyover at intersection No.2 is effective in reducing the total vehicle delay by as much as 29,000 veh.hrs. over a 12 hours period (comparing plans 3-2 and 3-3). However, a 4-lane at-grade intersection improvement (Plan 3-4) is found to be equally effective in reducing delay of up to 26,500 veh.hrs or 90% of the delay reduction of a flyover. It can be deduced from this analysis that either a flyover at intersection no.2 or a 4-lane at-grade improvement is equally desirable.

From this analysis of the simulation results, the following conclusions are arrived at:

a) The construction of a continuous flyover bridge from Intersection No.5 to 6 is more effective in reducing total vehicle delay than the construction of two individual flyovers at no.5 and 6.

b) The construction of a flyover at intersection no.2 is equally effective as having a 4-lane at-grade improvement.

c) The construction of two flyovers at intersection no.4 and 7 is as effective as construction of a flyover at intersection no.9.

d) Construction of a flyover at intersection no.3 has little impact on traffic flow along the three study routes up to 1998.

(2) Simulated Future Traffic Volumes on the Proposed Flyovers

Figs. T-3.9.1 through T-3.9.3 shows the simulated traffic volumes carried by the proposed flyovers.

These volumes are of course constrained by the capacity of these flyovers which are inturn dictated by the structural design, such as number of lanes.

Figure T-3.9.1 Simulated Traffic Volumes on Flyovers Along Route 1

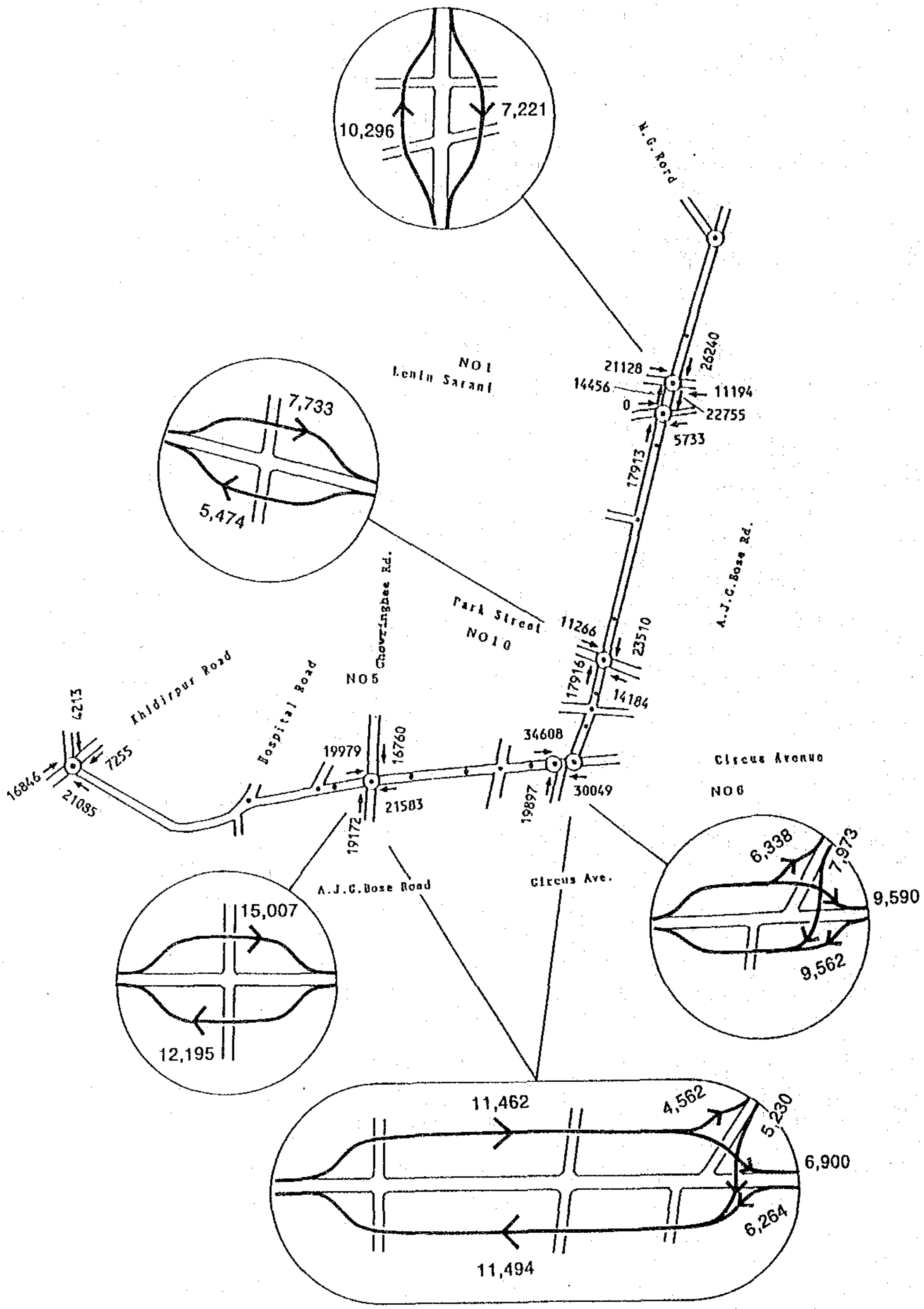


Figure T-3.9.2 Simulated Traffic Volumes on Flyovers Along Route 2

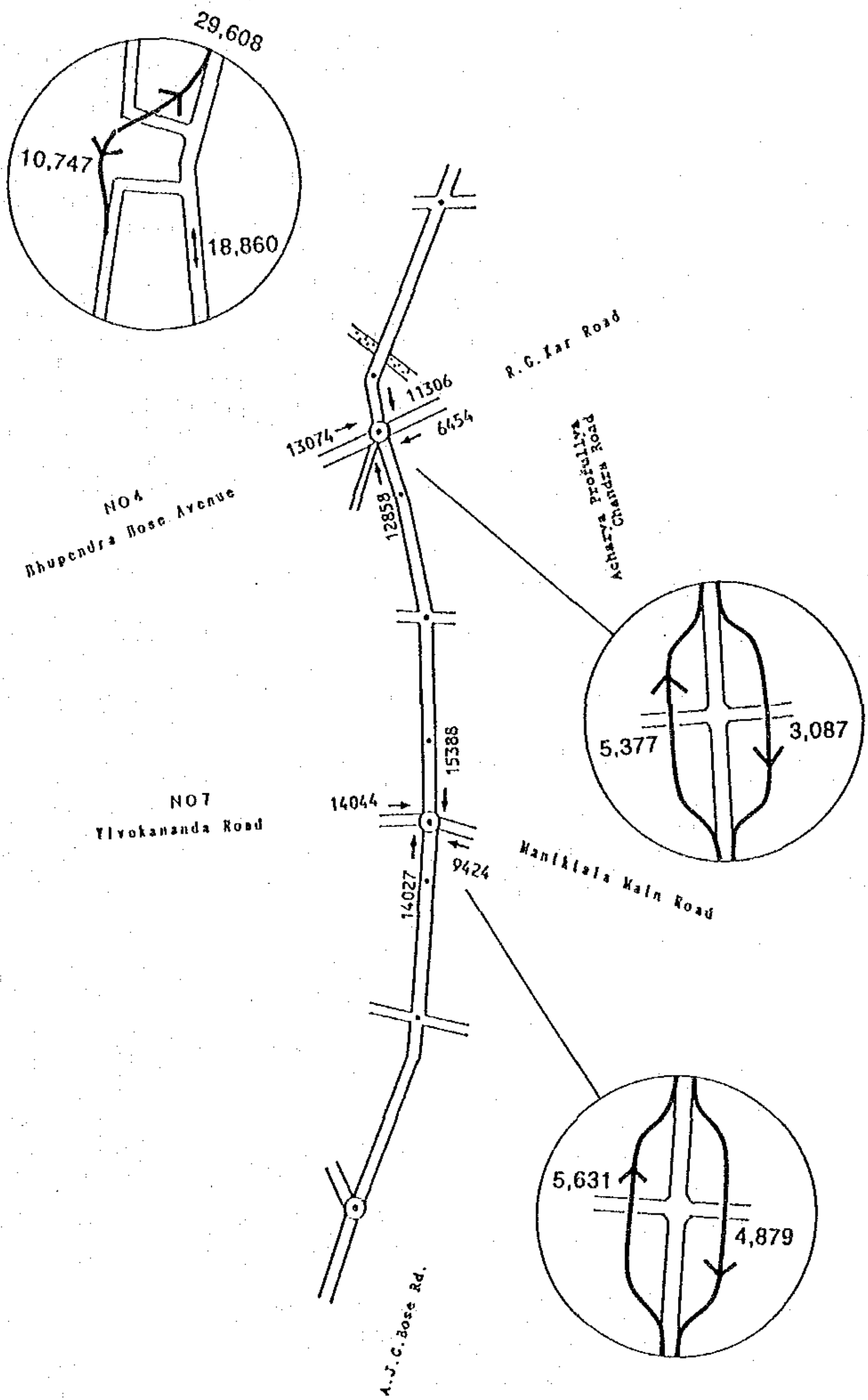
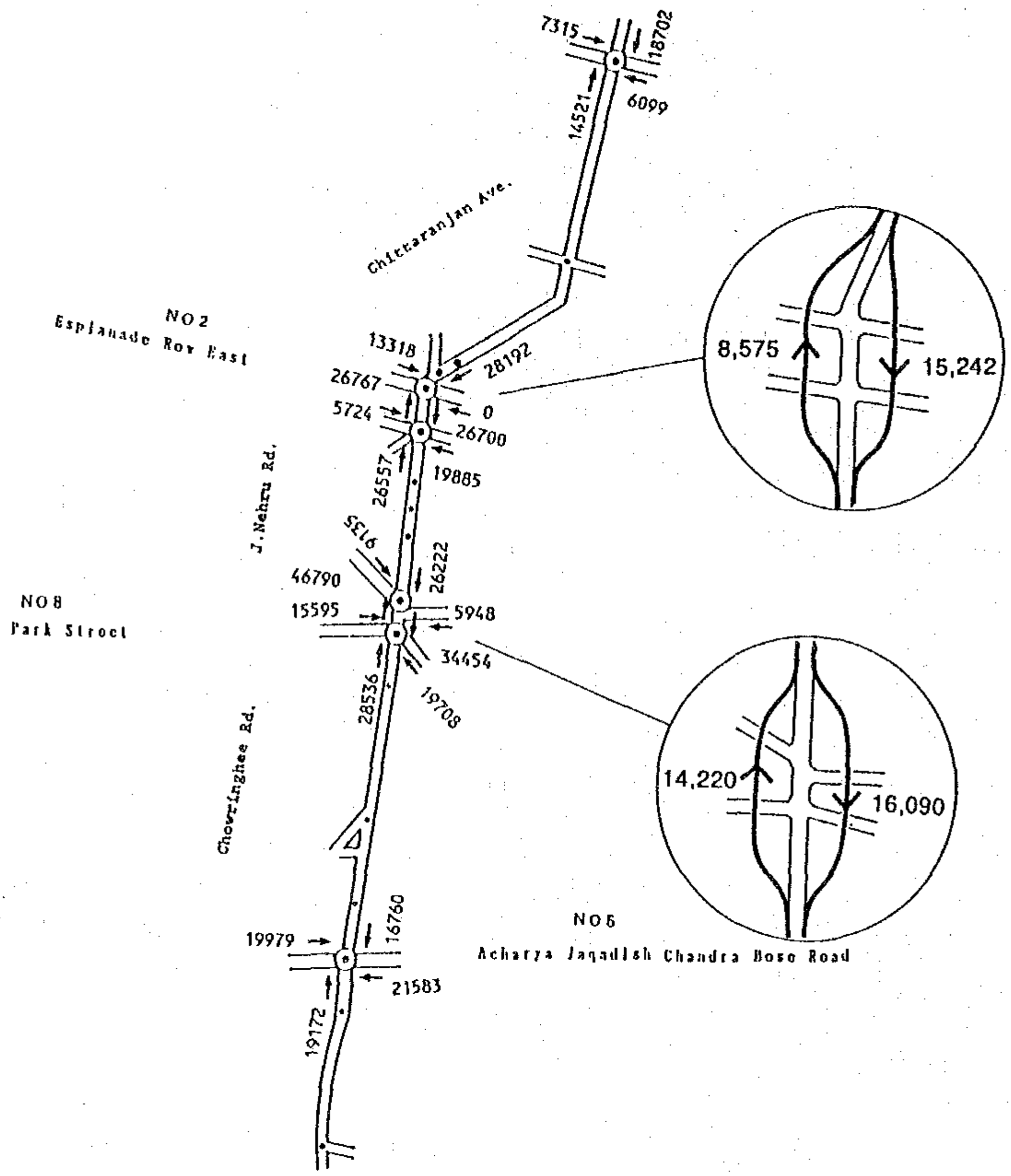


Figure T-3.9.3 Simulated Traffic Volumes on Flyovers Along Route 3



(3) Simulation Results by Alternative Infrastructure Improvement Plans

Based on the results of this simulation, various packages in flyover construction such as 3 flyovers plan, 5 flyovers plan, 7 flyovers plans may be generated covering all three study routes for further deliberation.

Tab. T-3.9.3 shows the comparative analyses of alternative infrastructure improvement plans.

By measure of their impact on reduction of delays, Plans 3-A-2 (9 flyovers and 4-lane improvement at #2), Plan 2-B-3 (6 flyovers and 4-lane improvement at #2) and 2-A-3 (7 flyovers and 4-lane improvement of #2) are by far the best plans, capable of reducing total delay to a level better than the present situation. All these three plans have the continuous flyover bridge from #5 to #6, and a total delay index of 0.9.

With their impacts on total delay being more or less equal, Plan 2-B-3 would probably be the most cost-effective plan among the three plans since it has the least number of flyovers.

Refering to Tab. T-3.9.3 again, if development fund is limited, Plan 1-A-2 would seem to be an effective plan, since it advocates the construction of only 4 flyovers and 4-lane improvement to intersection #2, yet it has a relatively good outcome of total delay index of 1.4.

The cost benefit analysis of these alternative improvement plans are given in the Chapter on Evaluation of Alternative Plans in the main report.

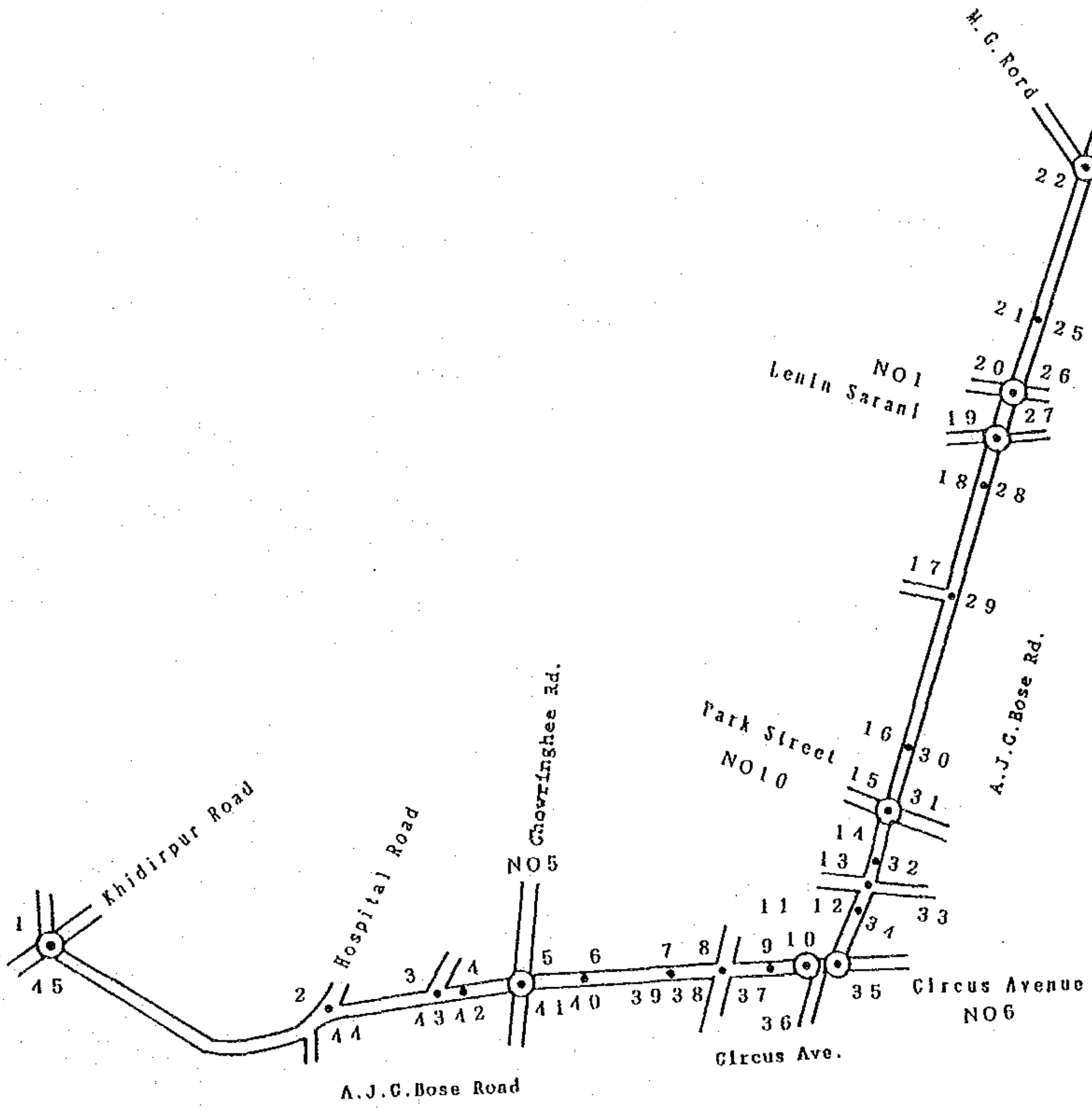
Table T-3.9.3 Comparative Analyses of Simulation Results of Alternative Infrastructure Improvement Plans

Alternative Cases		Flyover Along Route Route 1 (#1,5,6,10)	Route 2 (#4,7)	Route 3 (#2,8)	Isolated (#3,9)	12-Hour Volume (Vehicle)	Volume-Distance (Veh.Km)	Volume-Time (Veh.Hrs)	Average Speed (kph)	Total Delay (Veh.Hr)	Total Delay Index *
Alt 0	(Do-Nothing)	NF	NF	NF	NF	2,248,660	1,418,550	362,420	3.9	325,180	4.6
Alt-1	1-A-1	#1,#5,#6	NF	(#2-4L),#8	NF	2,241,100	1,527,490	168,640	9.1	128,550	1.8
	1-A-2	#1,#56	NF	(#2-4L),#8	NF	2,200,370	1,529,000	141,980	10.8	101,860	1.4
	1-B-1	#1,#5,#6	NF	#8	NF	2,184,120	1,498,890	194,360	7.7	155,010	2.2
	1-B-2	#1,#56	NF	#8	NF	2,143,380	1,500,410	167,700	8.9	128,320	1.8
Alt-2	2-A-1	#1,#5,#6,#10	#4,#7	(#2-4L),#8	NF	2,229,450	1,538,640	131,550	11.7	91,190	1.3
	2-A-2	#1,#5,#6,#10	#4,#7	#8	NF	2,172,470	1,510,040	157,260	9.6	117,650	1.7
	2-A-3	#1,#56,#10	#4,#7	(#2-4L),#8	NF	2,186,490	1,538,140	102,510	15.0	62,150	0.9
	2-A-4	#1,#56,#10	#4,#7	#8	NF	2,129,510	1,509,540	128,220	11.8	88,610	1.3
	2-B-1	#1,#5,#6,#10	#9	(#2-4L),#8	NF	2,141,940	1,420,720	128,220	11.1	90,940	1.3
	2-B-2	#1,#5,#6,#10	#9	#8	NF	2,084,950	1,392,130	153,930	9.0	117,410	1.7
	2-B-3	#1,#56,#10	#9	(#2-4L),#8	NF	2,098,980	1,420,220	99,180	14.3	61,910	0.9
	2-B-4	#1,#56,#10	#9	#8	NF	2,042,000	1,391,630	124,890	11.1	88,370	1.3
Alt-3	3-A-1	#1,#5,#6,#10	#4,#7,#9	(#2-4L),#8	#3	2,130,380	1,420,650	126,990	11.2	89,720	1.3
	3-A-2	#1,#56,#10	#4,#7,#9	(#2-4L),#8	#3	2,087,420	1,420,150	97,950	14.5	60,680	0.9
	3-B-1	#1,#5,#6,#10	#4,#7,#9	#8	#3	2,073,390	1,392,050	152,700	9.1	116,180	1.6
	3-B-2	#1,#56,#10	#4,#7,#9	#8	#3	2,030,430	1,391,550	123,660	11.3	87,140	1.2

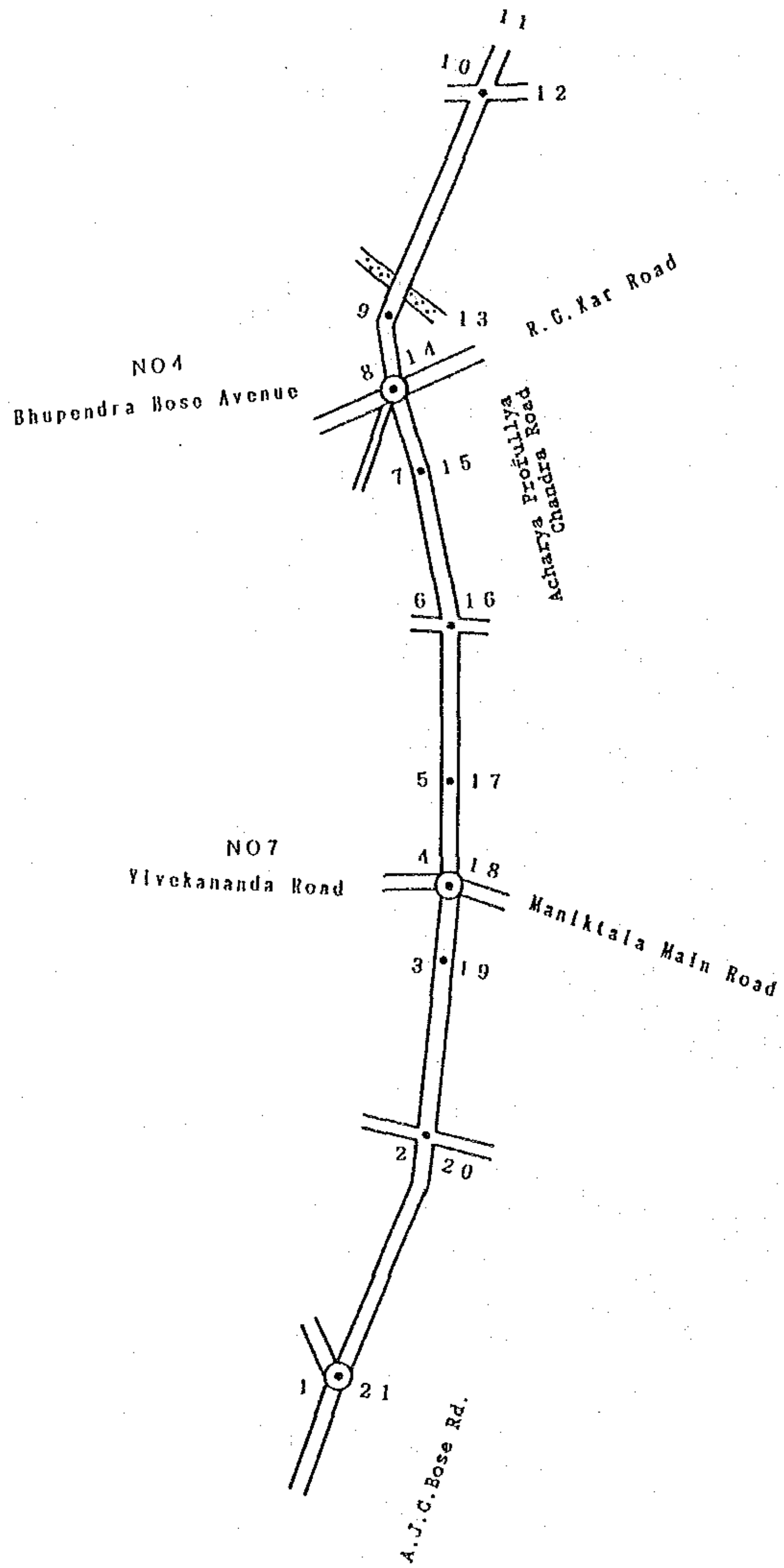
Note: NF = No Flyover; #56 = Continuous Flyover Bridge From #5 to #6; *Total Delay Index with that of Existing Conditions as 1.0

APPENDIX

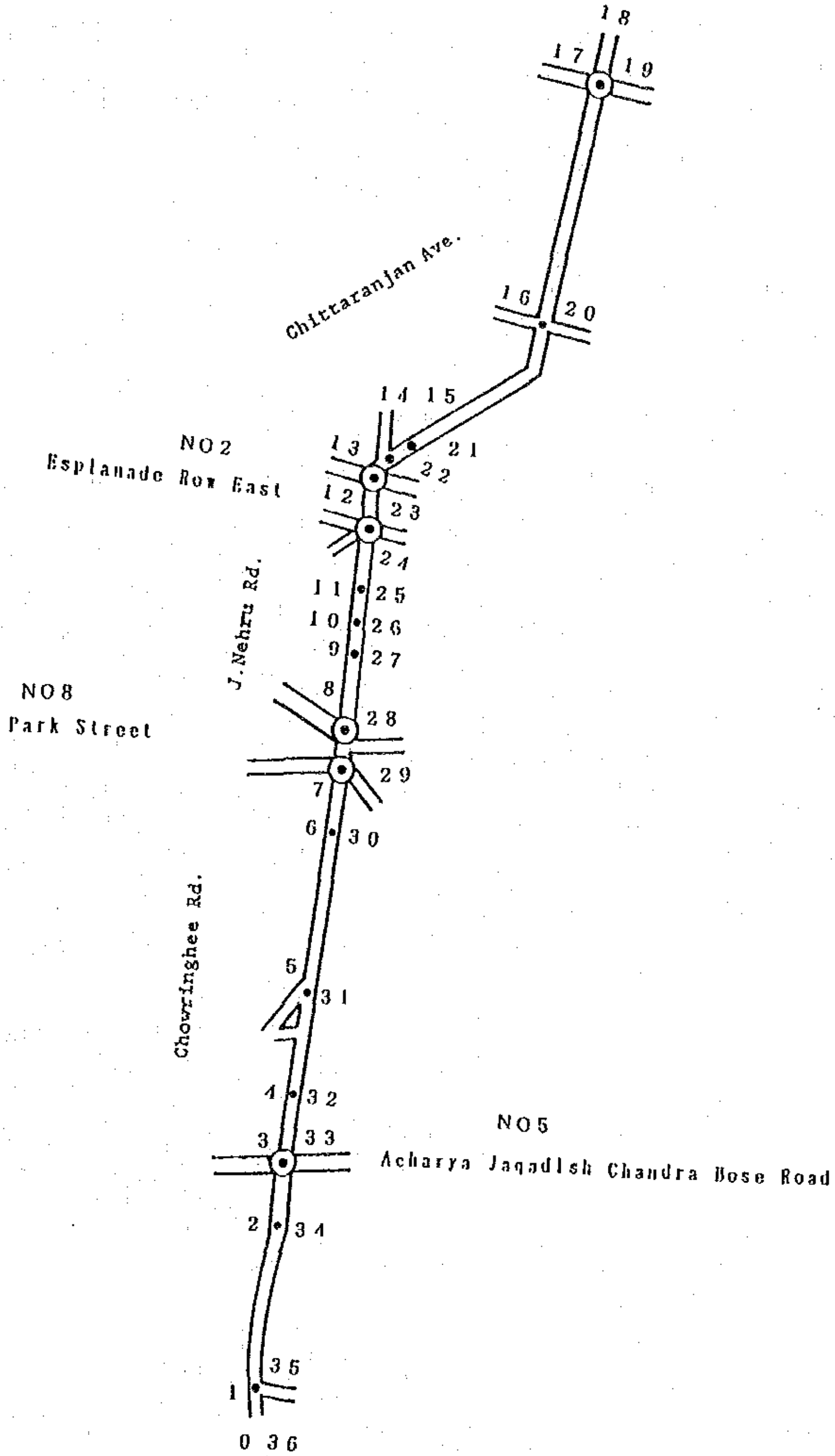
A: Simulation Routes and Intersection Numbers



(Route 1)


11
10
12
9
13
R.C.Kar Road
NO4
Bhupendra Bose Avenue
8
14
7
15
Acharya Profullya Chandra Road
6
16
5
17
NO7
Vivekananda Road
4
18
Maniktala Main Road
3
19
2
20
1
21
A.J.C.Bose Rd.

(Route 2)



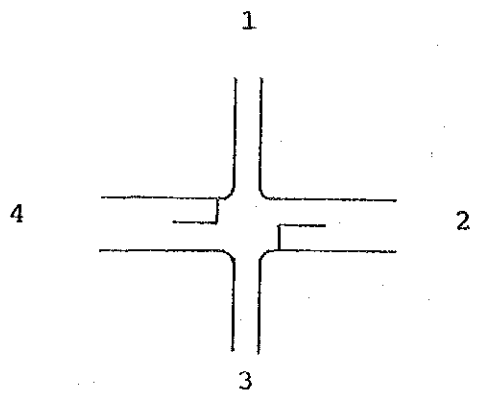
18
17
19
Chittaranjan Ave.
16
20
14 15
NO2
Esplanade Row East
13
21
22
12
23
24
J.Nehru Rd.
11
25
10
26
9
27
NO8
Park Street
8
28
7
29
6
30
Chowringhee Rd.
5
31
4
32
NO5
3
33
Acharya Jagadish Chandra Bose Road
2
34
35
1
0 36

(Route 3)

B: Traffic Capacity Input Data

Legend: Intersection No., Approach 1, Approach 2, Approach 3, Approach 4

1	3492	0	3492	0	3492	0	3492	0	8:00 - 14:00 Hours
2	3492	0	3492	0	3492	0	3492	0	
3	3600	0	3600	0	3600	0	3600	0	
4	1910	0	2080	0	1720	0	1650	0	
5	3600	0	3600	0	3600	0	3600	0	
6	3492	0	3492	0	3492	0	3492	0	
7	3600	0	3600	0	3600	0	3600	0	
8	2000	0	1280	0	800	0	1512	0	
9	3600	0	3600	0	3600	0	3600	0	
10	3492	0	3492	0	3492	0	3492	0	
1	3492	0	3492	0	3492	0	3492	0	14:00 - 20:00 Hours
2	3492	0	3492	0	3492	0	3492	0	
3	3600	0	3600	0	3600	0	3600	0	
4	2400	0	2200	0	1180	0	2200	0	
5	3600	0	3600	0	3600	0	3600	0	
6	3492	0	3492	0	3492	0	3492	0	
7	3600	0	3600	0	3600	0	3600	0	
8	2680	0	1330	0	740	0	1750	0	
9	3600	0	3600	0	3600	0	3600	0	
10	3492	0	3492	0	3492	0	3492	0	



1	3492	0	3492	0	3492	0	3492	0
2	3600	0	3600	0	3600	0	3600	0
3	2180	0	2760	0	2750	0	4000	0
4	3600	0	3600	0	3600	0	3600	0
5	3492	0	3492	0	3492	0	3492	0
6	3600	0	3600	0	3600	0	3600	0
7	5700	0	4000	0	4800	0	3650	0
8	4800	0	2000	0	2400	0	4800	0
9	3600	0	3600	0	3600	0	3600	0
10	3600	0	3600	0	3600	0	3600	0
11	3600	0	3600	0	3600	0	3600	0
12	3600	0	2500	0	3600	0	3300	0
13	2400	0	2200	0	3600	0	2400	0
14	3492	0	3492	0	3492	0	3492	0
15	3600	0	3600	0	3600	0	3600	0
16	3492	0	3492	0	3492	0	3492	0
17	3492	0	3492	0	3492	0	3492	0
1	3492	0	3492	0	3492	0	3492	0
2	3600	0	3600	0	3600	0	3600	0
3	2100	0	3500	0	2950	0	3430	0
4	3600	0	3600	0	3600	0	3600	0
5	3492	0	3492	0	3492	0	3492	0
6	3600	0	3600	0	3600	0	3600	0
7	5700	0	4500	0	5200	0	3700	0
8	4800	0	3100	0	2400	0	4500	0
9	3600	0	3600	0	3600	0	3600	0
10	3600	0	3600	0	3600	0	3600	0
11	3600	0	3600	0	3600	0	3600	0
12	3600	0	2600	0	3600	0	2600	0
13	2900	0	2500	0	3600	0	2400	0
14	3492	0	3492	0	3492	0	3492	0
15	3600	0	3600	0	3600	0	3600	0
16	3492	0	3492	0	3492	0	3492	0
17	3492	0	3492	0	3492	0	3492	0

Traffic Capacity by Link by Approach on Route 3

1	3492	0	3492	0	3492	0	3492	0
2	3492	0	3492	0	3492	0	3492	0
3	3600	0	3600	0	3600	0	3600	0
4	1910	0	2080	0	1720	0	1650	0
5	3600	0	3600	0	3600	0	3600	0
6	3492	0	3492	0	3492	0	3492	0
7	3600	0	3600	0	3600	0	3600	0
8	2000	0	1280	0	800	0	1512	0
9	3600	0	3600	0	3600	0	3600	0
10	3492	0	3492	0	3492	0	3492	0
1	3492	0	3492	0	3492	0	3492	0
2	3492	0	3492	0	3492	0	3492	0
3	3600	0	3600	0	3600	0	3600	0
4	2400	0	2200	0	1180	0	2200	0
5	3600	0	3600	0	3600	0	3600	0
6	3492	0	3492	0	3492	0	3492	0
7	3600	0	3600	0	3600	0	3600	0
8	2680	0	1330	0	740	0	1750	0
9	3600	0	3600	0	3600	0	3600	0
10	3492	0	3492	0	3492	0	3492	0

Traffic Capacity by Link by Approach on Route 2

1	3564	0	3600	0	3456	0	4032	0
2	3492	0	3492	0	3492	0	3492	0
3	3492	0	3492	0	3492	0	3492	0
4	3600	0	3600	0	3600	0	3600	0
5	2800	0	2750	0	4100	0	2160	0
6	3600	0	3600	0	3600	0	3600	0
7	3600	0	3600	0	3600	0	3600	0
8	3492	0	3492	0	3492	0	3492	0
9	3600	0	3600	0	3600	0	3600	0
10	3650	0	4080	0	4000	0	3500	0
11	3600	0	3800	0	3500	0	4800	0
12	3600	0	3600	0	3600	0	3600	0
13	3492	0	3492	0	3492	0	3492	0
14	3600	0	3600	0	3600	0	3600	0
15	4800	0	3420	0	4800	0	3420	0
16	3600	0	3600	0	3600	0	3600	0
17	3492	0	3492	0	3492	0	3492	0
18	3600	0	3600	0	3600	0	3600	0
19	3400	0	3200	0	2280	0	1600	0
20	3200	0	3120	0	3400	0	3000	0
21	4000	0	4000	0	4000	0	4000	0
22	4000	0	4100	0	4000	0	4000	0
1	3564	0	3600	0	3456	0	4032	0
2	3492	0	3492	0	3492	0	3492	0
3	3492	0	3492	0	3492	0	3492	0
4	3600	0	3600	0	3600	0	3600	0
5	3550	0	2950	0	3370	0	2040	0
6	3600	0	3600	0	3600	0	3600	0
7	3600	0	3600	0	3600	0	3600	0
8	3492	0	3492	0	3492	0	3492	0
9	3600	0	3600	0	3600	0	3600	0
10	3650	0	2860	0	4000	0	3930	0
11	3600	0	3500	0	3500	0	4800	0
12	3600	0	3600	0	3600	0	3600	0
13	3492	0	3492	0	3492	0	3492	0
14	3600	0	3600	0	3600	0	3600	0
15	4800	0	3420	0	4800	0	3420	0
16	3600	0	3600	0	3600	0	3600	0
17	3492	0	3492	0	3492	0	3492	0
18	3600	0	3600	0	3600	0	3600	0
19	3400	0	3400	0	2280	0	2200	0
20	3550	0	3750	0	3400	0	3000	0
21	4000	0	4000	0	4000	0	4000	0
22	4000	0	4100	0	4000	0	4000	0

Traffic Capacity by Link by Approach on Route 1

C: Simulation Results Outputs

Simulation Output for Alt 1-O (Existing Conditions -Route 1)

SIM101E --Summary of Total Delay

Items	Volume	Delay(mins)	Delay*vol(hrs)	Vol*KM(V.KM)	Travel(mins)	Vol*Trvl	Speed(km/hr)
INT. 1	15275	.02	4.	18371.		488.	37.7
INT. 2	26331	.00	0.	17443.		456.	38.2
INT. 3	26329	.54	238.	7850.		444.	17.7
INT. 4	26328	1.14	501.	5266.		639.	8.2
INT. 5	55480	5.77	5337.	20282.		5871.	3.5
INT. 6	29968	.00	0.	8344.		218.	38.2
INT. 7	29963	.00	0.	7491.		195.	38.5
INT. 8	51981	2.65	2298.	11527.		2599.	4.4
INT. 9	51980	.30	264.	8064.		476.	16.9
INT. 10	59242	2.06	2039.	14207.		2412.	5.9
INT. 11	43902	3.83	2803.	10281.		3072.	3.3
INT. 12	22920	.45	171.	3371.		258.	13.0
INT. 13	28108	.20	93.	4313.		206.	20.9
INT. 14	28109	.33	156.	4325.		269.	16.1
INT. 15	49625	.17	139.	16664.		578.	28.8
INT. 16	34021	.00	1.	15313.		402.	38.1
INT. 17	34022	1.31	743.	19326.		1252.	15.4
INT. 18	25529	3.34	1420.	9518.		1669.	5.7
INT. 19	35644	1.59	945.	7526.		1141.	6.6
INT. 20	57631	3.86	3704.	19266.		4209.	4.6
INT. 21	44234	2.56	1887.	19240.		2392.	8.0
INT. 22	44231	1.18	867.	35905.		1809.	19.8

TOTAL VOL(12hrs)= 820853. TOTAL DELAY(hrs)= 23609.1 AVG.DELAY(mins)= 1.726
TOTAL VOL*KM= 283890. TTL TRVL*VOL= 31057. AVG.SPEED= 9.141
ENTERING VOL= 154518.

Simulation Output for Alt 1-1 (Do Nothing - Route 1)

SIM101F --Summary of Total Delay

Items	Volume	Delay(mins)	Delay*vol(hrs)	Vol*KM(V.KM)	Travel(mins)	Vol*Trvl	Speed(km/hr)
INT. 1	31917	.00	0.	81737.		2142.	38.2
INT. 2	35201	18.52	10863.	48594.		12138.	4.0
INT. 3	34961	4.01	2338.	10320.		2607.	4.0
INT. 4	34859	1.85	1072.	6972.		1255.	5.6
INT. 5	68375	22.80	25977.	24586.		26624.	.9
INT. 6	37492	.93	583.	10475.		859.	12.2
INT. 7	37369	.85	528.	9342.		773.	12.1
INT. 8	75296	15.51	19468.	24090.		20102.	1.2
INT. 9	53975	1.33	1196.	7899.		1404.	5.6
INT. 10	70801	20.63	24349.	16261.		24776.	.7
INT. 11	52792	25.00	22001.	12772.		22335.	.6
INT. 12	26354	.95	418.	3742.		517.	7.2
INT. 13	51060	7.32	6232.	14114.		6603.	2.1
INT. 14	35896	1.07	639.	5531.		785.	7.0
INT. 15	63153	3.78	3975.	21327.		4537.	4.7
INT. 16	44109	3.28	2410.	19522.		2924.	6.7
INT. 17	44127	9.41	6919.	25215.		7582.	3.3
INT. 18	31197	.92	476.	11813.		787.	15.0
INT. 19	42645	.50	352.	9174.		592.	15.5
INT. 20	66480	14.68	16264.	21916.		16840.	1.3
INT. 21	52020	11.51	9984.	53119.		11377.	4.7
INT. 22	52925	9.28	8186.	134773.		11726.	11.5

TOTAL VOL(12hrs)=1043004. TOTAL DELAY(hrs)= 164229.4 AVG.DELAY(mins)= 9.447
TOTAL VOL*KM= 573294. TTL TRVL*VOL= 179285. AVG.SPEED= 3.198
ENTERING VOL= 245769.

Simulation Output for Alt 1-2 (Route 1)

SIM102F --Summary of Total Delay

Items	Volume	Delay(mins)	Delay*vol(hrs)	Vol*KM(V.KM)	Travel(mins)	Vol*Trvl	Speed(km/hr)
INT. 1							
	31347	.00	0.	80027.		2097.	38.2
INT. 2							
	37317	.42	262.	52574.		1639.	32.1
INT. 3							
	37319	.00	0.	11557.		303.	38.1
INT. 4							
	37317	.04	25.	9951.		285.	34.9
INT. 5							
	48582	.02	14.	20879.		564.	37.0
INT. 6							
	40304	1.75	1175.	14101.		1546.	9.1
INT. 7							
	40181	1.07	718.	10045.		981.	10.2
INT. 8							
	77820	14.84	19246.	25288.		19912.	1.3
INT. 9							
	58305	1.50	1461.	12103.		1779.	6.8
INT. 10							
	50325	.89	750.	14794.		1140.	13.0
INT. 11							
	27723	.11	51.	6761.		229.	29.6
INT. 12							
	29182	.56	271.	5959.		426.	14.0
INT. 13							
	54028	7.50	6754.	14426.		7134.	2.0
INT. 14							
	38864	.65	424.	5969.		581.	10.3
INT. 15							
	66335	3.56	3939.	22045.		4519.	4.9
INT. 16							
	47091	3.96	3107.	20968.		3659.	5.7
INT. 17							
	47101	9.75	7657.	26847.		8363.	3.2
INT. 18							
	34139	.58	329.	15338.		731.	21.0
INT. 19							
	28550	.00	0.	6322.		166.	38.2
INT. 20							
	55321	1.53	1408.	21270.		1967.	10.8
INT. 21							
	57074	.10	99.	89694.		2455.	36.5
INT. 22							
	57052	.00	0.	144916.		3806.	38.1

TOTAL VOL(12hrs)=1001277. TOTAL DELAY(hrs)= 47691.0 AVG.DELAY(mins)= 2.858
TOTAL VOL*KM= 631835. TTL TRVL*VOL= 64279. AVG.SPEED= 9.830
ENTERING VOL= 237337.

Simulation Output for Alt 1-3 (Route 1)

SIM103F --Summary of Total Delay

Items	Volume	Delay(mins)	Delay*vol(hrs)	Vol*KM(V.KM)	Travel(mins)	Vol*Trvl	Speed(km/hr)
INT. 1	32689	.00	0.	84053.		2205.	38.1
INT. 2	38657	.41	262.	53177.		1654.	32.2
INT. 3	38658	.00	0.	11758.		308.	38.1
INT. 4	38656	.00	1.	20513.		538.	38.1
INT. 5	54781	.32	295.	22255.		880.	25.3
INT. 6	21765	.84	304.	6065.		463.	13.1
INT. 7	21766	.44	160.	5442.		302.	18.0
INT. 8	63212	.78	826.	22414.		1416.	15.8
INT. 9	40623	.33	221.	5821.		374.	15.6
INT. 10	59474	1.51	1497.	16208.		1924.	8.4
INT. 11	36337	.01	3.	8492.		225.	37.7
INT. 12	29651	.24	120.	10661.		399.	26.7
INT. 13	54497	6.97	6329.	14478.		6710.	2.2
INT. 14	39335	.62	405.	6016.		564.	10.7
INT. 15	66806	3.53	3933.	22139.		4516.	4.9
INT. 16	47405	3.94	3109.	21047.		3663.	5.7
INT. 17	47416	9.60	7587.	27052.		8299.	3.3
INT. 18	34409	.57	329.	15468.		735.	21.1
INT. 19	28665	.00	0.	6351.		166.	38.2
INT. 20	55385	1.53	1408.	21276.		1968.	10.8
INT. 21	57293	.10	99.	89803.		2459.	36.5
INT. 22	57275	.00	0.	145585.		3823.	38.1

TOTAL VOL(12hrs)= 964755. TOTAL DELAY(hrs)= 26889.7 AVG.DELAY(mins)= 1.672
TOTAL VOL*KM= 636074. TTL TRVL*VOL= 43590. AVG.SPEED= 14.592
ENTERING VOL= 238847.

Simulation Output for Alt 1-4 (Route 1)

SIM104F --Summary of Total Delay

Items	Volume	Delay(mins)	Delay*vol(hrs)	Vol*KM(V.KM)	Travel(mins)	Vol*Trvl	Speed(km/hr)
INT. 1	31917	.00	0.	81737.		2142.	38.2
INT. 2	37875	.42	262.	52825.		1644.	32.1
INT. 3	37875	.00	0.	11640.		305.	38.1
INT. 4	37872	.00	0.	10150.		263.	38.7
INT. 5	48804	.00	0.	20937.		549.	38.2
INT. 6	40970	.14	97.	14314.		472.	30.3
INT. 7	40845	.35	241.	10211.		507.	20.2
INT. 8	79188	14.25	18806.	25434.		19475.	1.3
INT. 9	57864	2.11	2035.	12037.		2352.	5.1
INT. 10	49999	1.73	1441.	14724.		1829.	8.1
INT. 11	27913	1.19	552.	6789.		731.	9.3
INT. 12	29666	.02	12.	6113.		168.	36.5
INT. 13	54552	6.22	5658.	14482.		6039.	2.4
INT. 14	39389	1.26	825.	6044.		984.	6.1
INT. 15	54139	1.15	1035.	15679.		1448.	10.8
INT. 16	47685	2.33	1852.	21349.		2413.	8.8
INT. 17	47683	4.62	3673.	27140.		4387.	6.2
INT. 18	34127	.09	52.	15333.		454.	33.8
INT. 19	28545	.00	0.	6321.		165.	38.4
INT. 20	55321	1.53	1408.	21270.		1967.	10.8
INT. 21	57067	.10	99.	89689.		2455.	36.5
INT. 22	57046	.00	0.	144898.		3806.	38.1

TOTAL VOL(12hrs)= 996342. TOTAL DELAY(hrs)= 38048.8 AVG.DELAY(mins)= 2.291
TOTAL VOL*KM= 629118. TTL TRVL*VOL= 54556. AVG.SPEED= 11.532
ENTERING VOL= 224132.

Simulation Output for Alt 1-5 (Route 1)

SIM105F --Summary of Total Delay

Items		Volume	Delay(mins)	Delay*vol(hrs)	Vol*KM(V.KM)	Travel(mins)	Vol*Trvl	Speed(km/hr)
INT.	1	32773	.00	0.	84305.		2212.	38.1
INT.	2	38730	.41	262.	53210.		1654.	32.2
INT.	3	38730	.00	0.	11768.		307.	38.3
INT.	4	38727	.00	1.	20605.		541.	38.1
INT.	5	54802	.33	297.	22260.		882.	25.2
INT.	6	21786	.84	306.	6071.		465.	13.1
INT.	7	21786	.44	161.	5447.		303.	18.0
INT.	8	63268	.79	833.	22420.		1423.	15.8
INT.	9	40678	.34	227.	5832.		381.	15.3
INT.	10	59544	1.55	1538.	16215.		1965.	8.3
INT.	11	36470	.01	4.	8519.		227.	37.5
INT.	12	29832	.00	0.	10681.		278.	38.5
INT.	13	54719	6.21	5661.	14500.		6042.	2.4
INT.	14	39556	1.26	828.	6060.		987.	6.1
INT.	15	54307	1.14	1034.	15713.		1447.	10.9
INT.	16	47812	2.32	1846.	21381.		2409.	8.9
INT.	17	47811	4.58	3648.	27224.		4364.	6.2
INT.	18	34239	.09	52.	15386.		456.	33.8
INT.	19	28592	.00	0.	6333.		165.	38.4
INT.	20	55350	1.53	1408.	21273.		1968.	10.8
INT.	21	57160	.10	99.	89735.		2457.	36.5
INT.	22	57143	.00	0.	145189.		3813.	38.1

TOTAL VOL(12hrs)= 953815. TOTAL DELAY(hrs)= 18206.7 AVG.DELAY(mins)= 1.145
TOTAL VOL*KM= 630126. TTL TRVL*VOL= 34748. AVG.SPEED= 18.134
ENTERING VOL= 225642.

Simulation Output for Alt 2-0
(Existing Conditions -Route 2)

SIM201E --Summary of Total Delay

Items	Volume	Delay(mins)	Delay*vol(hrs)	Vol*KM(V.KM)	Travel(mins)	Vol*Trvl	Speed(km/hr)
INT. 1							
	19563	.00	1.	18824.		496.	38.0
INT. 2							
	19560	.00	1.	15788.		415.	38.0
INT. 3							
	19556	.72	235.	9355.		479.	19.6
INT. 4							
	40985	6.15	4200.	14960.		4594.	3.3
INT. 5							
	22504	.11	42.	11490.		343.	33.5
INT. 6							
	22504	.00	0.	15154.		397.	38.2
INT. 7							
	18804	.00	0.	9033.		237.	38.2
INT. 8							
	32665	8.24	4484.	11435.		4785.	2.4
INT. 9							
	23716	1.77	701.	12333.		1024.	12.0
INT. 10							
	23697	.00	0.	23252.		609.	38.2

TOTAL VOL(12hrs)= 243554. TOTAL DELAY(hrs)= 9663.1 AVG.DELAY(mins)= 2.381
TOTAL VOL*KM= 141622. TTL TRVL*VOL= 13378. AVG.SPEED= 10.586
ENTERING VOL= 54907.

Simulation Output for Alt 2-1 (Do Nothing - Route 2)

SIM201F --Summary of Total Delay

Items	Volume	Delay(mins)	Delay*vol(hrs)	Vol*KM(V.KM)	Travel(mins)	Vol*Trvl	Speed(km/hr)
INT. 1							
	25717	.00	0.	62986.		1656.	38.0
INT. 2							
	25693	.00	0.	50125.		1317.	38.1
INT. 3							
	25687	.00	0.	12465.		325.	38.3
INT. 4							
	50837	9.89	8377.	18379.		8861.	2.1
INT. 5							
	28132	1.47	691.	14093.		1060.	13.3
INT. 6							
	42477	.44	311.	26116.		997.	26.2
INT. 7							
	21563	6.26	2250.	10304.		2521.	4.1
INT. 8							
	40179	18.32	12270.	14584.		12654.	1.2
INT. 9							
	27204	18.95	8592.	34329.		9493.	3.6
INT. 10							
	28369	.00	0.	73801.		1929.	38.3

TOTAL VOL(12hrs)= 315858. TOTAL DELAY(hrs)= 32490.8 AVG.DELAY(mins)= 6.172
TOTAL VOL*KM= 317181. TTL TRVL*VOL= 40812. AVG.SPEED= 7.772
ENTERING VOL= 87726.

Simulation Output for Alt 2-2 (Route 2)

SIM202F --Summary of Total Delay

Items	Volume	Delay(mins)	Delay*vol(hrs)	Vol*KM(V.KM)	Travel(mins)	Vol*Trvl	Speed(km/hr)
INT. 1							
	26595	.00	0.	65620.		1723.	38.1
INT. 2							
	26572	.00	0.	50723.		1334.	38.0
INT. 3							
	26567	.00	0.	13901.		362.	38.4
INT. 4							
	42404	.41	289.	16468.		721.	22.8
INT. 5							
	29522	.00	0.	16452.		429.	38.4
INT. 6							
	43910	.00	0.	27067.		707.	38.3
INT. 7							
	23356	.00	0.	11765.		306.	38.4
INT. 8							
	35062	1.94	1134.	13647.		1492.	9.1
INT. 9							
	29504	.10	49.	39631.		1090.	36.4
INT. 10							
	29433	.00	0.	76993.		2013.	38.2

TOTAL VOL(12hrs)= 312925. TOTAL DELAY(hrs)= 1471.9 AVG.DELAY(mins)= .282
TOTAL VOL*KM= 332266. TTL TRVL*VOL= 10177. AVG.SPEED= 32.650
ENTERING VOL= 87726.

Simulation Output for Alt 2-3 (Route 2)

SIM203F --Summary of Total Delay

Items	Volume	Delay(mins)	Delay*vol(hrs)	Vol*KM(V.KM)	Travel(mins)	Vol*Trvl	Speed(km/hr)
INT. 1	15898	.00	0.	40177.		1056.	38.1
INT. 2	15895	.01	3.	28137.		744.	37.8
INT. 3	15894	.00	0.	7180.		186.	38.7
INT. 4	42168	1.25	876.	16409.		1307.	12.6
INT. 5	18831	.39	123.	10335.		394.	26.2
INT. 6	33224	.00	0.	19463.		510.	38.1
INT. 7	12727	.00	0.	5710.		148.	38.5
INT. 8	33001	.41	225.	13132.		571.	23.0
INT. 9	18914	.00	0.	24424.		639.	38.2
INT. 10	18862	.00	0.	49382.		1292.	38.2

TOTAL VOL(12hrs)= 225414. TOTAL DELAY(hrs)= 1227.6 AVG.DELAY(mins)= .327
TOTAL VOL*KM= 214348. TTL TRVL*VOL= 6846. AVG.SPEED= 31.308
ENTERING VOL= 76976.

Simulation Output for Alt 2-4 (Route 2)

SIM204F --Summary of Total Delay

Items	Volume	Delay(mins)	Delay*vol(hrs)	Vol*KM(V.KM)	Travel(mins)	Vol*Trvl	Speed(km/hr)
INT. 1	15910	.00	0.	40213.		1057.	38.1
INT. 2	15910	.00	0.	28149.		739.	38.1
INT. 3	15908	.00	0.	8464.		221.	38.4
INT. 4	34312	.00	0.	14445.		378.	38.2
INT. 5	18808	.00	0.	11018.		289.	38.2
INT. 6	33202	.00	0.	19446.		509.	38.2
INT. 7	12704	.00	0.	6138.		160.	38.4
INT. 8	29374	.00	0.	12225.		320.	38.2
INT. 9	18887	.00	0.	24871.		653.	38.1
INT. 10	18836	.00	0.	49304.		1290.	38.2

TOTAL VOL(12hrs)= 213851. TOTAL DELAY(hrs)= .5 AVG.DELAY(mins)= .000
TOTAL VOL*KM= 214273. TTL TRVL*VOL= 5616. AVG.SPEED= 38.153
ENTERING VOL= 76976.

Simulation Output for Alt 3-O
(Existing Conditions -Route 3)

SIM301E --Summary of Total Delay

Items	Volume	Delay(mins)	Delay*vol(hrs)	Vol*KM(V.KM)	Travel(mins)	Vol*Trvl	Speed(km/hr)
INT. 1	26829	1.05	470.	25253.		1134.	22.3
INT. 2	26379	4.47	1965.	15455.		2371.	6.5
INT. 3	55154	4.47	4111.	20686.		4655.	4.4
INT. 4	27011	2.78	1249.	8633.		1477.	5.8
INT. 5	46620	3.98	3092.	25713.		3769.	6.8
INT. 6	46298	2.42	1866.	19761.		2384.	8.3
INT. 7	73584	11.56	14181.	21265.		14737.	1.4
INT. 8	64687	2.15	2320.	14969.		2714.	5.5
INT. 9	41480	2.10	1450.	9318.		1695.	5.5
INT. 10	41381	3.18	2194.	12274.		2517.	4.9
INT. 11	23883	2.84	1129.	5334.		1270.	4.2
INT. 12	45137	1.65	1243.	16026.		1665.	9.6
INT. 13	35810	3.19	1901.	9423.		2149.	4.4
INT. 14	25087	.00	0.	3897.		101.	38.5
INT. 15	25082	.00	0.	9135.		238.	38.4
INT. 16	25074	.00	0.	17912.		470.	38.1
INT. 17	25057	.00	0.	24739.		650.	38.0

TOTAL VOL(12hrs)= 654553. TOTAL DELAY(hrs)= 37171.0 AVG.DELAY(mins)= 3.407
TOTAL VOL*KM= 259792. TTL TRVL*VOL= 43995. AVG.SPEED= 5.905
ENTERING VOL= 143587.

Simulation Output for Alt 3-1 (Do Nothing - Route 3)

SIM301F --Summary of Total Delay

Items	Volume	Delay(mins)	Delay*vol(hrs)	Vol*KM(V.KM)	Travel(mins)	Vol*Trvl	Speed(km/hr)
INT. 1	33104	.00	0.	80140.		2103.	38.1
INT. 2	32182	18.17	9748.	57964.		11271.	5.1
INT. 3	71514	23.75	28306.	27550.		29031.	.9
INT. 4	31804	2.65	1406.	10034.		1670.	6.0
INT. 5	54708	11.56	10544.	29880.		11330.	2.6
INT. 6	54712	3.67	3349.	23849.		3976.	6.0
INT. 7	86733	15.78	22805.	25485.		23476.	1.1
INT. 8	76931	4.63	5937.	17719.		6403.	2.8
INT. 9	48981	.47	383.	11109.		671.	16.6
INT. 10	49121	.37	305.	10053.		569.	17.7
INT. 11	46043	.52	402.	10584.		680.	15.6
INT. 12	68571	15.31	17500.	21687.		18071.	1.2
INT. 13	59356	4.62	4573.	13302.		4921.	2.7
INT. 14	46632	1.55	1207.	8183.		1419.	5.8
INT. 15	46755	3.31	2582.	19005.		3079.	6.2
INT. 16	47030	18.33	14369.	77215.		16398.	4.7
INT. 17	35622	8.50	5044.	84321.		7253.	11.6

TOTAL VOL(12hrs)= 889799. TOTAL DELAY(hrs)= 128458.0 AVG.DELAY(mins)= 8.662
TOTAL VOL*KM= 528079. TTL TRVL*VOL= 142323. AVG.SPEED= 3.710
ENTERING VOL= 187976.

Simulation Output for Alt 3-2 (Route 3)

SIM302F --Summary of Total Delay

Items		Volume	Delay(mins)	Delay*vol(hrs)	Vol*KM(V.KM)	Travel(mins)	Vol*Trvl	Speed(km/hr)
INT.	1	35759	.00	0.	88105.		2311.	38.1
INT.	2	35775	.00	2.	61441.		1617.	38.0
INT.	3	51794	.13	114.	16539.		549.	30.2
INT.	4	36448	.17	101.	11682.		407.	28.7
INT.	5	63605	1.11	1179.	35081.		2100.	16.7
INT.	6	63606	1.12	1183.	33515.		2065.	16.2
INT.	7	66275	30.95	34191.	22888.		34793.	.7
INT.	8	55306	1.31	1203.	13647.		1562.	8.7
INT.	9	56367	.12	117.	18227.		591.	30.9
INT.	10	56529	.01	6.	11574.		308.	37.6
INT.	11	52941	.00	0.	20508.		530.	38.7
INT.	12	55359	.52	480.	19633.		995.	19.7
INT.	13	43596	.00	0.	11429.		298.	38.4
INT.	14	29868	.00	0.	4915.		125.	39.3
INT.	15	53489	.00	0.	26718.		694.	38.5
INT.	16	53496	1.16	1032.	88655.		3360.	26.4
INT.	17	38553	.00	0.	91376.		2395.	38.2

TOTAL VOL(12hrs)= 848766. TOTAL DELAY(hrs)= 39607.2 AVG.DELAY(mins)= 2.800

TOTAL VOL*KM= 575933. TTL TRVL*VOL= 54699. AVG.SPEED= 10.529

ENTERING VOL= 161443.

Simulation Output for Alt 3-3 (Route 3)

SIM303F --Summary of Total Delay

Items	Volume	Delay(mins)	Delay*vol(hrs)	Vol*KM(V.KM)	Travel(mins)	Vol*Trvl	Speed(km/hr)
INT. 1	35129	.00	0.	86215.		2262.	38.1
INT. 2	35149	.00	2.	61285.		1612.	38.0
INT. 3	50979	.22	184.	16335.		614.	26.6
INT. 4	35602	.78	462.	11357.		760.	14.9
INT. 5	62424	2.80	2913.	34321.		3816.	9.0
INT. 6	62428	2.15	2236.	32324.		3087.	10.5
INT. 7	63815	14.55	15477.	22042.		16057.	1.4
INT. 8	51317	1.75	1493.	13071.		1837.	7.1
INT. 9	51803	3.99	3444.	17377.		3899.	4.5
INT. 10	52008	1.07	927.	10639.		1205.	8.8
INT. 11	48400	1.25	1004.	11114.		1294.	8.6
INT. 12	70917	15.36	18160.	22237.		18745.	1.2
INT. 13	61079	4.33	4406.	13559.		4760.	2.8
INT. 14	48130	1.45	1162.	8476.		1383.	6.1
INT. 15	48252	3.08	2478.	19676.		2992.	6.6
INT. 16	48525	15.33	12394.	80062.		14497.	5.5
INT. 17	36811	3.57	2193.	87061.		4475.	19.5

TOTAL VOL(12hrs)= 862768. TOTAL DELAY(hrs)= 68935.8 AVG.DELAY(mins)= 4.794
TOTAL VOL*KM= 547151. TTL TRVL*VOL= 83296. AVG.SPEED= 6.569
ENTERING VOL= 161443.

Simulation Output for Alt 3-4 (Route 3)

SIM304F --Summary of Total Delay

Items	Volume	Delay(mins)	Delay*vol(hrs)	Vol*KM(V.KM)	Travel(mins)	Vol*Trvl	Speed(km/hr)
INT. 1	35773	.00	0.	88147.		2313.	38.1
INT. 2	35791	.00	2.	61445.		1617.	38.0
INT. 3	51812	.13	112.	16543.		546.	30.3
INT. 4	36466	.16	98.	11689.		403.	29.0
INT. 5	63658	1.12	1189.	35115.		2112.	16.6
INT. 6	63670	1.08	1141.	33478.		2022.	16.6
INT. 7	66485	30.49	33784.	22928.		34387.	.7
INT. 8	55478	1.20	1110.	13691.		1471.	9.3
INT. 9	56400	.13	118.	18234.		598.	30.5
INT. 10	56560	.12	114.	11581.		419.	27.6
INT. 11	52959	.33	294.	12198.		612.	19.9
INT. 12	78922	2.55	3357.	24768.		4009.	6.2
INT. 13	67178	.06	68.	14632.		451.	32.4
INT. 14	53354	.06	56.	9535.		303.	31.4
INT. 15	53357	.00	0.	22022.		570.	38.6
INT. 16	53364	1.16	1032.	88581.		3359.	26.4
INT. 17	38480	.00	0.	91157.		2389.	38.2

TOTAL VOL(12hrs)= 919707. TOTAL DELAY(hrs)= 42474.9 AVG.DELAY(mins)= 2.771
TOTAL VOL*KM= 575746. TTL TRVL*VOL= 57582. AVG.SPEED= 9.999
ENTERING VOL= 161443.

Simulation Output for Alt 4-1 (Do Nothing - Int. # 3)

SIM401F --Summary of Total Delay

Items	Volume	Delay(mins)	Delay*vol(hrs)	Vol*KM(V.KM)	Travel(mins)	Vol*Trvl	Speed(km/hr)
INT. 1							
app 1	0	.00	0.	0.	.00	0.	.0
app 2	14281	.00	0.	28562.	3.16	752.	38.0
app 3	0	.00	0.	0.	.00	0.	.0
app 4	15109	.00	0.	7555.	.78	197.	38.3
12 Hours Total	29390	.00	0.	36117.		949.	38.1
INT. 2							
app 1	0	.00	0.	0.	.00	0.	.0
app 2	14266	.00	0.	7133.	.79	187.	38.1
app 3	0	.00	0.	0.	.00	0.	.0
app 4	15127	.00	0.	3782.	.39	98.	38.6
12 Hours Total	29393	.00	0.	10915.		285.	38.3
INT. 3							
app 1	8785	.00	0.	4393.	.79	116.	38.0
app 2	14258	.00	0.	3565.	.39	92.	38.7
app 3	10440	.00	0.	5220.	.79	137.	38.0
app 4	16459	.00	0.	4115.	.39	107.	38.6
12 Hours Total	49942	.00	0.	17292.		452.	38.3
INT. 4							
app 1	0	.00	0.	0.	.00	0.	.0
app 2	17478	.00	0.	4370.	.38	111.	39.2
app 3	0	.00	0.	0.	.00	0.	.0
app 4	16469	.00	0.	8235.	.79	216.	38.1
12 Hours Total	33947	.00	0.	12604.		328.	38.5
INT. 5							
app 1	0	.00	0.	0.	.00	0.	.0
app 2	17459	.00	0.	8730.	.78	228.	38.3
app 3	0	.00	0.	0.	.00	0.	.0
app 4	16488	.00	0.	32976.	3.16	868.	38.0
12 Hours Total	33947	.00	0.	41706.		1096.	38.1

TOTAL VOL(12hrs)= 176619. TOTAL DELAY(hrs)= .0 AVG.DELAY(mins)= .000

TOTAL VOL*KM= 118633. TTL TRVL*VOL= 3109. AVG.SPEED= 38.159

TOTAL ENTERING VOL 49994.

Simulation Output for Alt 4-2 (Intersection # 3)

SIM402F --Summary of Total Delay

Items	Volume	Delay(mins)	Delay*vol(hrs)	Vol*KM(V.KM)	Travel(mins)	Vol*Trvl	Speed(km/hr)
INT. 1							
app 1	0	.00	0.	0.	.00	0.	.0
app 2	14281	.00	0.	28562.	3.16	752.	38.0
app 3	0	.00	0.	0.	.00	0.	.0
app 4	15109	.00	0.	7555.	.78	197.	38.3
12 Hours Total	29390	.00	0.	36117.		949.	38.1
INT. 2							
app 1	0	.00	0.	0.	.00	0.	.0
app 2	14266	.00	0.	7133.	.79	187.	38.1
app 3	9063	.00	0.	4532.	.78	118.	38.4
app 4	6063	.00	0.	1516.	.39	39.	38.5
12 Hours Total	29392	.00	0.	13180.		344.	38.3
INT. 3							
app 1	8785	.00	0.	4393.	.79	116.	38.0
app 2	5352	.00	0.	1338.	.39	35.	38.3
app 3	10440	.00	0.	5220.	.79	137.	38.0
app 4	7391	.00	0.	1848.	.39	47.	38.9
12 Hours Total	31968	.00	0.	12798.		335.	38.2
INT. 4							
app 1	8901	.00	0.	4451.	.79	117.	38.2
app 2	8576	.00	0.	2144.	.39	55.	38.7
app 3	0	.00	0.	0.	.00	0.	.0
app 4	16469	.00	0.	8235.	.79	216.	38.1
12 Hours Total	33946	.00	0.	14829.		388.	38.2
INT. 5							
app 1	0	.00	0.	0.	.00	0.	.0
app 2	17459	.00	0.	8730.	.78	228.	38.3
app 3	0	.00	0.	0.	:00	0.	.0
app 4	16488	.00	0.	32976.	3.16	868.	38.0
12 Hours Total	33947	.00	0.	41706.		1096.	38.1

TOTAL VOL(12hrs)= 158643. TOTAL DELAY(hrs)= .0 AVG.DELAY(mins)= .000
TOTAL VOL*KM= 118630. TTL TRVL*VOL= 3112. AVG.SPEED= 38.116
TOTAL ENTERING VOL 49994.

Int No.	Volume	Delay(mins)	Delay*vol(hrs)	Vol*KM(V.KM)	Travel(mins)	Vol*Trvl	Speed(km/hr)
Int 2- 4	8901	.00	0.	4451.	.79	117.	38.20
Int 4- 2	9063	.00	0.	4532.	.78	118.	38.42

CHAPTER 4
TRAFFIC SIGNALIZATION PROPOSALS

CHAPTER 4 TRAFFIC SIGNALIZATION PROPOSALS

4.1 Introduction

In many cities of the world, traffic signal control is widely used as a form of traffic management methods. In most large cities and metropolitan areas, advanced and sophisticated traffic control systems are further introduced. These systems are used to manage the complex traffic demand at intersections in highly trafficked areas in the cities through the use of host computers operating from traffic control centres.

The city of Calcutta is one of the major cities in India that faces increasing traffic demand and possible worsening of traffic congestion situations in the future. Traffic signal control is one of the necessary and essential traffic improvement measures to help alleviate this traffic congestion through the promotion of better and smoother traffic flows.

Judging from the capacity of the many intersections in the city and the present manual traffic control method, traffic flow at intersections and hence along major thoroughfares can be substantially improved by the use of signal control.

This technical paper discusses the present traffic signal control problems in Calcutta, the objectives and necessity of a signal control system for Calcutta and lastly a proposal and its related traffic engineering measures for the city of Calcutta.

4.2 Existing Conditions of Traffic Control at Intersections

4.2.1 Existing Traffic Signal Installation

The study team has conducted a site survey covering the entire area bounded by AJC Bose Road, APC Roy Road, and Circular Canal. The survey was conducted in December 1991.

The site survey was to identify the locations and status of existing signal equipment in the city. A signalization plan was in fact implemented in Calcutta under the World Bank Assistance in the early 1980s.

Within the area surveyed, 30 critical intersections were found to have traffic signal equipment. However, out of these 30 locations, signals at only 2 intersections were found to be functioning but are manually operated by traffic policemen. Signals equipment at the remaining 28 intersections were either not functioning or were vandalized. Most signals were found to have been installed at intersections along the major arterials. (Figure T-4.2.1)

The locations of these signals are:

	Locations		Number
a.	AJC Bose Road and APC Road intersections (between Khidirpur Rd and Canal River)	--	13
b.	Government Place West and intersections Government Place East	--	10
c.	Mahatma Gandhi Road intersections	--	2
d.	Park Street	--	1
e.	Other Intersections	--	2

The 2 functioning traffic signals were found at:

a. Intersection of Red Road/Govt.Place East/Guru Nanak Sarani,

b. Intersection of Khidirpur Road/Hospital Road.

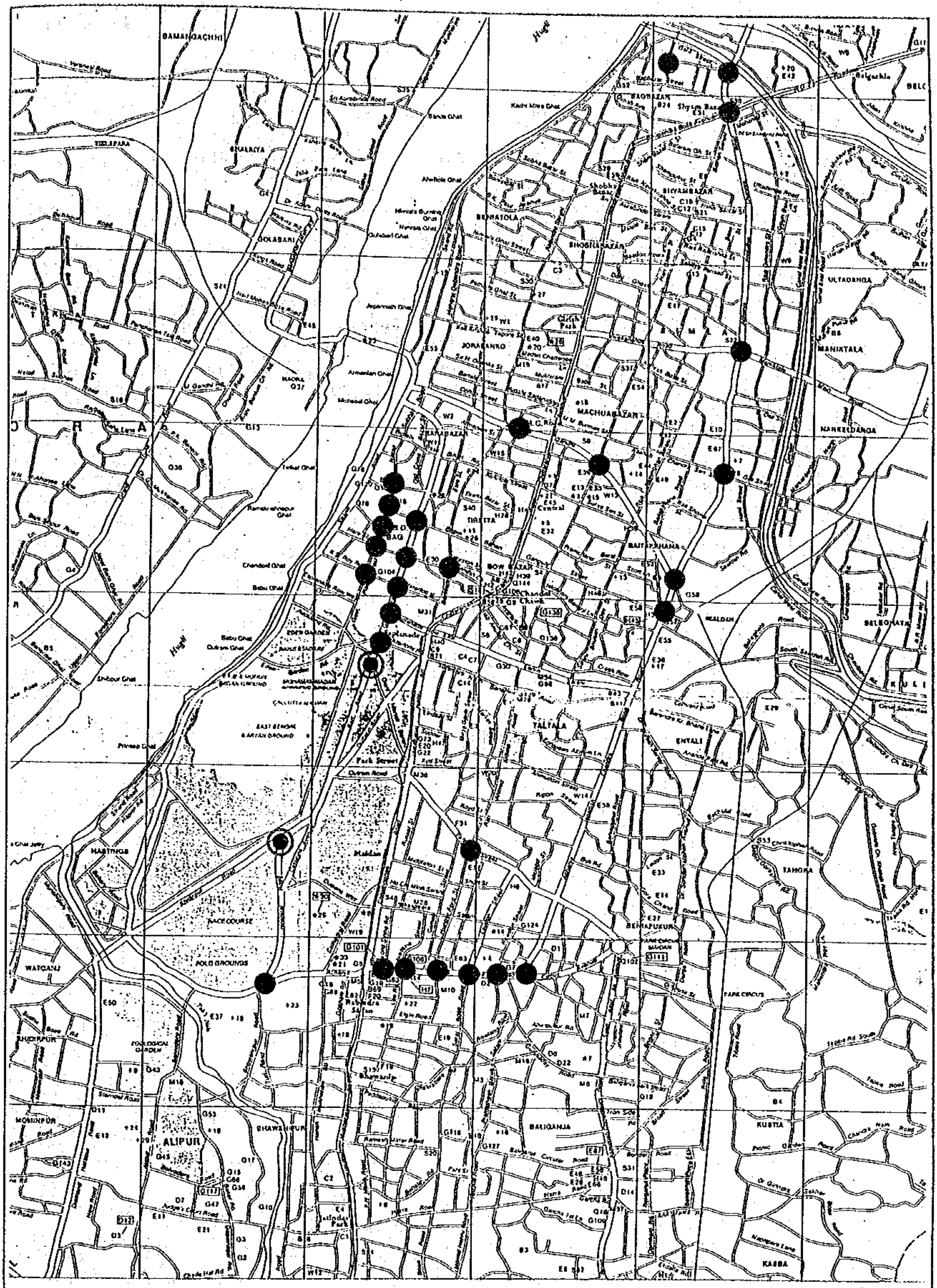


Figure T-4.2.1: Locations of Existing Signal Installations within The Survey Area

◉ Functional Signals (2 locations)

● Non-functional Signals (28 locations)

4.2.2 Manual Traffic Control by Police

During the site survey, the study team has also identify intersections where traffic is controlled by traffic policemen.

Figure T-4.2.2 shows the locations of the intersections with manual traffic control.

Manual traffic control by traffic policemen is observed at 122 intersections within the area surveyed. Policemen are stationed at these intersections from early morning until late night. This form of manual traffic control is applied both to intersections along arterials as well as other minor roads.

There are 97 intersections (including 27 intersections along arterials with non-functional signals) along arterials having manual traffic control. The location of these intersections are:

	Locations		Number
a.	AJC Bose Road and APC Road intersections	--	22
b.	Chowringhee Road to Bhupendra Bose Road intersections	--	22
c.	Government Place West, Government Place East, Bentick St. and Strand Road intersections	--	26
d.	Mahatma Gandhi Road intersections	--	9
e.	Lenin Sarani and SN Benerjee Road intersections (a pair of one way streets)	--	5
f.	Park St. and Shakespeare Sarani intersections(a pair of one way streets)	--	5
g.	KK Tagore St. and Vivekananda Road intersections	--	8

The other 25 intersections having manual traffic control by policemen are located at other minor streets.

The intersections along arterial road thus represent some 78% of the total intersections having manual traffic control by policemen within the area surveyed.

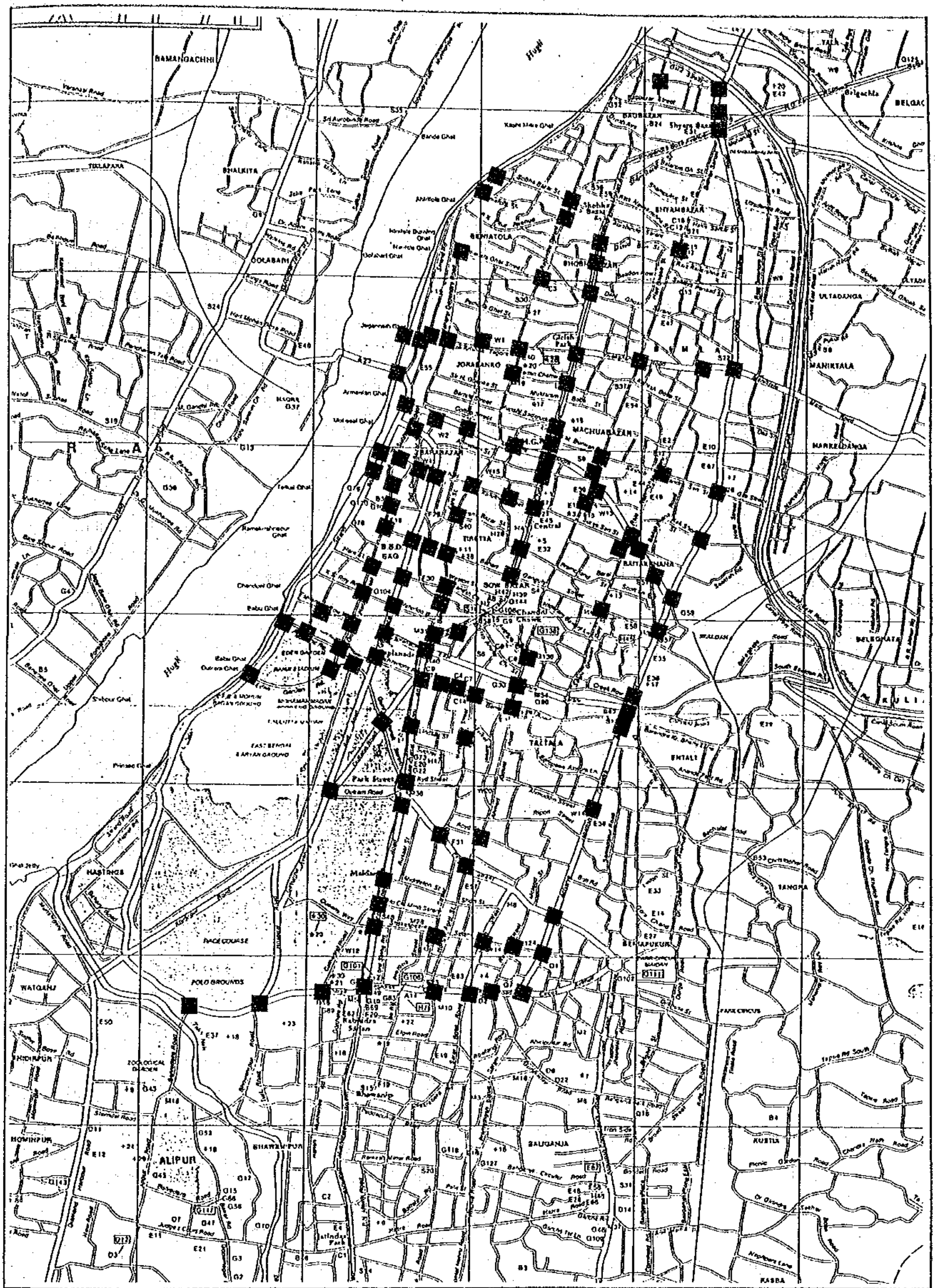


Figure T-4.2.2: Locations of Intersections with Manual Traffic Control by Policemen

4.3 Problems and Issues of present Method of Traffic Control in Calcutta

4.3.1 Existing Traffic Signals

From the survey, traffic signals at 28 major intersections are not functioning and some have also been broken. Signals at only 2 locations are functioning but even these are manually operated by traffic policemen.

According to information collected from the relevant department, the traffic signals installed some 10 years ago were fixed time, fixed pattern isolated control signals. Soon after their installation, they were found to be ineffective in managing the traffic flow in the city as demand fluctuates drastically and many intersections became over-saturated with traffic.

Judging from the location of these signals and the current traffic flow pattern, one can see that the number of signal equipment is grossly inadequate and they seemed to have not been installed based on a comprehensive study or survey. These equipment were installed along the major arterial of AJC Bose Road, M.Gandhi Road, Govt.Place East and Govt.Place West.

The number is too few for the signals to form a system whereby they can be coordinated to produce more effective control. The fixed time, fixed pattern type of rigid control is unsuitable for Calcutta.

The unsuitable operation algorithm and the inadequacy of signal equipment are the main reasons why the system is regarded as ineffective and efforts were not given to maintain and expand the system. Moreover, these installed signal equipment are also observed to have the following limitations:

(1) Poor visibility of signal lights

- signal location is inappropriate,
- signal height is too low,
- signal brightness is poor.

(2) Inadequate signal parameter timings,

- signals are non responsive to actual traffic demand

(3) Frequent interruption of power supply.

It is unfortunately that such an infrastructure investment has been left to deteriorate when the city is in urgent need of traffic control devices or measures.

4.3.2 Problems of Manual Traffic Control

(1) Traffic Policeman

Assuming that there are 3 policemen per intersection per shift, there are an estimated 720 policemen on duty per day just to control the traffic.

The traffic policemen face many kinds of problems in carrying out their duties in controlling the traffic at these intersections. Among them are:

a. The state of health of many policemen is adversely affected due to the fact that they have to work long hours at intersections which are locations with the worst level of air pollution from vehicle exhausts.

b. Due to the poor visibility especially during night time, traffic control policemen are constantly subjected to high chances of accident hazards.

c. It is difficult if not impossible to enforce traffic rules on errant drivers in the course of controlling traffic at intersections.

(2) Manual Traffic Control and Its Related Problems

a. For policeman to manually control the traffic efficiently at intersections, it is often necessary to limit the number of traffic movements by of implementing such measures as turning prohibition, one-way operation, etc. even though such measures may actually not needed from the view point of the intersection capacity.

   When this happens, the total travel time and vehicle trip distance in the road network would increase as turning vehicles have to make unnecessary detours. In addition, the resultant detour traffic would cause further congestion at other critical intersections.

b. The start-up time of traffic stream at manually control intersection is definitely longer. This is because the traffic policeman cannot possibly signal the 'stop' and 'go' signs simultaneously to the different traffic streams. Therefore this will result in lost time in the start-up of the traffic stream given the right of way at the intersection.

c. The policeman can only observe traffic situations within his range of vision. He cannot however obtain any information on traffic conditions of upstream or downstream intersections. This lack of information on traffic situations at adjoining intersections would render the control of traffic at the subject intersection inefficient and ineffective.

d. Cycle time practised by the policeman is usually longer than normal cycle time. This phenomenon is not confined to Calcutta but is also observed in many other cities such as Bangkok and Metro Manila which have manual traffic control practices (both cities have traffic signal lights and a sophisticated signal control system has just been introduced to Manila). This is a common human tendency.

This long cycle time is one of the causes of traffic congestion and excessive delays at intersections. At the intersection of Chowringhee Road/Park St./Guru Nanak Srn., for instance, the average cycle time is observed to be about 6 minutes. Normal signal cycle time even in large cities is usually about 2 minutes and rarely exceed a maximum of 3 minutes.

Delays caused by excessive long cycle time can be explained as below:

* With long cycle time, the right of way given to a traffic stream is not being used effectively. This is because traffic demand at an approach usually does not arrive continuously over the entire duration of a long right-of-way time.

  In the first half of the duration, traffic demand may arrive continuously and pass through the intersection. In the second half of the duration, usually only a few demand would arrive and pass through the intersection. If this latter half of the duration is assigned to other traffic streams which are waiting for their right-of-ways, the intersection can in fact process a larger volume of traffic flow.

  The rate of effective usage of the right-of-way of an approach is studied and illustrated in Figure T-4.3.1. The percentage of 10 seconds cycles having a rate of less than 6 vehicle/10 seconds to the total number of cycles observed is computed. It is found that more than 50 percent of the sampling cycles are not in the saturation flow condition. This is chiefly due to the fact that the approach is being influenced by downstream incidents such as bus stopping near the exits of the intersection, lane changing vehicles, poor channelization, etc.

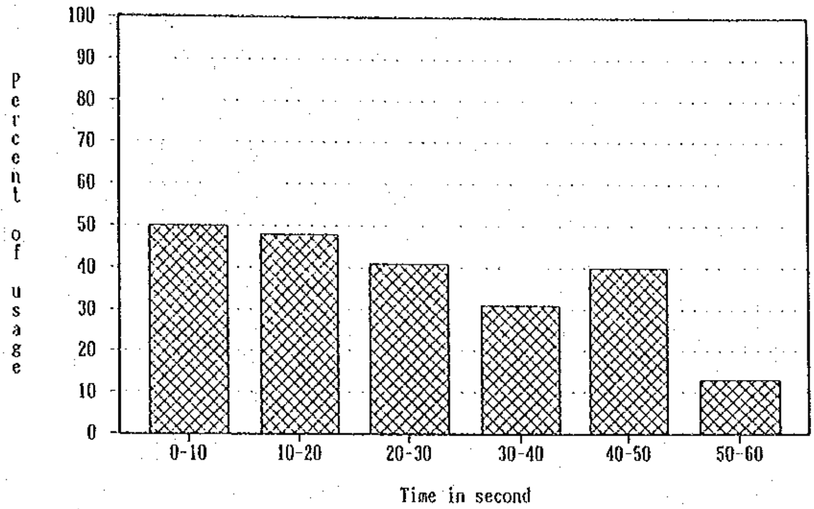


Figure T-4.3.1: Rate of Effective Usage of Right-of-Way Time at Intersection

* Due to the long duration of right-of-way time, the number of waiting vehicles at other approaches would increase rapidly. The queue lengths at these approaches are long and may even extend to the next intersection, causing block out effects of the traffic flow upstream.

* The large number of vehicles concentrated at the waiting approach would tend to rush out when its right-of-way is given. When the exits of this intersection cannot accommodate this sudden inundation within a short time period, the intersection may sometimes be totally blocked out or its capacity greatly reduced.

  The excessive long duration of right-of-way time often induces pedestrians to break traffic rule when crossing the road. Such behaviour is not only dangerous to the pedestrians themselves but it also reduces the traffic handling capacity of the road.

4.3.3 Inadequate Traffic Control Devices

Adequate installation of traffic control devices is one of the important requirements in managing high and complex urban traffic demand. Traffic control devices such as traffic signals, traffic signs, pavement markings, channelization is found to be inadequate in this city.

(1) Traffic Signal

Even though traffic signals were installed at critical intersections, most of them are not functional. Instead, policemen were stationed at the intersections to control the traffic. This manual traffic control practice is not effective as discussed above.

(2) Traffic Signs

Traffic signs in the city are poor. Regulatory signs such as turning prohibition signs are few. 'No Entry' signs for one-way streets are also not adequate in spite that such operation follows a time-of-day schedule which should be make known to the general road users.

(3) Pavement Markings

Pavement markings in the city are also not satisfactory. Vital markings such as stop lines at intersections, centre markings, lane markings at intersection approaches are largely not provided.

(4) Pedestrian Facilities

Pedestrian facilities such as pedestrian crossing markings and pedestrian signals are also not adequate.

(5) Channelization

Except for a few critical intersections, channelization facilities such as pavement markings and traffic islands are not installed at many of the intersections in Calcutta. The number of approach lanes at some intersections are also found to be more than the number of exit lanes. This creates traffic bottlenecks at the start of the exit points of these intersections.

4.3.4 Other Related Traffic Operation Problems

(1) Bus

Bus movements in the vicinity of intersections often impede smooth traffic flow at the traffic intersections.

a. Bus drivers have the habit of stopping at undesignated points, and particularly within the intersections for the loading and unloading of passengers. Intersections are in fact crowded with bus passengers waiting for their buses to come along instead of waiting at the designated stops.

b. Bus-stop capacity is grossly inadequate in coping with the large number of bus operations, frequency and bus passengers.

c. Many bus-stops are located too near to the intersections.

d. Many buses tend to converge at one stop simultaneously due to the long duration of right-of-way time at nearby intersections.

e. Bus passengers waiting for their buses at bus stops often overflowed to the road carriageway thus preventing the buses from approaching the curbs. Buses therefore tend to stop in the inner lane and thus blocking the passage of traffic stream behind.

(2) Parking

Stopping, waiting and parked vehicles near intersections are another cause of traffic congestion at many intersections in Calcutta.

At critical intersections, for instance, although the number of waiting or parking vehicles at the approaches is relatively small with the present prohibitions and enforcement, the number of such waiting and parking vehicles at the exits is observed to be relatively large. Such vehicles are the cause of blockages at the exits of the intersections and hence the reduction of intersection capacity.

(3) Surface Tram

Although the surface tram is an important mode of transport in the city, tram operation invariably decreases the traffic handling capacity at intersections. Trams are given priority in crossing the intersection.

On Lenin Sarani, for instance, the street is operated in one direction but the trams run both ways. As vehicles tend to drive even on the tram track, this can sometimes results in serious accidents.

(4) Drivers' Behaviour

Most drivers in Calcutta especially bus and taxi drivers are aggressive. They have the habit of trying to squeeze in between two waiting vehicles at intersection approaches, or to go ahead of them instead of waiting orderly within the traffic lane. Some drivers even drove on the opposite lane during congestion or when making a right turn. At times, they even attempt to make a left turn from the inner lane without queuing on the outer lane, thus blocking or endanger the through traffic. When the exit lanes are blocked at an intersection, drivers often enter the