5.4 Conclusion

Table 5.4.1 shows the implementation programme for the proposed TSM Plan by implementing body. Total implementation cost of the proposed TSM plan is about M$289 million. Based on financial analyses and an investigation on the financial capabilities of the implementing bodies, it is necessary to consider the following points:

(1) It is necessary to acquire federal funds or subsidies or even low-interest rate foreign loans secured through the Federal Government to finance the implementation of ATC System Expansion Plan. Total implementation cost of this plan is about M$54 million, of which the ATC system cost including intersection improvement cost is about M$37 million.

(2) It is necessary to acquire federal funds or subsidies for the Weld Quay Extension Project which costs M$60 million.

(3) It is necessary to begin as soon as possible the preparation work for the new CBD Bus Terminal such as determination of the implementing body, acquire the required land area and to seek long-term, low-interest loans for the project.

(4) The construction and management of a public parking building should be undertaken either by a public corporation or a private sector with special considerations given to the problem of high land cost in the CBD, such as leasing of public land to the project implementor.

(5) It is necessary to consider low-interest foreign loan for the purchase of new bus fleet and at the same time to conduct a study to formulate a Bus Transport Masterplan.

Table 5.4.1. : Implementation Cost for Proposed TSM Plan by Implementing Body

(Unit : M$ million)

Plan	Size	Unit	Implementation Body			
			MPPP	State	Public Corporation/ Others	Total
ATC System Expansion Plan						
System Cost	133 14 7	Signal Set Camera Sign Board	35.3	–	–	35.3
Intersection Improvement	133	Intersection	1.7	–	–	1.7
Operation Cost			6.5	–	–	6.5
Renewal Cost	65	Signal Set	10.0			10.0
Road Improvement Plan						
Construction Cost	25	km	72.2	121.7	–	193.9
Improvement Cost	1	km	1.0	–	–	1.0
Traffic Circulation System Improvement Plan						
System Modification/ Intersection Improvement Cost	16	Intersection	0.5	–	–	0.5
Bus Transport Improvement Cost						
CBD Bus Terminal	1	Building	–	–	7.4	7.4
Other Terminals/ Stops Improvement Cost	5 120	Lot Stop	–	–	1.7	1.7
Bus Fleet Improvement Cost	140	Bus	–	–	11.2	11.2
Bus Transport Study			–	1.0	–	1.0
Pedestrian Path Network Plan	10.8	km	3.8	–	–	3.8
Parking Plan						
Public Parking Building	5	Building	–	–	14.8	14.8
Total			131.0	122.7	35.1	288.8

Section B

Part I

Area Traffic Control (ATC) System Expansion Plan

PART I : AREA TRAFFIC CONTROL (ATC) SYSTEM EXPANSION PLAN

1.0 INTRODUCTION

1.1 General

This section describes an expansion plan for the computerized area traffic control system and its associated works. It also considers the first stage which has been implemented by the MPPP, and future road facilities as well as projected traffic conditions by the year 2000 in Penang Island.

The main principles of the expansion plan are:

(1) Required control functions of the system and its capabilities can be expanded by adding necessary equipment without explicit modifications.

(2) Finally, the comprehensive ATC system for the whole island and part of mainland will be developed effectively.

This section does not include a detail discussion on traffic surveillance and control system plan of the Penang Bridge, and the impending Coastal Road which will be constructed based on expressway standards to connect George Town, Bayan Lepas and the mainland. However, this system is of great importance.

1.2 Stage I ATC System

The outline of the ATC system in Penang for the first stage is as follows:

In 1983, the Majlis Perbandaran Pulau Pinang (MPPP) initiated plans to introduce a computerised area traffic control system in Penang.

The MPPP accepted the Stage I System Plan which was proposed in the report 'Basic Design for Area Traffic Control System in George Town, Penang' in April 1985.

In Stage I, the MPPP originally planned to carry out various traffic engineering and management works within the area bounded by Sungai Pinang Road – Perak Road – Anson Road, and the most significant arterial roads in George Town, namely Ayer Itam Road, Green Lane, Scotland Road and Western Road.

Initially, the major installations of Stage I include:

(1) Centralized signal system controlling thrity-seven for pedestrians are included.

(2) Closed Circuit Television (CCTV) System controlling four (4) cameras to be installed at key locations.

(3) Channelization and geometric improvements at major intersections.

(4) Lane markings and traffic signs.

However, implementation was reviewed and modified, and the scale of the system was reduced to suit budget allocations and the economic situation in Malaysia. Thus, the first stage system was divided into two portions : that is, the first portion under Stage I was completed by April 1987, and the last portion will begin in the near future.

For the revised Stage I ATC System, the number of intersections to be signalised by computer control was reduced from thirty-seven (37) intersections to sixteen (16) intersections, while the number of CCTV cameras and Monitor TV was reduced from four (4) to two (2). However, the functions of the ATC System and the centre equipment capacity remain the same as in the original Stage I system.

Thus, the following explanation of the ATC system is based on the revised Stage I system.

A. Traffic Signal System

The Stage I traffic signal system controls a total of sixteen (16) sets of signals, of which two (2) are for pedestrians. All the signals are located within the area bounded by Anson Road, Perak Road and Sungai Pinang Road.

The twelve (12) sets of signals are replaced by new signals and the remaining intersections are newly signalized during Stage I.

The Stage I traffic signal control system is centrally controlled from the Control Centre located at 13th floor, KOMTAR in Penang.

The signal system consists of the central computer system, local controllers, detectors, communication cables and other equipment.

The Stage I system diagram is presented in Figure 1.2.1.

The system is controlled by a micro-computer which has capability of operating up to sixty-four (64) sets of signals. If the micro-computer fails, then the local controller installed at each intersection provides a fail-safe mode operation.

Phase sequences are programmed and the controllers are pretimed type with phase skip capability and actuated operation are also performed through the central computer. In the Stage I system, nine (9) intersections are equipped with actuated purpose detectors.

Both solid state and micro-processor based local controllers are used in Stage I. Both controllers have capability of controlling from sixteen (16) to twenty-four (24) signal intervals (Step).

The signal timing is adjusted using data obtained from system detectors installed around critical intersections in the area. The detector types used in the Stage I system are magnetic loop type. A total of twenty-nine (29) detectors are installed.

The local controllers are connected to the Control Centre by Telecoms public cables and operated by the MPPP.

In the Control Centre, the wall map display indicates location, signal status and traffic congestion level.

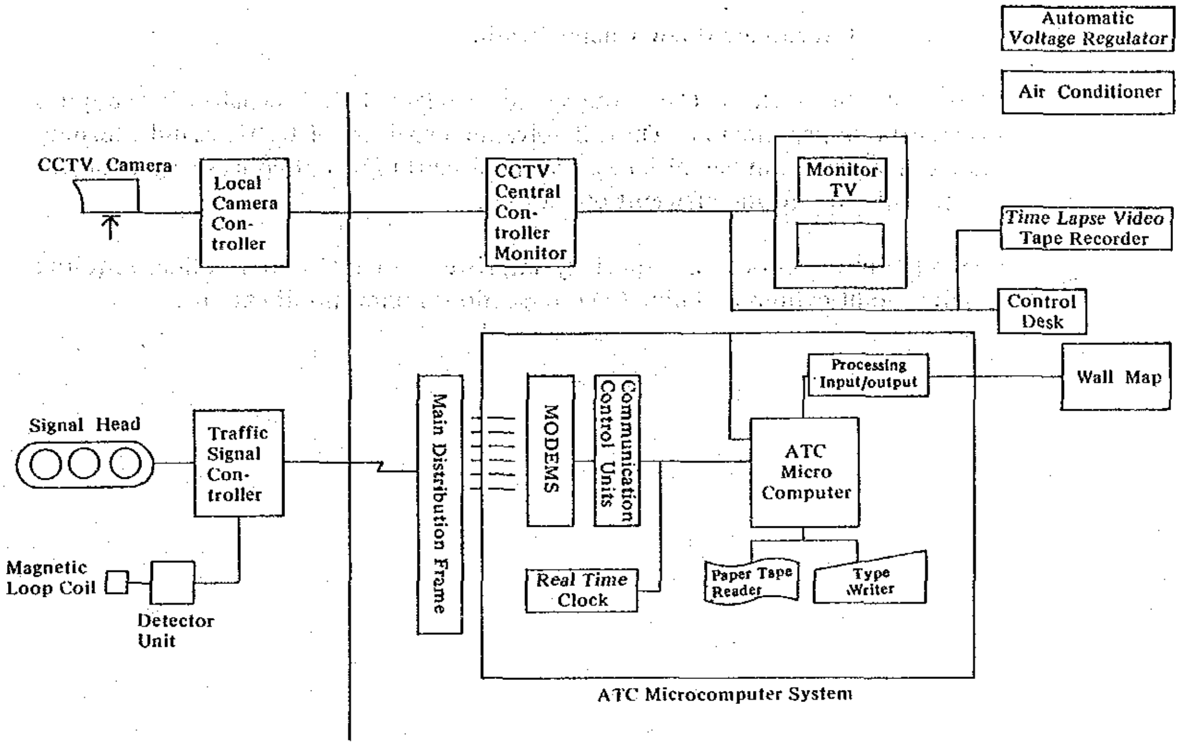

Figure 1.2.1 : Stage I ATC System Diagram

B. Closed Circuit Television System

The Stage I closed circuit television (CCTV) system consists of two cameras, two monitors and a control desk. Each camera is mounted on the top of a pole near a critical intersection so that traffic conditions can be observed. Each camera can be remote-controlled from the control desk at the control centre. Zooming, tilting and panning are possible. The CCTV system is capable of expanding to accommodate up to eight (8) cameras and eight (8) monitor TV's without major modification.

The video signals are transmitted to the control centre through coaxial cables, which connect these cameras, TV monitors and other necessary equipment.

In addition, a video-tape recorder is provided as an additional element to analyse the transient phenomena of traffic.

Locations where CCTV cameras are installed :

(1) Level 64, KOMTAR Tower

(2) Intersection of Dato Keramat Road, Perak Road and Ayer Itam Road.

C. **Geometric Improvement and Channelization**

Most of the sixteen (16) intersections selected for signalization require geometric improvements. These involve the provision of traffic islands, turning lanes, adequate number of lanes, and road markings that collectively or signly contribute to safe and efficient operations.

Two (2) intersections* are specially improved. Five (5) intersections required major modifications and nine (9) intersections minor modifications.

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* Intersections required special improvements are:
  (1) Intersection of Macalister Road and Anson Road
  (2) Intersection of Magazine Road and McNair Street

2.0 CONCEPTUAL AREA TRAFFIC CONTROL (ATC) SYSTEM PLAN

2.1 Necessity and Objective of an ATC System

2.1.1 Necessity of an ATC System

Signalization is one of the most effective ways to control traffic at intersections. However, an increase in the number of signalized intersections in a conventional way will entail the following problems :

(1) The short distance between signalized intersections necessitates well-coordinated operation in order to get effective performance.

(2) Field survey is the only way to get information concerning traffic conditions and signal controls in operation. It is difficult to get this information simultaneously over a wide area.

(3) Adjustment of control timings for signal control on-the-spot is very troublesome. So it is nearly impossible to maintain the optimum control timing constantly.

(4) Drivers cannot get information related to road and traffic conditions such as congested locations, accident locations and parking conditions at parking facilities while driving and also before a trip. So it is difficult for drivers to decide the route and time of a trip.

(5) Malfunction of a traffic signal controller, if it happens, produces a serious traffic problem. So it is important not only to introduce highly reliable controllers, but also to ensure efficient relaying of information regarding occurrence of malfunction as soon as possible.

The solution to the above problems lie in the introduction of centralized traffic control system, namely the Area Traffic Control (ATC) System.

2.1.2 Objectives of an ATC System

The objectives of an ATC System are :

(1) Alleviation of traffic congestion
(2) Reduction of traffic accidents
(3) Comprehensive interpretation of traffic conditions
(4) Conveying traffic related information to drivers
(5) Training

2.2 Functions of Comprehensive ATC System

In order to achieve the objectives of a comprehensive ATC System, the following main functions are included in the system :

(1) Traffic information gathering
(2) Traffic signal control
(3) Conveying information to drivers
(4) Statistical data collection

A concept of a multi-functional ATC System is shown in Figure 2.2.1. (However, it does not include freeway surveillance and control system)

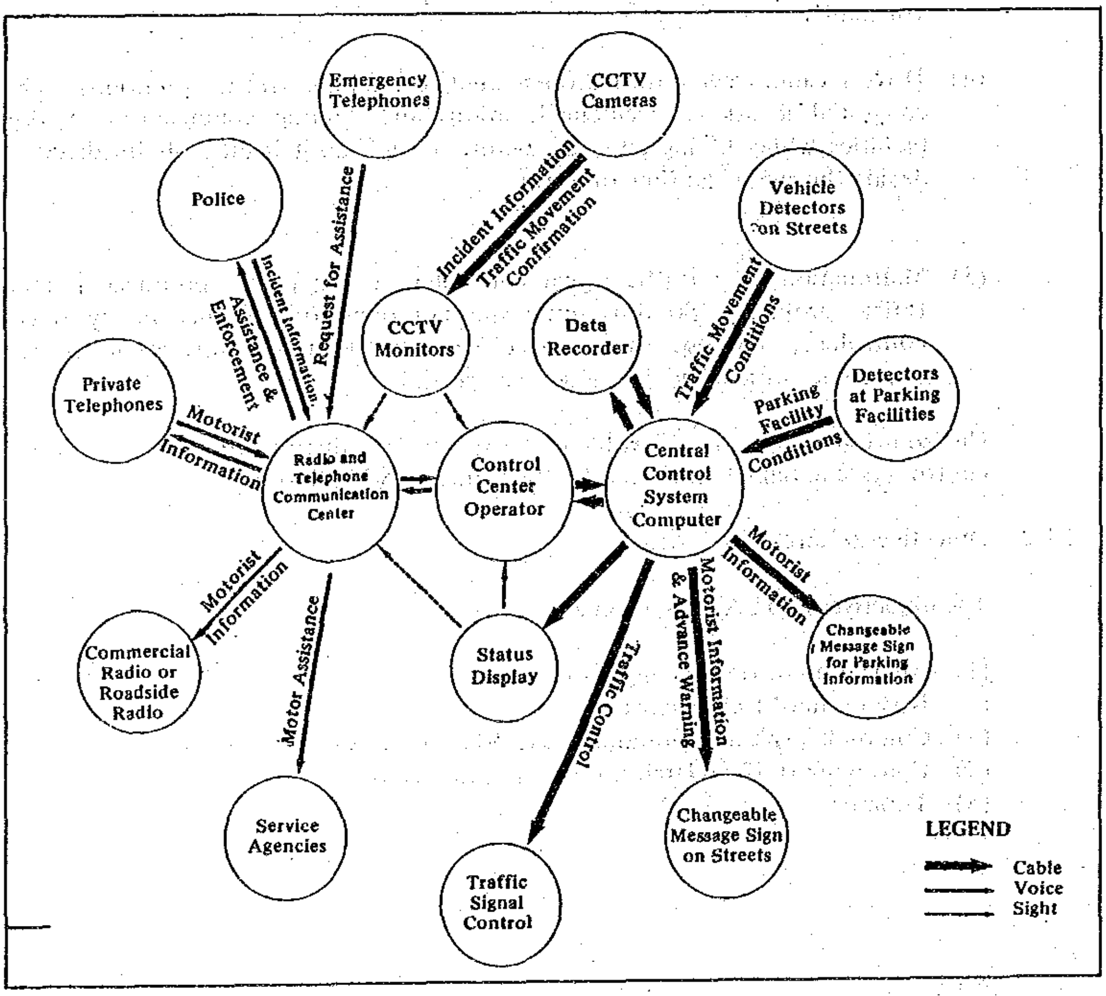

Figure 2.2.1 : A Concept of a Multi-functional ATC System

2.3 Perspective ATC System Plan

The future comprehensive ATC System is to be geared towards traffic surveillance and/or control, covering the Greater Metropolitan Area of George Town. Bayan Lepas, the Coastal Road, the Penang Bridge and furthermore Butterworth and Bukit Mertajam, even if traffic in these areas is managed and controlled by different traffic authorities. Of course, problems that involve overlapping of the concerns of the various authorities will occur when the ATC System is implemented and will have to be settled through by cooperation and sometimes, compromise.

It is especially, recommended that traffic flow between George Town and the Coastal Road, which are closely inter-related be managed and controlled by one traffic control authority with one particular policy and method. If this is not possible, then at least the various authorities should exchange traffic information with each other.

The Greater Metropolitan Area will be mainly divided into four areas as follows:

(1) George Town
(2) Bayan Lepas
(3) Coastal Road and Penang Bridge
(4) Butterworth and Bukit Mertajam

Figure 2.3.1 shows the ATC system perpective plan covering of an area stage by stage.

Covering of an area stage by stage by the ATC System has been planned as follows :

The period for implementation of each ATC System will depend on road and traffic conditions as well as the degree of necessity. The rough scheme for the introduction of the ATC System in each sub-area is :

Stage I	:	Central Area of George Town
Stages II & III	:	George Town
Stages II & IV	:	Bayan Lepas
Future Stages	:	Coastal Road and Penang Bridge as well as Butterworth and Bukit Mertajam

Stage I has been implemented by the MPPP. Stages II and III which will cover the entire city of George Town are to be carried out by the MPPP in the future. Similarly, Stages II and IV which will cover Bayan Lepas will be implemented by the MPPP in the future.

In the future stages, the ATC system for Penang will be connected to a expressway surveillance and control system for the Coastal Road and Penang Bridge. Alternatively the Penang System will include the expressway system. In addition, an ATC system for Butterworth and/or Bukit Mertajam will be connected to the ATC System of Penang to facilitate exchange of road and traffic-related information. It is expected that Majlis Perbandaran Seberang Perai (MPSP) will introduce an Area Traffic Control System to cope with traffic pressure in the areas of Butterworth and Bukit Mertajam.

Thus, the ATC System shall be capable of accommodating other systems such as the expressway surveillance and control system for Penang Bridge and Coastal Road, as well as Butterworth and Bukit Mertajam without major modification to the ATC System for Penang.

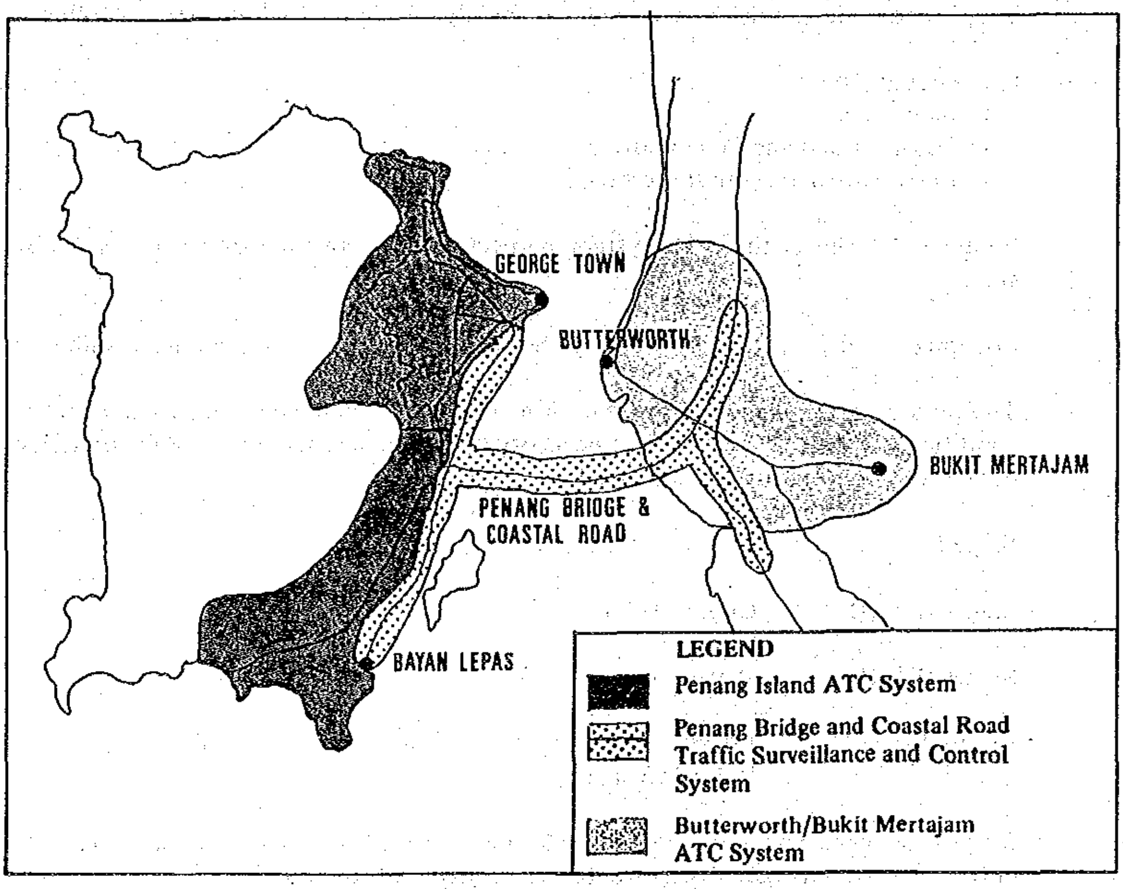

Figure 2.3.1 : ATC System Perspective Plan

3.0 COMPONENTS OF AREA TRAFFIC CONTROL (ATC) SYSTEM

3.1 Traffic Signal Control System

3.1.1 Conceptual Plan of Traffic Signal Control System

A. Concepts of Traffic Signal Control Plan

The area-wide traffic signal control system is the backbone of this comprehensive traffic control system in Penang. The ATC System aims at solving problems of existing signal control by centralizing the traffic signal controllers, systematizing necessary functions comprehensively and also operating traffic control with high reliability. Problems of existing signal control is given in Appendix A. Typical features of the ATC system are :

1. On-line Control

   Every terminal equipment is connected to the control centre by communication cable. All traffic related information is available in the control centre and each traffic signal controller is controlled directly from the centre.

2. Computer Control

   Using a computer provided with high speed operation and sophisticated software in the control centre, many complicated taks are performed in a short time.

3. Fail-safe operation

   If equipment fails, the system provides a fail-safe operation in which the minimum function will be performed.

Introducing on-line control using the computer would provide the following advantages :

(1) Traffic signal controllers are controlled by the computer in the control centre. Any co-ordination between intersections are available easily.

(2) Traffic-related information is gathered in the central computer, and is available any time for the traffic responsive control and monitoring of traffic condition.

(3) Control timing plans for the traffic signal control are stored in the central computer, and can easily be altered through man-machine interface in the control centre, if necessary.

(4) The central computer always checks every equipment in operation. A special circuit is also provided to detect the malfunction of the computer. If any malfunction occurs, an alarm is given in the control centre.

(5) If the computer fails, then the local controllers installed at each intersection provide a fail-safe mode operation.

B. Traffic Control Method of the ATC System

The Stage I system provides the following traffic signal control method.

1. Same Signal Cycle Time Operation within a Sub-area

Under computer control, all traffic signals always operate with same cycle time within a sub-area that has several signalized intersections.

2. Preparation of Control Parameter

A control parameter is a combination of a cycle time, split and offset. In the central computer, eight (8) sets of cycle time are prepared for each sub-area. Five (5) sets of split and eight (8) sets of offset are prepared for each intersection.

3. Control Parameter Selection

There are two ways to select the most suitable control parameter from prepared ones.

a. Automatic Selection

Every five (5) minutes the computer selects one control parameter according to the traffic data which are counted automatically. For this selection, the threshold values of traffic data and the corresponding parameter's number are prepared in the central computer.

b. Time-of-Day Selection

The automatic selection method has a tendency of delayed response. For morning, lunch time and evening peak hours, we can predict the accurate beginning time; the traffic condition repeats itself almost every week-day. In these cases, the time-of-day selection method acts effectively. The time-of-day selection schedule is also prepared in the central computer to avoid delay of response.

4. Vehicle-Actuated Control

At a signalized intersection, a vehicle-actuated control, which extends the end of a green time in every cycle by arrival of vehicles, is more effective in giving a better split time than the fixed method. To keep up a synchronized operation, a semi-actuated control method is provided. At an isolated intersection, however, a fully-actuated control method can be applied.

5. Status Change

The status change control method is to change the sequential display pattern of signal lights at a intersection. For example, the flashing operation at midnight and the cancellation of the special step (for example, the step dedicated to right turn) of the sequential display according to the traffic condition to reduce waste of time.

6. Manual Control

In anticipation of special circumstances like a traffic accident, manual control by a policeman is provided for.

These control functions have already been provided in Stage I, although on a small scale. These functions should remain. Other additional functions may not be necessary for the expansion of the traffic signal control system. Thus, the expansion plan is based on this consideration. However, it may be necessary to modify existing methods or introduce new ones to this system in the future, although it is at present the state-of-art and is highly-reliable compared to others.

3.1.2 Locations where Signalization will be Required

This section describes the candidate intersections to be controlled by centrally computerized signals in the future, based on 1986 traffic conditions. Furthermore, the locations and number of signalizations will be reconsidered, based on estimated data regarding signal effectiveness of future road and traffic situations for the year 2000.

A. Ranking of Intersection where Signalisation is Necessary

1. Candidate Intersection

   The candidate intersections for signalisation in George Town are shown in Figure 3.1.1. There are one hundred and nineteen (119) intersections including the existing forty (40) signalised intersections.

2. Signalisation

   a. Warrant Analysis

      In general, several warrants such as Minimum Vehicular Volume and etc.* can be used to evaluate the necessity for the installation of traffic signals at intersection.

      The warrants were developed in United States where the traffic conditions are different from that in Malaysia. As such, they are not appropriate to use in Penang, Malaysia. In Penang, there are distinct morning and evening peak hour traffic volumes on a typical road with the latter peak the highest. This results in the highest congestion degree (vehicles per lane) at the evening peak hour, if there is any.

      Thus, the most appropriate warrant for traffic signal installation in Penang is Peak-Hour Volume Warrant but with certain modification.

      In Peak-Hour Volume Warrant, the parameter used is vehicles per hour for a given combination of approach lanes. For traffic signal installation in Penang, the parameter is modified to vehicles per hour per lane. This conflict factor (CONF) is defined as follows :

$$CONF = \sum_{i}^{n} V_i / N_i$$

V_i : two directional traffic volume on approach i in the evening peak hour

N_i : number of lanes on the approach i

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* Kell, James H & Fullerton, Iris J. (1982). Manual of Traffic Signal Design. Institute of Transportation Engineers. Washington, D.C.

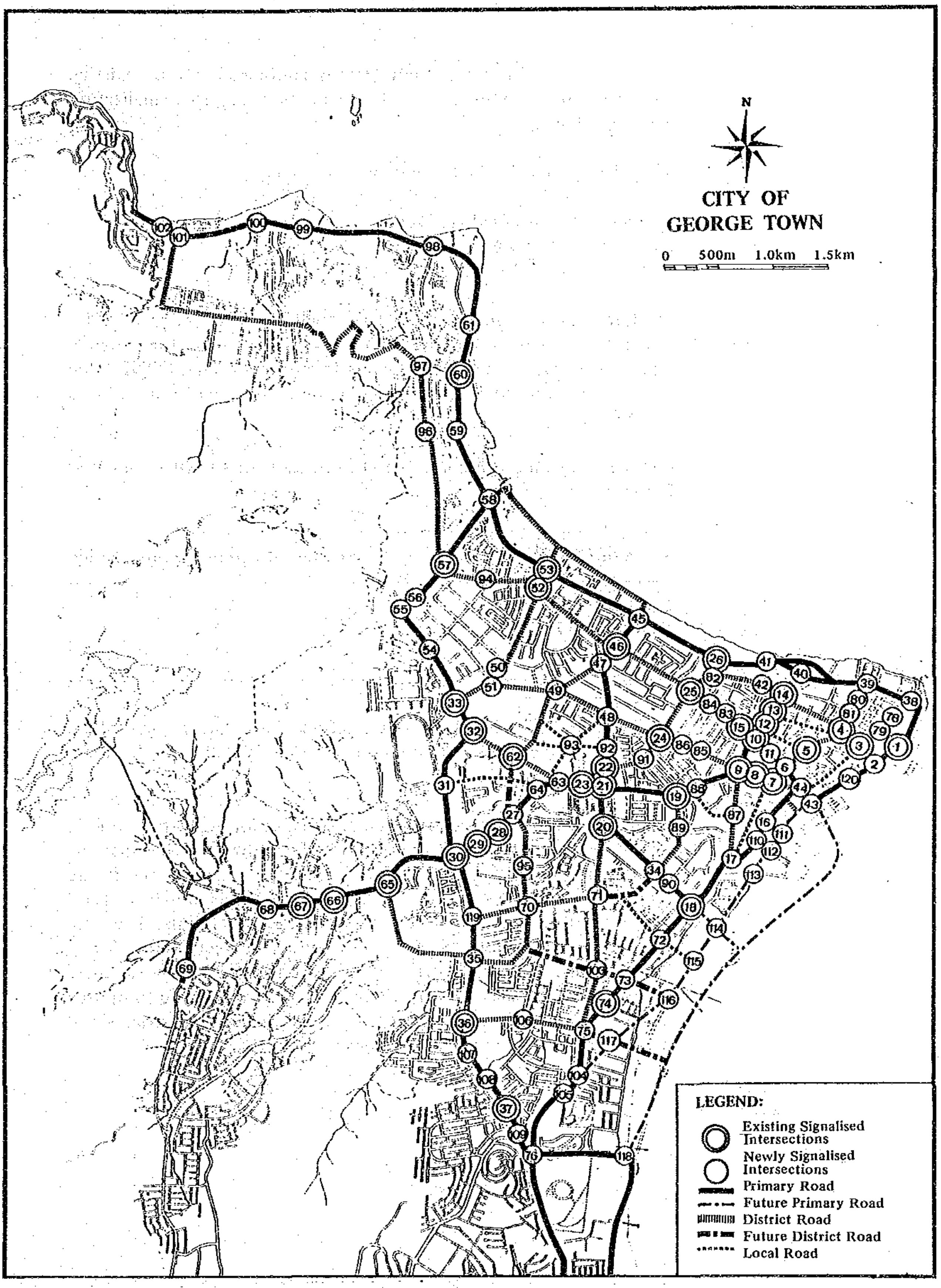


Figure 3.1.1 : Intersections for Signalisation in George Town

Table 3.11 shows the present (1986) conflict factor of existing signalised intersections and candidate intersections for signalization in George Town.

For existing signalized intersections:

Smallest value of CONF = 1007
Largest value of CONF = 3056
Mean value of CONF = 1695

Existing signalized intersection have smallest CONF value of 1007 and mean CONF value of 1695. Compared with the existing signalized intersections, if the candidate intersection has CONF value of 1007 or more, then signalization at that particular intersection is warranted.

For candidate intersections, the classification of CONF values is as follows:

Value of CONF	Number of candidate intersection
1300 or more	20
1000 – 1299	17
less than 1000	42

Thirty-seven (37) candidate intersections have larger values than some existing signalised intersections. Thus, signalisation at these intersections is warranted.

Based on the present traffic volume, signalisation at forty-two (42) candidate intersections is not warranted. However, this may be changed in the future as illustrated in Table 3.1.2 where the future (2000) CONF values of the candidate intersections are above 1000 except at two candidate intersections in George Town. They are Beach Street/Church Street and Beach Street/China Street intersections. Low CONF values is estimated at both these intersections because Beach Street forms part of the proposed pedestrian network in George Town. Nevertheless, pedestrian signal may be required at both intersections in the future.

Table 3.1.1(1) : Present (1986) Traffic Signal Installation Ranking In George Town

Intersection		Existing Traffic Signal (E)	Traffic Volume (V) & Number of Lanes (N)								Surveyed ** Estimated * Traffic Volume	Conflict Factor (CONF) Vi/Ni	Ranking	Accident	
No.	Name		V1	N1	V1	N2	V3	N3	V4	N4				No. of Accidents	No. of Accidents per Km
1	Weld Quay/Ferry Terminal	E1	2026	4	1000	2					*	1007			175.7
3	Beach St/Chulia St Ghaut	E2	1998	2	680	1	622	1			**	2301		11	
4	Pitt St/Chulia St Ghaut	E3	1632	2	2101	2					**	1867		9	
5	CarnarvonSt/Kimberly St	E4	3400	4	200	1					*	1050			250
7	McNair St/Magazine Rd	E5	1316	2	280	2	483	2			**	1040		5	
8	Ria Rd/Magazine Rd	E6	2357	4	2102	4					**	1115		9	
9	Magazine Intersection	E7	1378	3	964	1	4362	4			**	2514		18	
10	Prangin Rd/Penang Rd/Burma Rd	E8	2871	4	2863	4					**	1434		17	
12	Penang Rd/Kimberly St/Phee Choon St	E9	2293	3	590	2	145	1			**	1204		5	
13	Penang Rd/Hutton Lane/Campbell St	E10	2277	3	226	1	302	1			**	1287		9	
14	Penang Rd/Chulia St/Argyll Rd	E11	874	3	1319	2	1163	1			**	2114		14	
15	Transfer Rd/Burma Rd	E12	1005	2	2695	3					**	1401		5	
16	Bridge St/Macallum St/Macallum St Ght	E13	2119	2	351	2	278	1			**	1513		5	
17	Bridge St/Brick Kiln Rd/Jelutong Rd	E14	3603	2	1235	1					**	3037		8	
18	Sg. Pinang Rd/Jelutong Rd	E15	4031	2	701	1					**	2717		16	
19	Dato Keramat Rd/Patani Rd/Siam Rd	E16	992	2	3403	4					**	1347		9	
20	Perak Rd/Sg. Pinang Rd	E17	2877	2	612	1	1005	1			**	3056		14	
21	Perak Rd/Dato Keramat Rd	E18	2764	2	3493	4					**	2255		34	
22	Perak Rd/Anson Rd	E19	2882	2	1204	2					**	2043		14	
23	Dato Keramat Rd	E20	3350	4	200	1					*	1038			205
24	Anson Rd/Macalister Rd	E21	2101	2	1977	2					**	2039		19	
25	Burma Rd/Larut Rd/Anson Rd	E22	1864	2	2054	2					**	1959		14	
26	Larut Rd/Northam Rd	E23	2242	2	337	1					**	1458		6	
28	Ayer Itam Rd/Kampar Rd	E24	3300	4	200	1					*	1025			101.3
29	Ayer Itam Rd/Old Ayer Itam Rd	E25	3300	4	200	1					*	1025			101.3
30	Ayer Itam Rd/Green Lane/Scotland Rd	E26	3400	4	1050	2					*	1375		44	
32	Scotland Rd/Western Rd/Sepoy Lines	E27	2731	2	2227	2					**	2479		23	
33	Western Rd/Macalister Rd/Brook Rd	E28	2189	2	632	2					**	1411		9	
36	Green Lane/Batu Lanchang Rd	E29	3723	4	670	1					**	1601		12	
37	Green Lane/Jln Delima	E30	3723	4	1091	1					*	2022		15	
46	Pangkor Rd/Burma Rd	E31	1347	2	1593	2					**	1470		10	
52	Burma Rd/Cantonment Rd	E32	722	2	1539	2					**	1131		7	
53	Kelawei Rd/Cantonment Rd	E33	1983	2	275	2					**	1129		25	
57	Burma Rd/Gottlieb Rd/Bayan Jermal Rd	E34	1463	2	1303	2					**	1383		28	
60	Tg. Tokong Rd/Fettes Rd	E35	1700	2	800	2					*	1250		6	
62	Western Rd/Ross Rd/Residency Rd	E36	900	2	600	1	300	1			*	1350			59.6
65	Ayer Itam Rd/Batu Lanchang Lane	E37	3765	2	245	1					**	2128		15	
66	Thean Teik Rd/Ayer Itam Rd	E38	3976	2	310	1					**	2298		12	
67	Boundary Rd/Ayer Itam Rd	E39	3063	2	492	2					*	1778		8	
74	Jelutong Rd/Perak Close/Jln Tengku	E40	3500	2	400	1					*	2150			120
	Mean Value of CONF											1695			

Table 3.1.1(2) : Present (1986) Traffic Signal Installation Ranking In George Town

Intersection		Existing Traffic Signal	Traffic Volume (V) & Number of Lanes (N)								Surveyed ** Estimated * Traffic Volume	Conflict Factor (CONF)	Ranking	Accident	
No.	Name	(E)	V1	N1	V1	N2	V3	N3	V4	N4		Vi/Ni		No. of Accidents	No. of Accidents per Km
6	Carnarvon Circus		1741	2	446	1	1482	1	315	1	**	3114	1	15	
39	Pitt St/Light St		1200	1	1000	2	1200	2			*	2300	2	6	
72	Jelutong Rd/Perak Lane		4023	2	215	1					**	2227	3	16	
75	Jelutong Rd/Perak Rd/Batu Lanchang Rd		3137	2	498	1					**	2067	4	14	
27	Ayer Itam Rd/Trengganu Rd		3200	2	350	1					*	1950	5	14	
64	York Rd/Ayer Itam Rd		3363	4	1106	1					**	1947	6	11	
73	Jelutong Rd/Van Praagh Rd		3650	2	100	1					*	1925	7		147
34	Sg. Pinang Rd/Patani Rd		2312	2	676	1					**	1832	8	5	
2	Weld Quay/Chulia St Ghaut		2026	2	1140	2					**	1583	9	14	
68	Zoo Rd/Ayer Itam Rd		2800	2	100	1					*	1500	10		147
47	Pangkor Rd/Perak Rd/Peel Avenue		714	2	633	2	1593	2			*	1470	11	12	
11	Prangin Rd/Ria Rd/Sg. Ujong Rd		3709	4	534	1					**	1461	12	5	
45	Northam Rd/Pangkor Rd		2294	2	512	2					**	1403	13	19	
35	Green Lane/Batu Lanchang Lane/Hamilton Rd		3322	4	1118	2					**	1390	14	10	
119	Green Lane/Free School Rd		2678	4	687	1					**	1357	15	11	
40	Penang Rd/Farquhar St		2500	2	100	1					*	1350	16	5	
31	Scotland Rd/York Rd/Batu Gantong Rd		3128	4	1050	2					**	1307	17	11	
43	Weld Quay/North Coastal Rd		2000	2	600	2					*	1300	18	5	
55	Western Rd/Gottlieb Rd		1600	2	1000	2					*	1300	19	5	
56	Ayer Rajah Rd/Gottlieb Rd		1600	2	1000	2					*	1300	20		98
70	Free Sch. Rd/Trengganu Rd/Hamilton Rd		1100	2	1400	2					*	1250	21		44
41	Northam Rd/Transfer Rd		2242	2	250	2					*	1246	22	10	
42	Transfer Rd/Argyll Rd		2242	2	250	2					*	1246	23	5	
63	Western Rd/Dato Keramat Rd		3365	4	800	2					*	1241	24	5	
48	Perak Rd/Macalister Rd/Barrack Rd		1151	2	1257	2					**	1204	25	14	
110	Bridge St/Cecil St/Cecil St Ghaut		2200	2	200	2					*	1200	26		100
103	Perak Rd/Van Praagh Rd		2000	2	100	1					*	1100	27		69
82	Larut Rd/Hutton Lane/Argyll Rd		1800	2	400	2					*	1100	28		41.6
59	Tg. Tokong Rd/Hock Lim Terrace		1700	2	500	2					*	1100	29	5	
71	Free Sch. Rd/Perak Rd/Perak Lane		2000	2	100	1					*	1100	30	5	
58	Tg. Tokong Rd/Bagan Jermal Rd		501	2	1606	2					**	1054	31	18	
91	Anson Rd/Siam Rd		1500	2	600	2					*	1050	32	5	
51	Macalister Rd/Cantonment Rd		1000	2	700	2	400	2			*	1050	33	5	
50	Ayer Rajah Rd/Cantonment Rd		1000	2	700	2	400	2			*	1050	34		33.9
54	Western Rd/Brown Rd		1700	2	200	1					*	1050	35		56
69	Paya Terubung Rd/Kg. Pisang Rd		1400	2	600	2					**	1000	36	5	
88	Kampung Jawa Baru/Dato Keramat Rd		3100	4	450	2					*	1000	37		258.3

Table 3.1.1(3) : Present (1986) Traffic Signal Installation Ranking In George Town

Intersection		Existing Traffic Signal (E)	Traffic Volume (V) & Number of Lanes (N)								Surveyed ** Estimated * Traffic Volume	Conflict Factor (CONF) Vi/Ni	Ranking	Accident	
No.	Name		V1	N1	V1	N2	V3	N3	V4	N4				No. of Accidents	No. of Accidents per Km
83	Burma Rd/Jln Zainal Abidin		1700	2	100	1					*	950	38		275
84	Rangoon Rd/Burma Rd		1700	2	100	1					*	950	39		200
85	Macalister Rd/Jln Zainal Abidin		1700	2	100	1					*	950	40	5	
86	Macalister Rd/Rangoon Rd		1700	2	100	1					*	950	41		262.5
107	Green Lane/Jln Tembaga		3000	4	200	1					*	950	42		137
108	Green Lane/Batu Lanchang Avenue		3000	4	200	1					*	950	43		137
109	Green Lane/Yeap Chor Ee Rd		3000	4	200	1					*	950	44		104
76	Gelugor Rd/Green Lane/Udini Rd		3224	4	123	1					**	929	45	33	
49	Macalister Rd/Peel Avenue/Residency Rd		1100	2	700	2					*	900	46	21	
87	Brick Kiln Rd/Macallum St		1150	2	300	1					*	875	47		126
90	Sg. Pinang Rd/River Rd		1300	2	400	2					*	850	48	5	
61	Tg. Tokong Rd/old Tg. Tokong Rd		1500	2	100	1					*	850	49	5	
44	Prangin St Ghaut/Beach St/Bridge St		1300	2	330	2					*	815	50	5	
104	Jelutong Rd/Jelutong Avenue		2800	4	100	1					*	800	51	9	
105	Gelugor Rd/Gelugor Avenue		2800	4	100	1					*	800	52		37
80	Pitt St/Church St		1400	2	100	1					*	800	53		94
81	Pitt St/China St		1400	2	100	1					*	800	54		94
78	Beach St/Church St/Church St Ghaut		1400	2	100	1					*	800	55		103.1
79	Beach St/China St/China St Ghaut		1400	2	100	1					*	800	56		103.1
95	Trengganu Rd/Caunter Hall Rd		1400	2	100	1					*	800	57		64.5
38	Beach St/Light St/King Edward Place		1266	2	330	2					**	798	58	7	
94	Burma Rd/Brown Rd		1300	2	100	1					*	750	59		77.1
98	Tg. Tokong Rd/Jln Gajah		1200	2	100	1					*	700	60	5	
96	Mount Erskine Rd/Hock Hin Terrace		1200	2	100	1					*	700	61		36.5
97	Mount Erskine Rd/Fettes Rd		1200	2	100	1					*	700	62		36.5
99	Jln Tg. Bungah/Jln Bunga Pudak		1100	2	100	1					*	650	63	5	
89	Patani Rd/Lines Rd		1100	2	100	1					*	650	64		69
100	Tg. Bungah Rd/Cheah Beng Kim Rd		1000	2	100	1					*	600	65	5	
101	Tg. Bungah Rd/Vale of Tempe Rd		950	2	100	1					*	575	66	5	
102	Tg. Bungah Rd/Chan Siew Teong Rd		950	2	100	1					*	575	67		164
93	Barrack Rd/Tull Rd/Lim Khoon Huat Rd		600	2	500	2					*	550	68		24.6
92	Perak Rd/Lim Khoon Huat Rd		800	2	100	1					*	500	69		60
106	Batu Lanchang Rd/Jln Sir Ibrahim		700	2	100	1					*	450	70		69.6
111	Macallum St Ghaut/Weld Quah Extension														
112	Cecil St Ghaut/Weld Quah (Bunn Rd)														
113	Sandilands St Ghaut/Weld Quay Extension														
114	Sg. Pinang Rd/Weld Quah Extension														
115	Perak Lane/Weld Quay Extension														
116	Van Praagh Rd/Weld Quay Extension														
117	Batu Lanchang Rd/Weld Quah Extension														
118	Udini Rd/Weld Quay Extension														
120	Weld Quay/Lebuh Acheh														

Table 3.1.2(1) : Future (2000) Traffic Signal Installation Ranking In George Town

Intersection		Existing Traffic Signal (E)	Traffic Volume (V) & Number of Lanes (N)								Surveyed ** Estimated * Traffic Volume	Conflict Factor (CONF) Vi/Ni	Ranking	Accident	
No.	Name		V1	N1	V1	N2	V3	N3	V4	N4				No. of Accidents	No. of Accidents per Km
1	Weld Quay/Ferry Terminal	E1	3915	4	1950	2					*	1954			175.7
3	Beach St/Chulia St Ghaut	E2	5160	2	2895	1	608	1			*	6083		11	
4	Pitt St/Chulia St Ghaut	E3	6675	2	5160	2					*	5918		9	
5	Carnarvon St/Kimberly St	E4	6765	4	200	1					*	1891			250
7	McNair St/Magazine Rd	E5	5715	2	3915	2					*	4815		5	
8	Ria Rd/Magazine Rd	E6	9960	4	8880	4					*	4710		9	
9	Magazine Intersection	E7	8685	3	4590	1	9960	4			*	9975		18	
10	Prangin Rd/Penang Rd/Burma Rd	E8	8370	4	7065	4					*	3859		17	
12	Penang Rd/Kimberly St/Phee Choon St	E9	3915	3	1005	2	248	1			*	2055		5	
13	Penang Rd/Hutton Lane/Campbell St	E10	3915	3	390	1	521	1			*	2216		9	
14	Penang Rd/Chulia St/Argyll Rd	E11	1223	3	4215	2	1365	1			*	3880		14	
15	Transfer Rd/Burma Rd	E12	2820	2	4515	3					*	2915		5	
16	Bridge St/Macallum St/Macallum St Ght	E13	3855	2	638	2	506	1			*	2752		5	
17	Bridge St/Brick Kiln Rd/Jelutong Rd	E14	3904	2	2685	2					*	3295		8	
18	Sg. Pinang Rd/Jelutong Rd	E15	5910	2	8835	2					*	7373		16	
19	Dato Keramat Rd/Patani Rd/Siam Rd	E16	2715	2	8685	4					*	3529		9	
20	Perak Rd/Sg. Pinang Rd	E17	9465	4	2610	2	5295	2			*	6319		14	
21	Perak Rd/Dato Keramat Rd	E18	10455	4	10815	4					*	5318		34	
22	Perak Rd/Anson Rd	E19	10815	4	5025	4					*	3960		14	
23	Dato Keramat Rd	E20	10455	4	200	1					*	2814			205
24	Anson Rd/Macalister Rd	E21	6345	2	5025	2					*	5685		19	
25	Burma Rd/Larut Rd/Anson Rd	E22	4125	2	5340	2					*	4733		14	
26	Larut Rd/Northam Rd	E23	8565	2	2955	1					*	7238		6	
28	Ayer Itam Rd/Komtar Rd	E24	7350	4	200	1					*	2038			101.3
29	Ayer Itam Rd/Old Ayer Itam Rd	E25	7350	4	200	1					*	2038			101.3
30	Ayer Itam Rd/Green Lane/Scotland Rd	E26	11550	4	10695	4					*	5561		44	
32	Scotland Rd/Western Rd/Sepoy Lines	E27	9735	4	9840	2					*	7354		23	
33	Western Rd/Macalister Rd/Brook Rd	E28	9840	2	5070	2					*	7455		9	
36	Green Lane/Batu Lanchang Rd	E29	14070	4	3705	4					*	4444		12	
37	Green Lane/Jln Delima	E30	12195	4	3570	2					*	4834		15	
46	Pangkor Rd/Burma Rd	E31	4890	2	4755	2					*	4823		10	
52	Burma Rd/Cantonment Rd	E32	2805	2	4095	2					*	3450		7	
53	Kelawei Rd/Cantonment Rd	E33	6390	2	2805	2					*	4598		25	
57	Burma Rd/Gottlieb Rd/Bagan Jermal Rd	E34	4770	2	3735	2					*	4253		28	
60	Tg. Tokong Rd/Fettes Rd	E35	6600	2	3105	2					*	4853		6	
62	Western Rd/Ross Rd/Residency Rd	E36	4335	2	3210	2					*	3773			59.6
65	Ayer Itam Rd/Batu Lanchang Lane	E37	11550	2	5220	2					*	8385		15	
66	Thean Teik Rd/Ayer Itam Rd	E38	10050	2	780	1					*	5805		12	
67	Boundary Rd/Ayer Itam Rd	E39	10050	2	1614	2					*	5832		8	
74	Jelutong Rd/Perak Close/Jln Tengku	E40	7470	2	855	1					*	4590			120
		Mean Value of CONF										4684			

Table 3.1.2(2) : Future (2000) Traffic Signal Installation Ranking In George Town

Intersection		Existing Traffic Signal	Traffic Volume (V) & Number of Lanes (N)								Surveyed ** Estimated * Traffic	Conflict Factor (CONF)	Ranking	Accident	
No.	Name	(E)	V1	N1	V1	N2	V3	N3	V4	N4	Volume	Vi/Ni		No. of Accidents	No. of Accidents per Km
6	Carnarvon Circus		3383	2	3915	1	3533	1	2295	1	*	11434	1	15	
39	Pitt St/Light St		2025	1	5970	2	3285	2			*	6653	2	6	
72	Jelutong Rd/Perak Lane		4905	2	263	1					*	2715	3	16	
75	Jelutong Rd/Perak Rd/Batu Lanchang Rd		5205	4	7470	2					*	5036	4	14	
27	Ayer Itam Rd/Trengganu Rd		9120	4	3210	2					*	3885	5	14	
64	York Rd/Ayer Itam Rd		9120	4	3000	2					*	3780	6	11	
73	Jelutong Rd/Van Praagh Rd		7470	2	2565	2					*	5018	7		147
34	Sg. Pinang Rd/Patani Rd		8835	4	1358	1					*	3566	8	5	
2	Weld Quay/Chulia St Ghaut		5475	2	2445	2					*	3960	9	14	
68	Zoo Rd/Ayer Itam Rd		10050	2	100	1					*	5125	10		147
47	Pangkor Rd/Perak Rd/Peel Avenue		6105	2	4755	2					*	5430	11	12	
11	Prangin Rd/Ria Rd/Sg. Ujong Rd		7065	4	1017	1					*	2783	12	5	
45	Northam Rd/Pangkor Rd		8400	2	4125	2					*	6263	13	19	
35	Green Lane/Batu Lanchang Lane/Hamilton Rd		14070	4	5220	2					*	6128	14	10	
119	Green Lane/Free School Rd		11535	4	3090	2					*	4429	15	11	
40	Penang Rd/Farquhar St		4350	2	100	1					*	2275	16	5	
31	Scotland Rd/York Rd/Batu Gantong Rd		10695	4	4140	2					*	4744	17	11	
43	Weld Quay/North Coastal Rd		10305	2	5955	2					*	8130	18	5	
55	Western Rd/Gottlieb Rd		4770	2	2970	2					*	3870	19	5	
56	Ayer Rajah Rd/Gottlieb Rd		4770	2	2970	2					*	3870	20		98
70	Free Sch. Rd/Trengganu Rd/Hamilton Rd		3390	2	2685	2					*	3038	21		44
41	Northam Rd/Transfer Rd		8565	2	960	2					*	4763	22	10	
42	Transfer Rd/Argyll Rd		8565	2	960	2					*	4763	23	5	
63	Western Rd/Dato Keramat Rd		10455	4	4335	2					*	4781	24	5	
48	Perak Rd/Macalister Rd/Barrack Rd		5940	2	6555	2					*	6248	25	14	
110	Bridge St/Cecil St/Cecil St Ghaut		3855	2	348	2					*	2102	26		100
103	Perak Rd/Van Praagh Rd		5370	2	2565	2					*	3968	27		69
82	Larut Rd/Hutton Lane/Argyll Rd		3810	2	2880	2					*	3345	28		41.6
59	Tg. Tokong Rd/Hock Lim Terrace		6600	2	1935	2					*	4268	29	5	
71	Free Sch. Rd/Perak Rd/Perak Lane		5370	2	100	1					*	2785	30	5	
58	Tg. Tokong Rd/Bagan Jermal Rd		6600	2	2925	2					*	4763	31	18	
91	Anson Rd/Siam Rd		5025	2	2010	2					*	3518	32	5	
51	Macalister Rd/Cantonment Rd		5070	2	2010	2					*	3540	33	5	
50	Ayer Rajah Rd/Cantonment Rd		48570	2	2010	2					*	25290	34		33.9
54	Western Rd/Brown Rd		4770	2	200	1					*	2585	35		56
69	Paya Terubung Rd/Kg. Pisang Rd		10050	2	4307	2					*	7178	36	5	
88	Kampung Jawa Baru/Dato Keramat Rd		8685	4	1260	2					*	2801	37		258.3

Table 3.1.2(3) : Future (2000) Traffic Signal Installation Ranking In George Town

Intersection		Existing Traffic Signal	Traffic Volume (V) & Number of Lanes (N)								Surveyed ** Estimated * Traffic Volume	Conflict Factor (CONF) Vi/Ni	Ranking	Accident	
No.	Name	(E)	V1	N1	V1	N2	V3	N3	V4	N4				No. of Accidents	No. of Accidents per Km
83	Burma Rd/Jln Zainal Abidin		5640	2	100	1					*	2920	38		275
84	Rangoon Rd/Burma Rd		5340	2	100	1					*	2770	39		200
85	Macalister Rd/Jln Zainal Abidin		4590	2	100	1					*	2395	40	5	
86	Macalister Rd/Rangoon Rd		6345	2	100	1					*	3273	41		262.5
107	Green Lane/Jln Tembaga		12195	4	200	1					*	3249	42		137
108	Green Lane/Batu Lanchang Avenue		12195	4	200	1					*	3249	43		137
109	Green Lane/Yeap Chor Ee Rd		12195	4	200	1					*	3249	44		104
76	Gelugor Rd/Green Lane/Udini Rd		11070	4	12195	4					*	5816	45	33	
49	Macalister Rd/Peel Avenue/Residency Rd		4875	2	3735	2					*	4305	46	21	
87	Brick Kiln Rd/Macallum St		2685	2	705	1					*	2048	47		126
90	Sg. Pinang Rd/River Rd		8835	2	2700	2					*	5768	48	5	
61	Tg. Tokong Rd/Old Tg. Tokong Rd		6600	2	100	1					*	3400	49	5	
44	Prangin St Ghaut/Beach St/Bridge St		5955	2	3855	2					*	4905	50	5	
104	Jelutong Rd/Jelutong Avenue		5265	4	100	1					*	1416	51	9	
105	Gelugor Rd/Gelugor Avenue		5265	4	100	1					*	1416	52		37
80	Pitt St/Church St		3285	2	100	1					*	1743	53		94
81	Pitt St/China St		3285	2	100	1					*	1743	54		94
78	Beach St/Church St/Church St Ghaut		1215	2	100	1					*	708	55		103.1
79	Beach St/China St/China St Ghaut		1215	2	100	1					*	708	56		103.1
95	Trengganu Rd/Caunter Hall Rd		2640	2	100	1					*	1420	57		64.5
38	Beach St/Light St/King Edward Place		4050	2	810	2					*	2430	58	7	
94	Burma Rd/Brown Rd		3735	2	100	1					*	1968	59		77.1
98	Tg. Tokong Rd/Jln Gajah		3205	2	100	1					*	1953	61		36.5
97	Mount Erskine Rd/Fettes Rd		3930	2	100	1					*	2065	62		36.5
99	Jln Tg. Bungah/Jln Bunga Pudak		3270	2	100	1					*	1735	63	5	
89	Patani Rd/Lines Rd		2715	2	100	1					*	1458	64		69
100	Tg. Bungah Rd/Cheah Beng Kim Rd		3225	2	100	1					*	1713	65	5	
101	Tg. Bungah Rd/Vale of Tempe Road		3225	2	100	1					*	1713	66	5	
102	Tg. Bungah Rd/Chan Siew Teong Rd		3225	2	100	1					*	1713	67		164
93	Barrack Rd/Tuli Rd/Lim Khoon Huat Rd		2700	2	2250	2					*	2475	68		24.6
92	Perak Rd/Lim Khoon Huat Rd		6555	2	100	1					*	3378	69		60
106	Batu Lanchang Rd/Jln Sir Ibrahim		3705	2	100	1					*	1953	70		69.6
111	Macallum St Ghaut/Weld Quay Extension		10305	4	750	2					*	2951	71		
112	Cecil St Ghaut/Weld Quay (Bunn Rd)		9900	4	750	2					*	2850	72		
113	Sandilands St Ghaut/Weld Quay Extension		9900	4	750	2					*	2850	73		
114	Sg. Pinang Rd/Weld Quay Extension		11460	4	9735	4					*	5299	74		
115	Perak Lane/Weld Quay Extension		11460	4	525	2					*	3128	75		
116	Van Praagh Rd/Weld Quay Extension		11460	4	2565	2					*	4148	76		
117	Batu Lanchang Rd/Weld Quay Extension		11460	4	5205	4					*	4166	77		
118	Udini Rd/Weld Quay Extension		12195	4	7935	4					*	5033	78		
120	Weld Quay/Lebuh Acheh		7000	2	2200	2					*	4600	79		

Figure 3.1.2 illustrates the candidate intersections for signalisation in Bayan Lepas whereas Table 3.1.3 illustrates the future (2000) CONF values of the candidate intersections in Bayan Lepas. As depicted in the table, there are forty-one (41) candidate intersections in the Bayan Lepas Area that have CONF of 1000 or more. However, this CONF of 1000 is derived from the present (1986) traffic volume in George Town. Furthermore, signal installation in George Town is given higher priority than that in Bayan Lepas at the present moment. From the future (2000) traffic volumes at intersections in George Town, the minimum CONF values is 1416 except at Beach Street/Church Street and Beach Street/ China Street intersections as depicted in Table 3.1.2. From Table 3.1.3, there are thirty (30) candidate intersections in Bayan Lepas that have CONF of 1400 or more in the year 2000 thereby signalisation is warranted at these intersections.

b. Prioritizing Warranted Signals

Prioritizing warranted signals is necessary as there are seldom sufficient funds or other resources to signalise all warranted locations.

To assure that the most critical locations are installed first, a priority ranking system is used.

For prioritizing warranted signal installation in Penang, the criteria used is the degree of satisfaction of the peak hour volume warrant. To be more specific, the candidate intersections are arranged in a decreasing order of their conflict factor which means that the intersection with the highest CONF values is prioritized to be signalised.

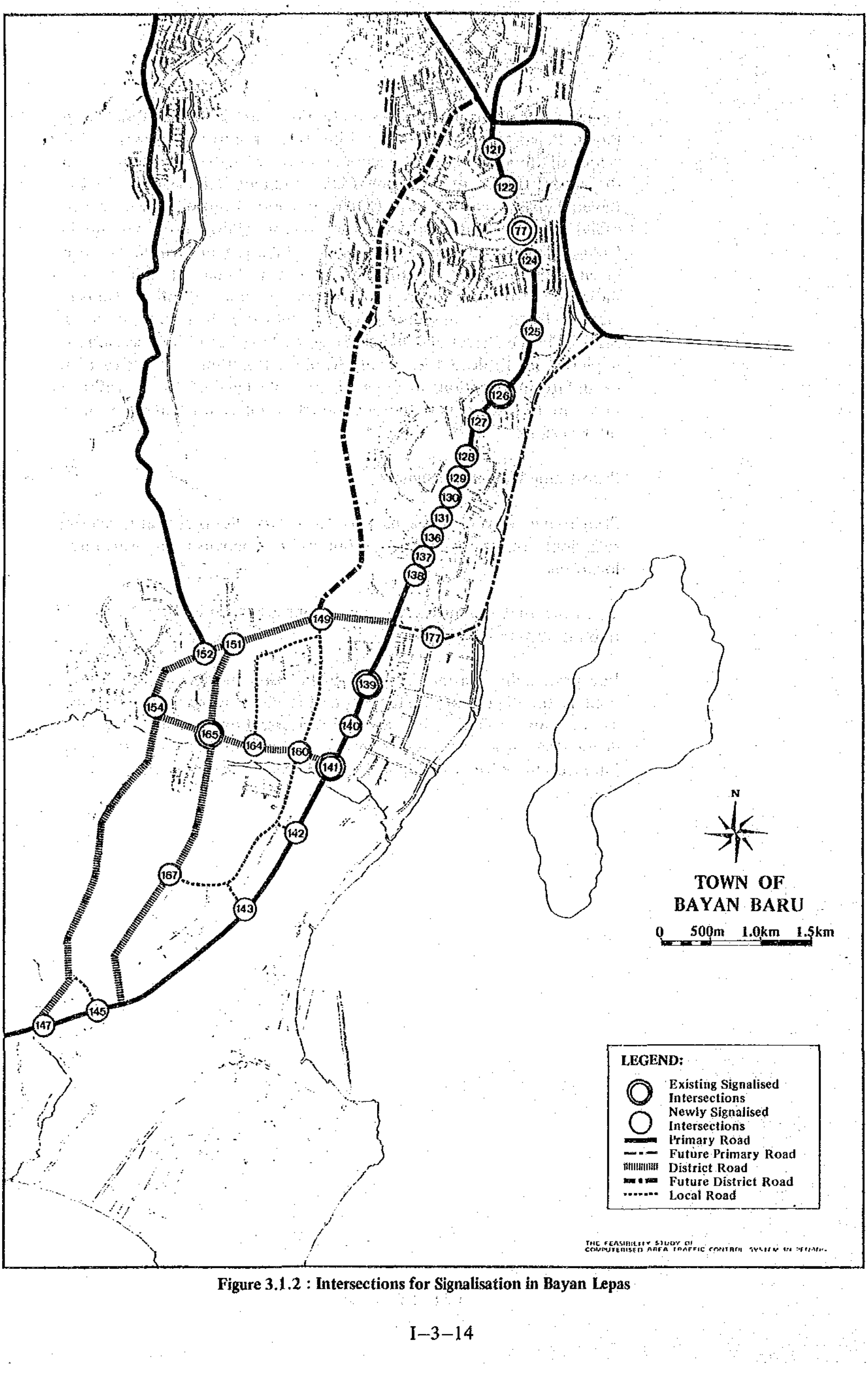


Figure 3.1.2 : Intersections for Signalisation in Bayan Lepas

Table 3.1.3(1) : Future (2000) Traffic Signal Installation Ranking In Bayan Lepas

Intersection No.	Intersection Name	Existing Traffic Signal (E)	Traffic Volume (V) & Number of Lanes (N) V1	N1	V1	N2	V3	N3	V4	N4	Surveyed ** Estimated * Traffic Volume	Conflict Factor (CONF) Vi/Ni	Ranking	Accident: No. of Accidents	Accident: No. of Accidents per Km
139	Sg Nibong Rd/Jln Mahsuri	E	6870	4	3100	2					*	3268	1		
177	Relau Rd/Gerbang Bukit Kecil Satu (nearby)		4000	2	2000	2					*	3000	2		
77	Gelugor Rd/Jln Hilir Pemancar	E	11070	4	200	1					*	2968	3		
149	Relau Rd/Mayang Pasir Rd		2990	2	2030	2					*	2510	4		
141	Sg Nibong Rd/Jln Tengah	E	6870	4	1570	2					*	2503	5		
151	Relau Rd/Jln Tun Datuk Dr Haji Awang		2990	2	1960	2					*	2475	6		
152	Relau Rd/Paya Terubong Rd		2990	2	1410	2					*	2200	7		
140	Sg Nibong Rd/Lebuhraya Nibong		6870	4	900	2					*	2168	8		
125	Glugor Rd/USM Main Entrance		5720	4	1050	2					*	1955	9		
136	Sg Dua Rd/Sg Nibong Rd		4570	4	1600	2					*	1943	10		
165	Jln Tun Datuk Dr Haji Awang/Jln Tengah	E	1570	2	2250	2					*	1910	11		
124	Glugor Rd/Jln Helen Brown		5720	4	820	2					*	1840	12		
126	Glugor Rd/Sg Dua Rd	E	4570	4	1000	2					*	1643	13		
121	Glugor Rd/South Road (opposite Rescam)		5720	4	200	1					*	1630	14		
122	Glugor Rd/Hala Pemancar		5720	4	200	1					*	1630	15		
131	Sg Nibong Rd/Jln Aziz Ibrahim		4570	4	750	2					*	1518	16		
142	Bayan Lepas Rd/Factory Entrance		3710	4	1120	2					*	1488	17		
145	Bayan Lepas Rd/Jln Mahkamah		3710	4	1100	2					*	1478	18		
147	Bayan Lepas Rd/Jln Relau		1590	2	1330	2					*	1460	19		
137	Sg Nibong Rd/Persiaran Pantai Jerejak		4570	4	620	2					*	1453	20		
130	Sg Nibong Rd/Jln Helang		4650	4	550	2					*	1438	21		
129	Sg Nibong Rd/Jln Pantai Jerejak		4570	4	575	2					*	1430	22		
138	Sg Nibong Rd/Jln Bukit Kecil Satu		4570	4	575	2					*	1430	23		
127	Sg Nibong Rd/Tingkat Batu Uban Satu		4750	4	475	2					*	1425	24		
128	Sg Nibong Rd/Persiaran Batu Uban		4650	4	525	2					*	1425	25		
164	Jln Tengah/Persiaran Mahsuri		1900	2	925	2					*	1413	26		
160	Jln Tengah/Jln Mayang Pasir		1770	2	1050	2					*	1410	27		
154	Relau Rd/Jln Tengah		1700	2	1100	2					*	1400	28		
167	Jln Tun Datuk Dr Haji Awang/Jln Sg Tiram Dua		1700	2	1100	2					*	1400	29		
143	Bayan Lepas Rd/Jln Mayang Pasir		4400	4	600	2					*	1400	30		

Table 3.1.3(2) : Future (2000) Traffic Signal Installation Ranking In Bayan Lepas

Intersection		Existing Traffic Signal	Traffic Volume (V) & Number of Lanes (N)								Surveyed ** Estimated * Traffic	Conflict Factor (CONF)	Ranking	Accident	
No.	Name	(E)	V1	N1	V1	N2	V3	N3	V4	N4	Volume	Vi/Ni		No. of Accidents	No. of Accidents per Km
150	Relau Rd/Padang Golf Bukit Jambul		2100	2	600	2					*	1350	31		
159	Jln Mahsuri/Jln Mayang Pasir		1900	2	700	2					*	1300	32		
144	Bayan Lepas Rd/Jln Sg Tiram Satu		3710	4	600	2					*	1228	33		
163	Jln Mahsuri/Persiaran Mahsuri		1900	2	520	2					*	1210	34		
146	Bayan Lepas Rd/Jln Kg Perlis		1590	2	680	2					*	1135	35		
157	Relau Rd/Jln Mahkamah		1330	2	920	2					*	1125	36		
132	Sg Dua Rd/USM Sg Dua Gate		1480	2	700	2					*	1090	37		
148	Bayan Lepas Rd/Jln Permatang Damar Laut		1590	2	580	2					*	1085	38		
135	Sg Dua Rd/Lengkok Nipah		1480	2	580	2					*	1030	39		
133	Sg Dua Rd/Jln Pekaka Satu		1480	2	520	2					*	1000	40		
174	Jln Bukit Gambiar/Hilir Pemancar		700	2	1300	2					*	1000	41		
134	Sg Dua Rd/Tingkat Pekaka Satu		1480	2	460	2					*	970	42		
158	Relau Rd/Jln Kg Perlis		1330	2	510	2					*	920	43		
153	Relau Rd/Gerbang Sg Dua 3 (nearby)		1260	2	200	1					*	830	44		
155	Relau Rd/Lebuh Sg Dua Satu		1330	2	100	1					*	765	45		
156	Relau Rd/Halaman Relau Satu		1330	2	100	1					*	765	46		
178	Jln Kg Jawa/Solok Kg Jawa 8(nearby)		1000	2	400	2					*	700	47		
166	Jln Tun Datuk Dr Haji Awang/Persiaran Mayang Pasir		820	2	460	2					*	640	48		
161	Persiaran Mayang Pasir/Jln Mayang Pasir		700	2	460	2					*	580	49		
175	Jln Bukit Gambiar/Jln Kaki Bukit		700	2	460	2					*	580	50		
168	New Pasir Rd/Persiaran Nipah		700	2	200	1					*	550	51		
162	Jln Sg Tiram Dua/Jln Mayang Pasir		700	2	340	2					*	520	52		
169	New Pair Rd/Jln Pekaka Satu		700	2	340	2					*	520	53		
170	New Pair Rd/Taman Bukit Gambiar Satu		700	2	340	2					*	520	54		
171	New Pair Rd/Persiaran Minden Satu		700	2	340	2					*	520	55		
172	New Pair Rd/Lebuh Bukit Gambiar Dua		700	2	340	2					*	520	56		
173	New Pair Rd/Cangkat Minden Jalan Satu		700	2	340	2					*	520	57		
179	Lintang Kg Jawa/Lengkok Kg Jawa 1 (nearby)		580	2	340	2					*	460	58		
180	Lebuhraya Kg Jawa/Lengkok Kg Jawa 2 (nearby)		400	2	340	2					*	370	59		

3. Traffic Signal Computerisation in Penang

The existing computerised signalised intersection are depicted in Table 3.1.4. These sixteen (16) intersections are under Phase 1 of Stage I of the Computerised Area Traffic Control System in Penang.

Table 3.1.4 : Existing Computerised Signalised Intersections (Phase 1 of Stage I)

No.	Intersection No.†	Name of Intersecting Streets
1	7	Magazine Road – McNair Street
2	8	Magazine Road – Ria Road
3	9	Magazine Road – Penang Road – Dato Keramat Road
4	10	Penang Road – Prangin Road – Burma Road
5	12	Penang Road – Phee Choon St – Kimberley Street
6	13	Penang Road – Campbell Street – Hutton Lane
7	14	*Penang Road – Chulia Street – Argyll Road
8	15	Burma Road – Transfer Road
9	19	Dato Keramat Road – Patani Road
10	20	Perak Road – Sungei Pinang Road
11	21	Dato Keramat Road – Perak Road
12	22	Perak Road – Anson Road
13	23	*Dato Keramat Road – Infront of City Stadium
14	24	Macalister Road – Anson Road
15	25	Burma Road – Anson Road
16	26	Northam Road – Larut Road

Note : * is Pedestrian Signal
† See Figure 3.1.1 for location

Existing and proposed traffic signals to be computerised are ranked by the following two factors :

(1) existing signalised intersection

(2) priority ranking of candidate signal installation

For candidate intersections in George Town, after Stage I, the remaining existing signalised intersections as well as those proposed candidate intersections with CONF values of 1300 or more are computerised under Stage II (1990–1993). The remaining proposed signalised intersections are to be computerised under Stage III (1994–1996).

The breakdown of signalised intersections to be computerised in each stage are depicted in Table 3.1.5 and the locations are shown in Figures 3.1.3 to 3.1.5.

Table 3.1.5 : Computerisation Plan in George Town

	Stage I (1987)	Stage II (1990–1993)	Stage III (1994–1996)
Classification Index		Remaining Existing Intersection CONF of 1300 or more	CONF of less than 1300
Existing Signalised Intersection	16*	24	0(0)
Proposed Signalised Intersection	0	20	59(29)
Total	16	44**	59(29)
Stock	16	60	119(89)

Note : * including four (4) newly signalised intersection in 1986
** including Phase II of Stage I
( ) CONF of 850–1250

For candidate intersections in Bayan Lepas, the existing signalised intersections are computerised under Stage II (1990–1993) and twenty-five (25) proposed signalised intersections are to be computerised under Stage IV (1997–2000)

The breakdown of signalised intersections to be computerised in each stage are depicted in Table 3.1.6 and the locations are shown in Figure 3.1.6.

Table 3.1.6 : Computerisation Plan in Bayan Lepas

	Stage I (1987)	Stage II (1990–1993)	Stage III (1994–1996)	Stage IV (1997–2000)
Classification Index		Existing Signalised Intersection		CONF of 1400 or more
Existing Signalised Intersection	0	5	0	0
Proposed Signalised Intersection	0	0	0	25
Total	0	0	0	25
Stock	0	5	5	30

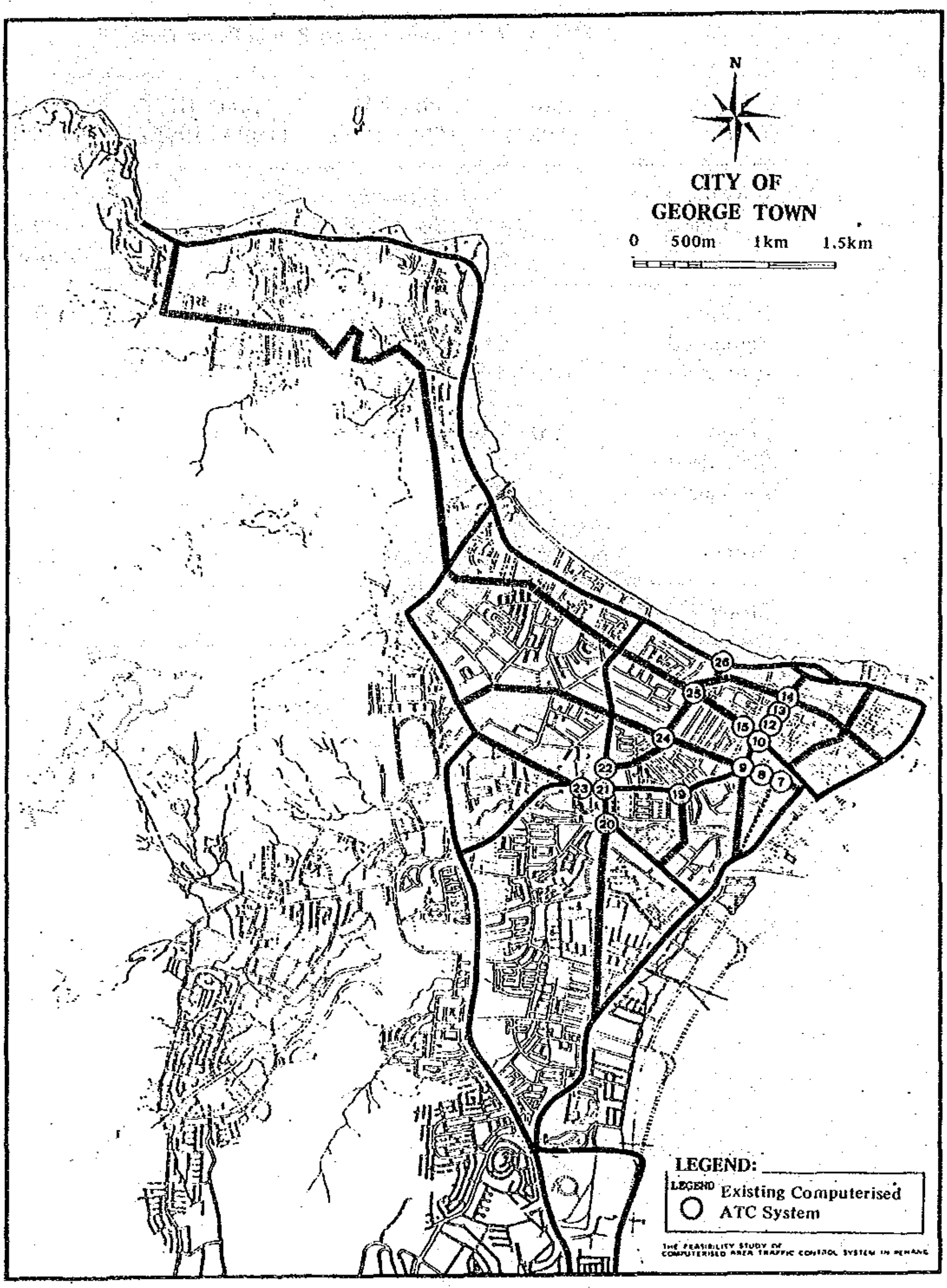


Figure 3.1.3 : Signal Locations in Stage I for George Town

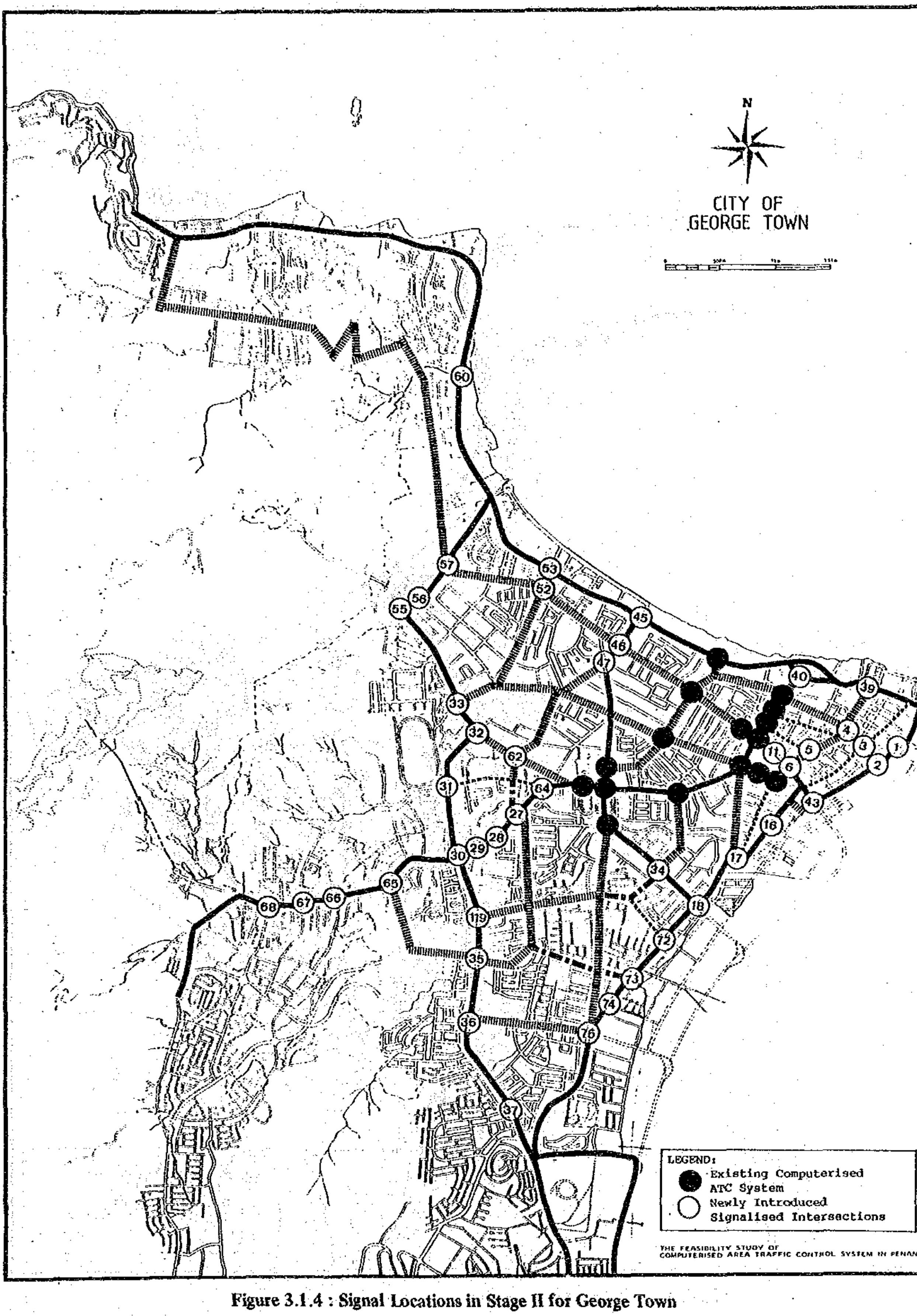


Figure 3.1.4 : Signal Locations in Stage II for George Town

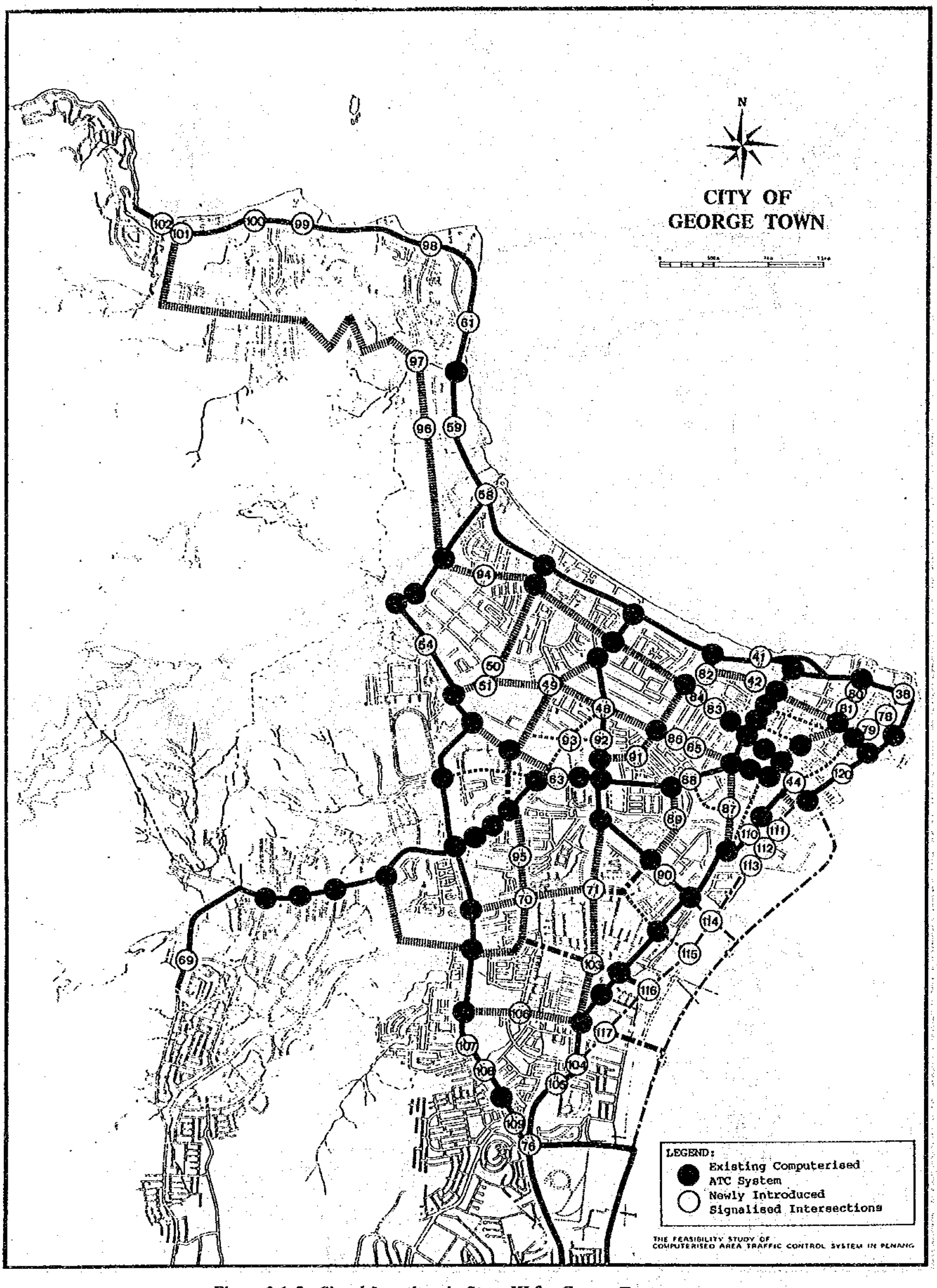


Figure 3.1.5 : Signal Locations in Stage III for George Town

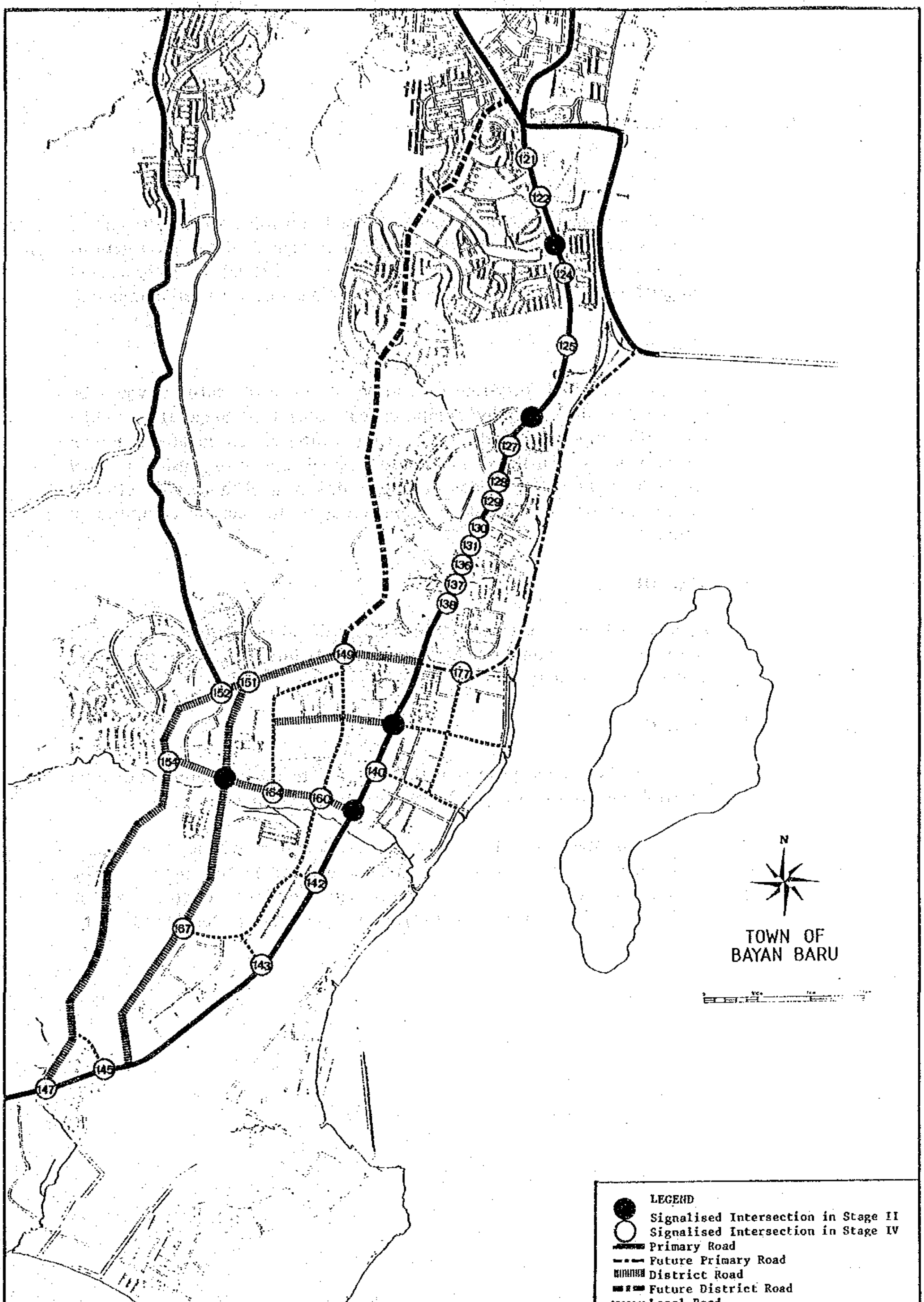


Figure 3.1.6 : Signal Locations in Stages II & IV for Bayan Lepas

B. Proposed Staging Plan of the ATC System

I. Stage I

The traffic signal control system in Stage I controls sixteen (16) sets of traffic signals including the three pedestrian signals at the intersections located in the Central Area, bordered by Anson Road, Perak Road and Sungai Pinang Road. This Stage I system has already been completed.

2. Stage II

It is proposed that forty-four (44) intersections in the entire city area be signalized under centrally computerised control in Stage II including Phase II of Stage I. Besides these, five (5) intersections located in Bayan Lepas will be signalized in isolated signal operation, using a local controller with the functions of time-of-day control mode and actuated action, and will be capable of connecting to the central computer in future.

3. Stage III

In Stage III, it is necessary to install additional signals to be controlled centrally by the computer at fifty-nine (59) intersections in the entire city and its periphery.

4. Stage IV

In Stage IV, it is proposed that twenty-five (25) intersections be controlled centrally in Bayan Lepas area and its periphery.

However, at this stage, it is difficult to propose locations which are necessary to be signalized due to new road constructions, road improvements, traffic pattern changes, etc.. Therefore, in future, signalization requirement will be examined during the course of the project and necessary actions will then be taken.

3.2 Closed Circuit Television (CCTV) System

3.2.1 General

Closed Circuit Television (CCTV) has become a major part of computerised Traffic Control System for urban streets in cities. It is extensively utilized in developed countries for this purpose. Closed-circuit television enables operators in a central control room to view traffic conditions at locations where cameras are placed. The time and nature of an incident, the type of service facility required and the effect on the up-stream network can be determined quickly, so that suitable action can be taken.

3.2.2 Conceptual Structure of CCTV System Equipment

Figure 3.2.1 shows the basic equipment of a CCTV system. They are as follows :

- Cameras
- Transmission system
- Monitors
- Peripheral devices

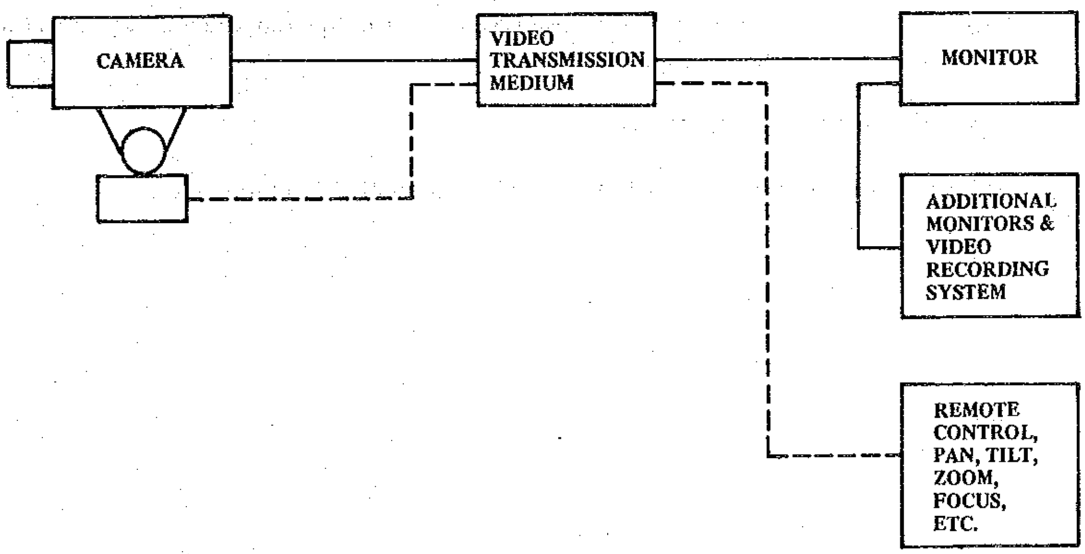


Figure 3.2.1 : Basic Elements of CCTV System

The Stage I closed circuit television (CCTV) system consists of two cameras, two monitors and a control desk. Each camera is mounted on the top of a pole near a critical intersection so that traffic conditions can be observed. Each camera can be remote-controlled from the control desk at the control centre. Zooming, tilting, panning are possible.

The video signals are transmitted to the control centre through coaxial cables, which connect these cameras, TV monitors and other necessary equipment.

The hardware structure for the future system is the same as that of the Stage I system except that the numbers of cameras and TVs monitor will be increased.

In addition, video-tape recorders will be considered as additional elements to analyse transient phenomena of traffic.

3.2.3 Locations where Field Cameras are to be Required

The Staging Plans of placing cameras is considered based on the following criteria.

(1) Locations along the primary radial road and ring road.

(2) The top of KOMTAR building which has a panorama view of the whole city. (Another purpose is to provide visitors to the centre a panorama view of the city).

(3) Locations along the North Coastal Road, and its related streets, as well as the Penang Bridge.

(4) Others necessary locations.

The locations where camera will be placed are presented in Figure 3.2.2.

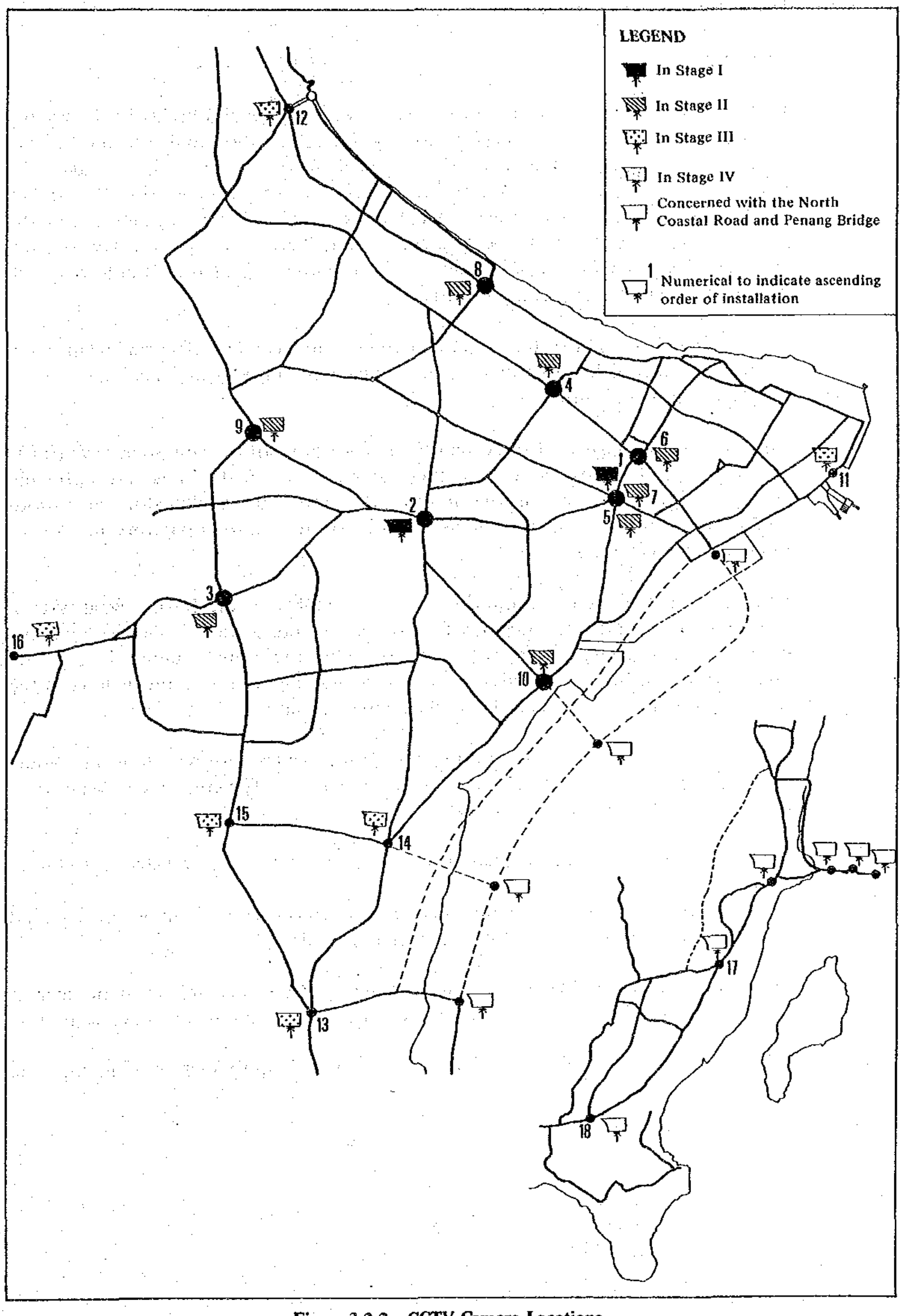


Figure 3.2.2 : CCTV Camera Locations

3.3 Driver Information System

3.3.1 General

Driver Information System is a man-machine system, which obtains traffic related information from various sources and conveys the information to drivers on the road as quickly and as accurately as possible, so that the drivers can either avoid traffic congestion, or follow the traffic regulations being enforced by the traffic menagement authority concerned. What is expected from the installation of the system will be, hopefully, less traffic congestion, (because drivers will try to avoid the locations which are already congested) and better regulated traffic flow, as well as more efficient use of parking facilities.

The driver information system is part of the comprehensive traffic surveillance and control system which is expected to be implemented on Penang Island and part of the main land in the future.

The area traffic signal control system is the back-bone of the comprehensive traffic surveillance and control system in these areas. The signal timings are optimally adjusted to traffic through the information obtained by detectors at various locations in the system, as well as by the control centre operators in case of unpredictable incidents.

However, there are certain limitations in the capability of the traffic signal system. For example, if the incoming traffic flow at an intersection is heavier than the intersections capacity, then regardless of how the signal timing is set, the intersection will be oversaturated. The queue will continue to grow as long as the incoming traffic is higher than the intersection's capacity.

Thus, the use of driver information system that provides information on a real-time basis should be considered in relation to its effect on traffic control over wide areas of street as well as expressway operation.

Three categories of problems related to traffic operations can be listed as follows :

(1) Recurring problem – Mainly peak-period traffic congestion where demand exceeds capacity for relatively short time periods.

(2) Non-recurring problems – Caused by random of unexpectable incidents such as traffic accidents, temporary street blockage, maintenance operation, etc.

(3) Environmental problem – Caused by acts of nature such as rain, fog, etc.

It is possible not only to get traffic related information rapidly, but also to display these conditions at the traffic control centre. Once such information is available in the control centre, it becomes possible to convey the information to drivers through a driver information system. With the stored information, drivers may then make individual decisions (time of trip, routes of trip, mode, etc.) to facilitate their trip from origin to destination.

3.3.2 Objectives

Some basic objectives of a driver information system are as follows :

(1) To improve the operating efficiency of existing facilities.

(2) To reduce the mental and physical stress involved in the use of urban traffic facilities.

(3) To fulfil the driver's expectation with respect to information on the following.

- Regulatory information
- Operational information
- Road Conditions
- Traffic Conditions
- Parking Conditions at parking facilities
- Navigational information
- Positional information
- Locational information

3.3.3 Functions

The functions of the driver information system are two-fold. One is to gather traffic information, and the other is to convey traffic information to drivers.

The flow of information in the driver information system is presented in Figure 3.3.1.

A. Gathering traffic related information

It is important to gather traffic-related information such as traffic congestion degree and its locations, accident locations, road maintenance locations, etc.. Based on this information, the comprehensive traffic control system is performed.

Several ways to obtain this information are considered : traffic detector, CCTV camera, police mobile radio, telephone, etc.. The main ways are through traffic detectors and CCTV camera for the ATC system in Penang.

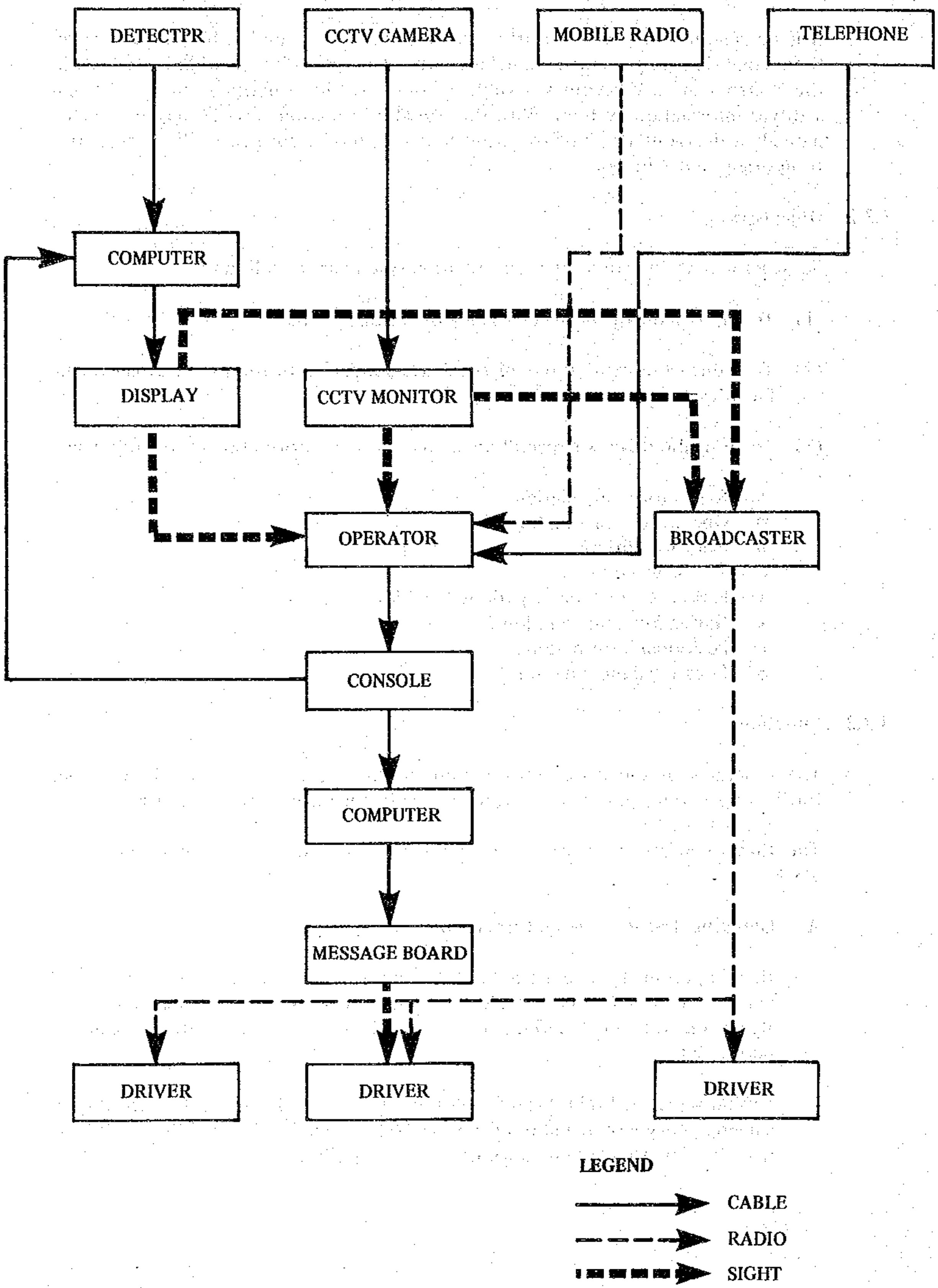


Figure 3.3.1 : Flow of Information in the Driver Information System

1. Map Display Method of Traffic Condition

In Stage I, two types of displays through information from traffic detectors are adopted : (1) Traffic congestion degree display in the Central Area of George Town and (2) Traffic queue length display outside the Central Area.

a. Traffic congestion degree

One to two detectors (one detector at one location) are placed at the intersection approach, where heavy traffic congestion is expected. The congestion degree will be estimated from the observed occupancy levels at the detector(s).

b. Traffic queue length

Two or three detectors are placed at every intersection approach, where heavy traffic congestion is expected. These detectors will be placed at arbitrary locations; for example, a detector at 250 m, 500 m and 750 m upstream from the stop line may be possible. The maximum queue length in a cycle will be estimated from the observed occupancy levels at these three detectors. The estimated queue length can be expressed by ranges : for example, less than 250 m, 250 m to 500 m, 500 m to 750 m, over 750 m.

2. Number of Critical Intersections

The number of intersections where heavy traffic congestion is expected in the near future (Stage II) will be approximately eight (8). In future (Stage III and IV), the number of such intersections is expected to increase. The candidated intersections are shown in Figure 3.3.2.

3. Queue Display Map (or Terminals) at the Control Centre

In Stage II, the existing display map will be modified so that it can also display congestion degree and queue lengths at additional critical intersections. In Stages III and IV, either a new display map will be added to the existing map on the wall of the control room, or the existing map will be replaced by a new display map. As another display method, colour graphics terminals are considered to display queue conditions at critical intersections and other traffic-related information obtained through the main computer.

Figure 3.3.3 shows the existing queue display map in the control centre.

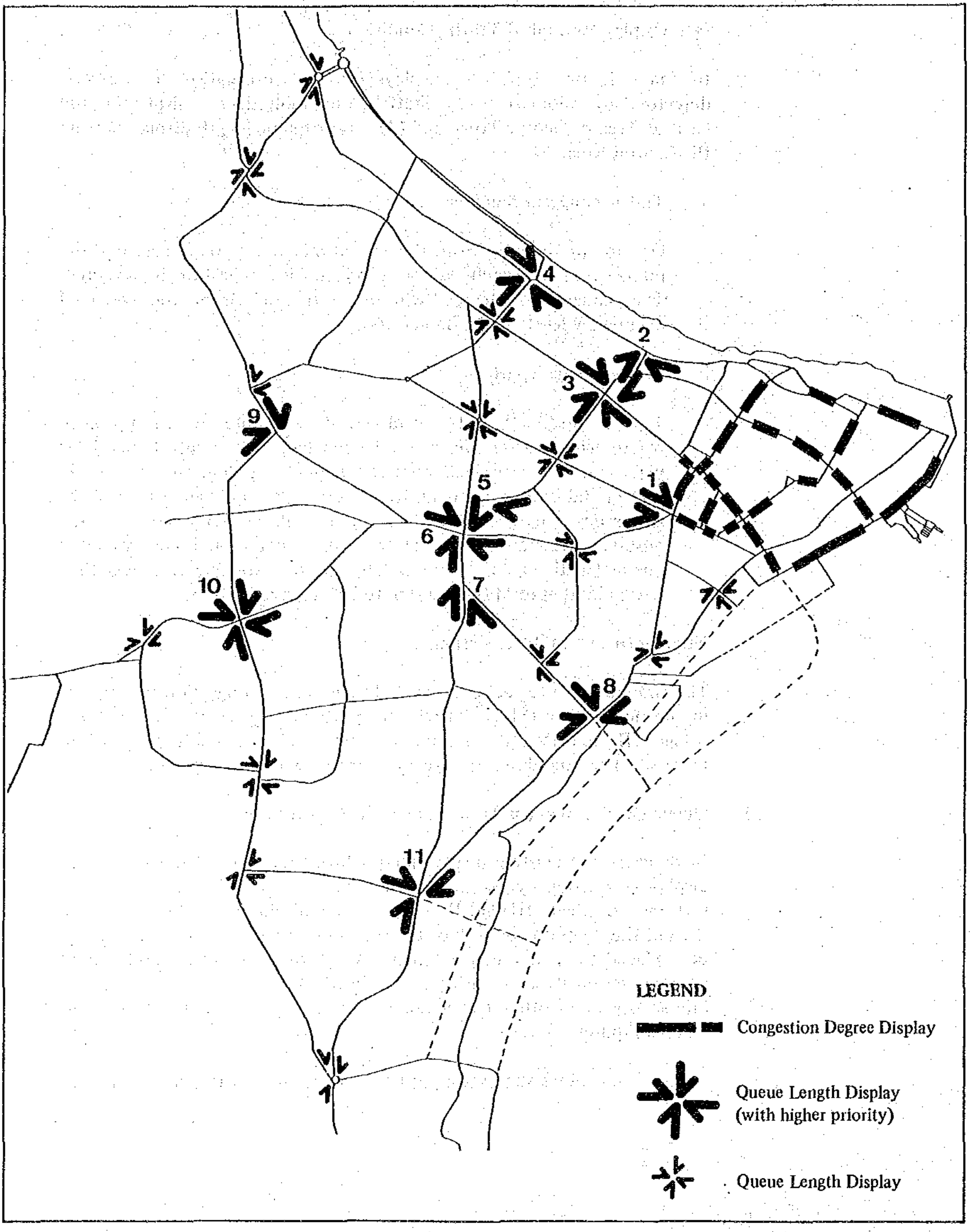


Figure 3.3.2 : Intersections where Congestion Degree (or length) will be expressed on Wall Map Display

MAINTENANCE PANEL DISPLAY MAP

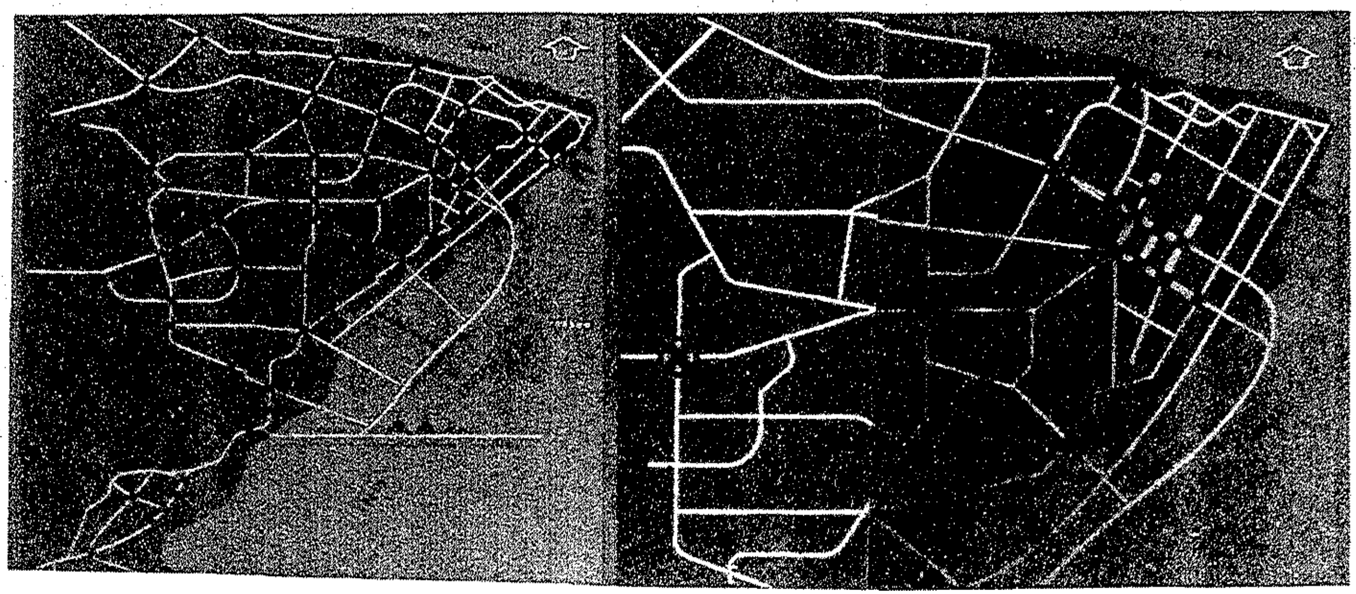


Figure 3.3.3 : Existing Wall Map Display

B. **Conveying Traffic=Related Information To Drivers**

The basic techniques used to convey traffic related information to drivers can be classified under the broad categories of visual and audio. The major visual techniques for conveying driver information would include the following:

(1) Signals
(2) Signal message signs
(3) Changeable signs
(4) Changeable message signs
(5) Vehicle displays

The major audio techniques for conveying driver information would include the following:

(1) Warning signals (bells, whistle, horn, etc.)
(2) Public address system
(3) Telephone (to traffic information service centre)
(4) Commercial radio
(5) Roadside radio (non-commercial)

The basic concept of some technique which will be fitted in Penang Island and the expressway including the Penang Bridge will be briefly discussed in the following sections.

1. Changeable Traffic Signs

The changeable traffic signs have been used on highway. The traffic signs usually apply in urban street operation in conveying information of a regulatory and advisory nature. Such signals demonstrated their ability to communicate real time information to drivers.

These signs are mostly used to control limited speed for safety; that is the values of limited speed are changed on a time by time basis depending on the road and traffic conditions or situation. Also, the signs are used mostly to control turning movements at an intersection on a time by time basis by means of changing arrows of prohibited ways.

2. Changeable Message Signs

Through giving real-time information to drivers, they could be advised on congested arterial section that might be as much as two (2) km away. This information could accomplish the re-routing of vehicles around congested intersections or off overloaded arterials. It also serves to reduce frustration by informing drivers of congested situation before they are encountered.

The use of changeable message signs implied the need for a system that would include the following:

(1) Detection of conditions or situations

(2) Transmission of information to a Control Centre.

(3) Decision-making capability relative to the information received and the action desired.

(4) Feed back link to operate the sign and thereby communicate with the driver.

Changeable message boards will be installed at the upstream of key locations in the city. The messages input by its operator will be displayed on the board. The messages do not have to be related to traffic; for example, welcome message to foreign dignitaries can also be displayed. A central message controller is needed in the control centre. It is a computer whose function is to store, select, and transmit messages to be displayed on the changeable message board in the field. The central message controller is able to control up to eight (8) changeable message boards in the field. It will also be linked to the driver information system's control desk, the main computer, the board controller, and the colour graphics terminals, through communication devices. The candidated locations are shown in Figure 3.3.4. In Stage III, it is considered to adopt changeable message boards at a couple of key locations. After Stage III, they will be added at other locations.

3. Vehicle Displays

A conceptual technique of providing information to drivers that has been investigated is one of display information on a device within each individual vehicle. Some countries has investigated this technique for route gidance. Such system is intended as a method for automatically providing drivers with routing instructions at various decision points in a road network. The instructions would guide the driver along a best route to his destination, considering such factors as distance and traffic congestion.

It is very likely, however, that such devices will be a part o the traffic control systems of the future.

4. Public Address System

Public address system may be useful in Penang. Loudspeakers placed at key intersections, so that it is possible for operators at the control centre to make public announcements over the system.

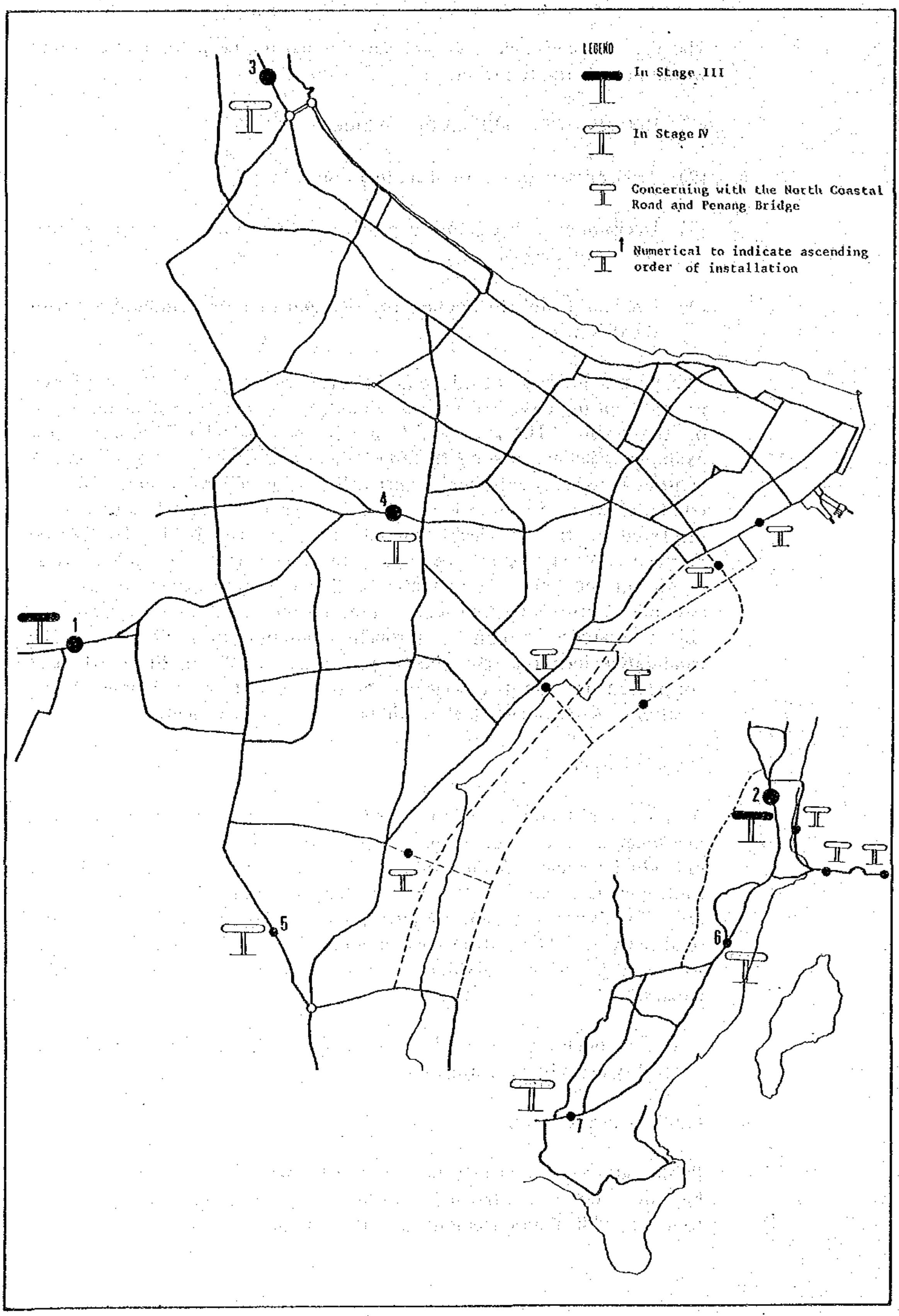


Figure 3.3.4 : Changeable Message Board Locations

5. Telephone

The use of the telephone as a driver information device is aimed at:

- Pre-trip planning
- Motorist aid

The oncept of pre-trip planning is that a driver calls a traffic information centre to obtain information on road and traffic conditions as an aid in planning a trip from an origin to a destination. Such information might affect the starting time and/or the route of the trip. The telephones for pre-trip planning would be mostly private phones at homes or business.

The concept of the motorist aid service would be to respond to problems such as stalled vehicles, accidents, or other similar incidents. The main point of consideration is that a capacity reducing incident can be rapidly removed to recover normal traffic flow.

Some roadside phones could be provided for motorist aid service.

Other main requirement in a telephone system is a central information centre which can provide accurate, comprehensive, and up to date information on traffic and road conditions throughout a large area.

6. Commercial Radio

Commercial radio has been widely used as a means of audio communication with drivers. Therefore, there are some advantages of using commercial radio as a driver information tool.

In Japan, Driver Information System via public broadcasting is emphasised considerably. All major Japanese cities have traffic control centres with excellent facilities for collecting traffic flow conditions (television, electronic sensors, police vehicles) and for displaying these conditions in central command control centres. As part of the command-control centre, soundproof broadcasting booth are provided for all public broadcast stations serving the area. These booths are operated by broadcasters who are able to view the display boards and communicate directly with personnel of the control centre to obtain accurate and timely information on traffic flow condition.

7. Roadside Radio (Low Power Radio)

The use of low-power, non-commercial radio is an audio technique. The concept of this radio is that an operating agency such as city or state department could install and operate low power radio braodcasting system. The range of the broadcasts would be limited to selected area where special transmitting devices were installed.

Furthermore, in Tokyo, Japan, a technique of making message contents and broadcasting the message automatically, responding to the traffic flow conditions has been performed experimentally using high level computers.

3.4 *Statistical Data Collection System*

Main functions of the statistical data collection system are to record traffic data, control data and error data of the ATC system, and also to print appropriate reports automatically.

The data to be stored are:

- Traffic data :
  traffic volume, occupancy on detectors

- Control data :
  signal timing (cycle, split, offset)

- Error list :
  system error, detector error, controller error, etc.

It is preferable that only the error lists be printed out daily and parameters be saved on a magnetic tape.

Periodic saving of the tape data to a history file or development of special application programs to generate summary statistics could be useful for research, traffic study, and timing plan development purposes.

3.5 Detector Location Plan

3.5.1 Functions of Detector

The vehicular detectors to be adopted in the Penang ATC System are divided into the following functional categories :

- Signal system detector
- Actuation detector
- Detector for map display
- Statistics gathering detector

Signal system detectors are used to determine the parameters of signal control which are selected for every small groups of signalized intersections (also called a Sub-Area). Therefore they are required, in each Sub-area, at the approaches of critical intersections for determination of cycle and split, and both directions of the main route for determination of offset.

Actuation detectors are located in the right turning lane of a critical intersection and at approach of the minor road in which the green time may be shortened before the phase is terminated. Therefore they are required for example at the intersections on Green Lane, Anson Road, Perak Road, Dato Keramat Road, Ayer Itam Road and so on.

Detectors for map display are located in almost all the approaches of an intersection where the traffic queue length or congestion degree are to be measured. One to three detectors are located in each approach depending on the expected length of traffic queue.

Statistics gathering detectors are, in general, required at all the lanes of the roadway at the location between intersections where there are many right or left turning traffic flows.

3.5.2 Standard Installation Location

The signal system detectors are installed to obtain information of traffic flow. Based on information gathered by the signal system detector, the parameters of signal control (i.e. cycle length, split, offset) are selected from the presetting tables. The detectors, in general, shall be installed at 150 meters upstream from the stop line of an intersection.

The actuation detectors are installed for demand actuation, especially on the right turning lane for actuated signal control. The standard actuation detector location is approximately 40 meters upstream from the stop line.

The detectors for map display are installed to measure the length of traffic queue or degree of congestion at intersections. In order to gather the desired information, it is necessary to arrange a series of two or three detectors along the approach of an intersection. In general, a series of two detectors is enough on one approach in the city centre. However, some approaches shall require three detectors ; on approaches where frequent occurrences of heavy congestion are experienced. The standard locations for these detectors are 250 meters, 500 meters and 750 – 1,000 meters upstream from the stop line of an intersection.

The statistics gathering detectors are installed to obtain long term and continuous data of traffic flow, which are useful for future traffic planning, and the evaluation of the traffic control system. The detectors are, in general, installed at all the lanes of the roadway at 150 meters or further, upstream from the stop line.

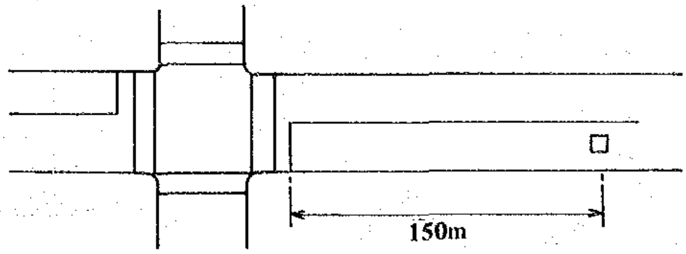
Figure 3.5.1 shows the standard location for the installation of each category of vehicular detectors described above.

3.5.3 Detectors to be installed

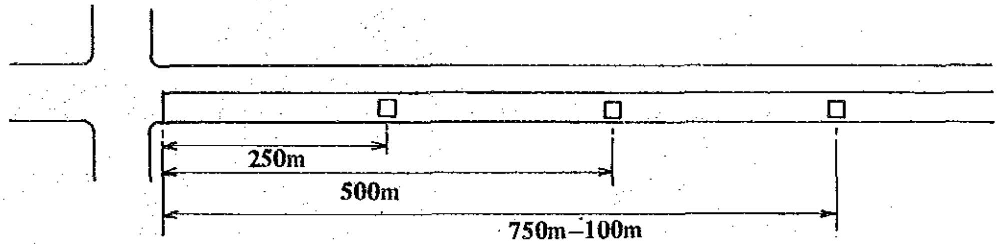
Detectors for different functions except actuation detectors, are occasionally required at almost the same point. In such a case, one detector is installed at the point and it is used for the different two or three functions. Therefore, the actual number of detectors to be installed are enumerated from the locations requiring each functional category of detectors. Thus, there are two hundred and twenty-six (226) detectors in Stage II.

Figure 3.5.2 illustrates the locations of detectors to be installed in Stage II.

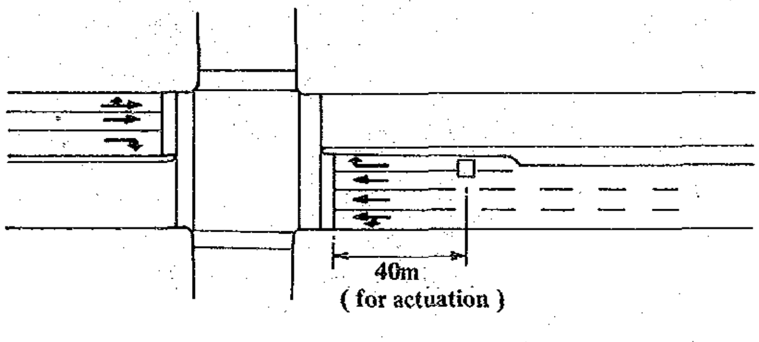
1. **Signal System Detector**



2. **Detector For Map Display**



3. **Actuation Detector**



4. **Statistics Detector**

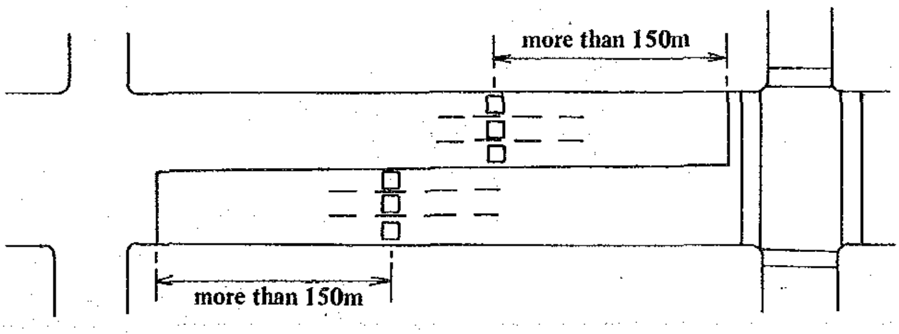


Figure 3.5.1 : Standard Location of Vehicular Detector

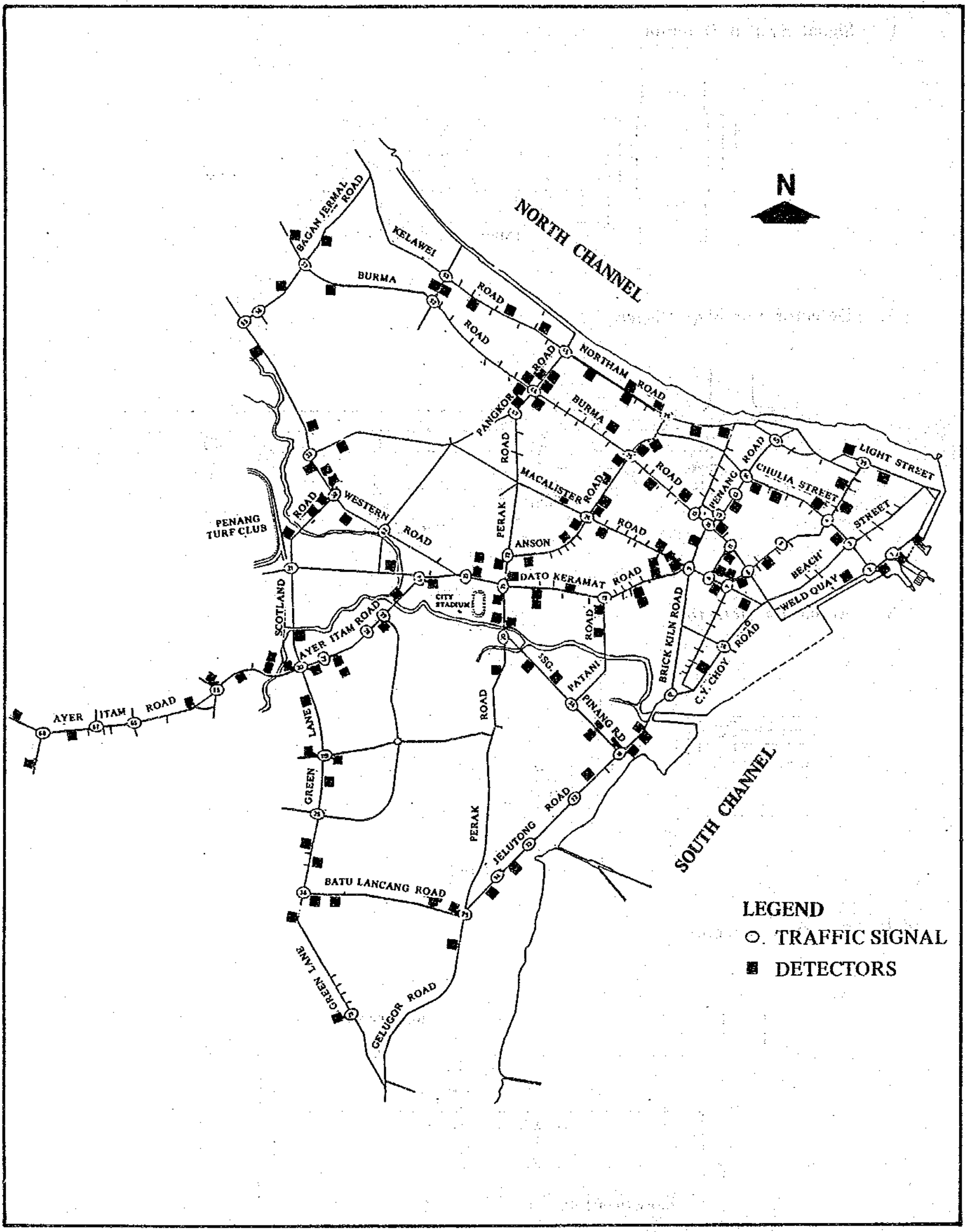


Figure 3.5.2 : Location of Vehicle Detectors in Stage II

3.6 Expressway Surveillance and Control System

3.6.1 Necessity

The necessity and objectives for expressway surveillance and control system are largely similar to that of traffic control on urban street system.

- The periodic congestion bottlenecks must be reduced and the expressway facility must be utilized efficiently.
- When an accident or major incident happens the effect of congestion must be minimised
- Safety of operation must be maximised on the road
- In order to aid drivers in the efficient utilization of the facilities and to reduce their mental and physical stress, necessary information must be provided to drivers.
- Users who have encountered problems (accidents, breakdowns, confusion, etc.) on the expressway have to be aided by necessary means.

3.6.2 Main Function

Main functional differences for expressway system are that entrance ramp control is used instead of signal control on urban street, and, function of detection of incident and its removal is important for expressway.

A. Surveillance System

The monitoring of traffic performance and the monitoring of control system operation is termed surveillance. Generally information provided by the surveillance system is used to :

- select control strategies that are responsive to traffic conditions
- evaluate the effectiveness of control
- detect the occurrence of incidents
- determine the status of control system components

The concept of surveillance is a real-time traffic responsive control system which features electronic surveillance techniques and computer control.

Incidents are a major cause of expressway congestion and it has been determined that significant reductions in delay to drivers can be realised by early detection and removal of incidents. One of the main purposes is to determine the time of occurrence and nature of incidents so that appropriate action can be taken quickly in order to minimize their impact on traffic flow. The provision of surveillance for incident detection and removal on urban street is less common than for expressway because emergency and repair services and alternate routes are usually more readily available.

The following types of surveillance methods used to detect incidents are considered :

- Electronic surveillance

  Incident detection by electronic surveillance is real-time computer monitoring of traffic data from detectors on the roadway to determine when and where incidents have occurred.

- Close circuit television (CCTV)
- Emergency call boxes
- Emergency telephone
- Police and service patrols
- Cooperative motorist-aid

B. Ramp Control

Entrance ramp control is the most widely used form of expressway traffic control. Its objective is the elimination, or at least the reduction of congestion on expressway network. The principle of entrance ramp control is limiting the number of vehicles entering the expressway so that the demand on the expressway itself will not exceed capacity and also, when an accident occurs, by limiting demand to avoid accummulating heavy congestion on expressway. Consequently, some of the traffic desiring to use the expressway will be required to wait at the entrance ramps before being allowed to enter it. Instead of waiting, some vehicles may choose not to use the expressway at all, to enter it from another location, or to enter at another time of day.

Entrance ramp control will offer several direct benefits. Generally, it provides a higher level of service on the expressway. By maintaining noncongested flow or by at least reducing expressway congestion the efficiency and safety of expressway operation are improved.

The following types of entrance ramp control are considered:

- closure
- pretimed metering
- traffic-responsive metering
- merge control
- integrated ramp control

C. **Driver Information System**

Driver information system are used primarily to advise motorists of expressway as well as urban street conditions ahead. They are designed to provide meaningful, real time information that will enable motorists to drive safely and divert to alternate routes if necessary. Also, it is believed to reduce mental and physical aggravation and frustration of motorists.

3.7 Staging Plan of the ATC System Components

The traffic control system staging plan is presented in Figure 3.7.1.

The content of works in each stage of the traffic signal control system, closed circuit television system and driver information system are illustrated in Tables 3.7.1, 3.7.2 and 3.7.3 respectively.

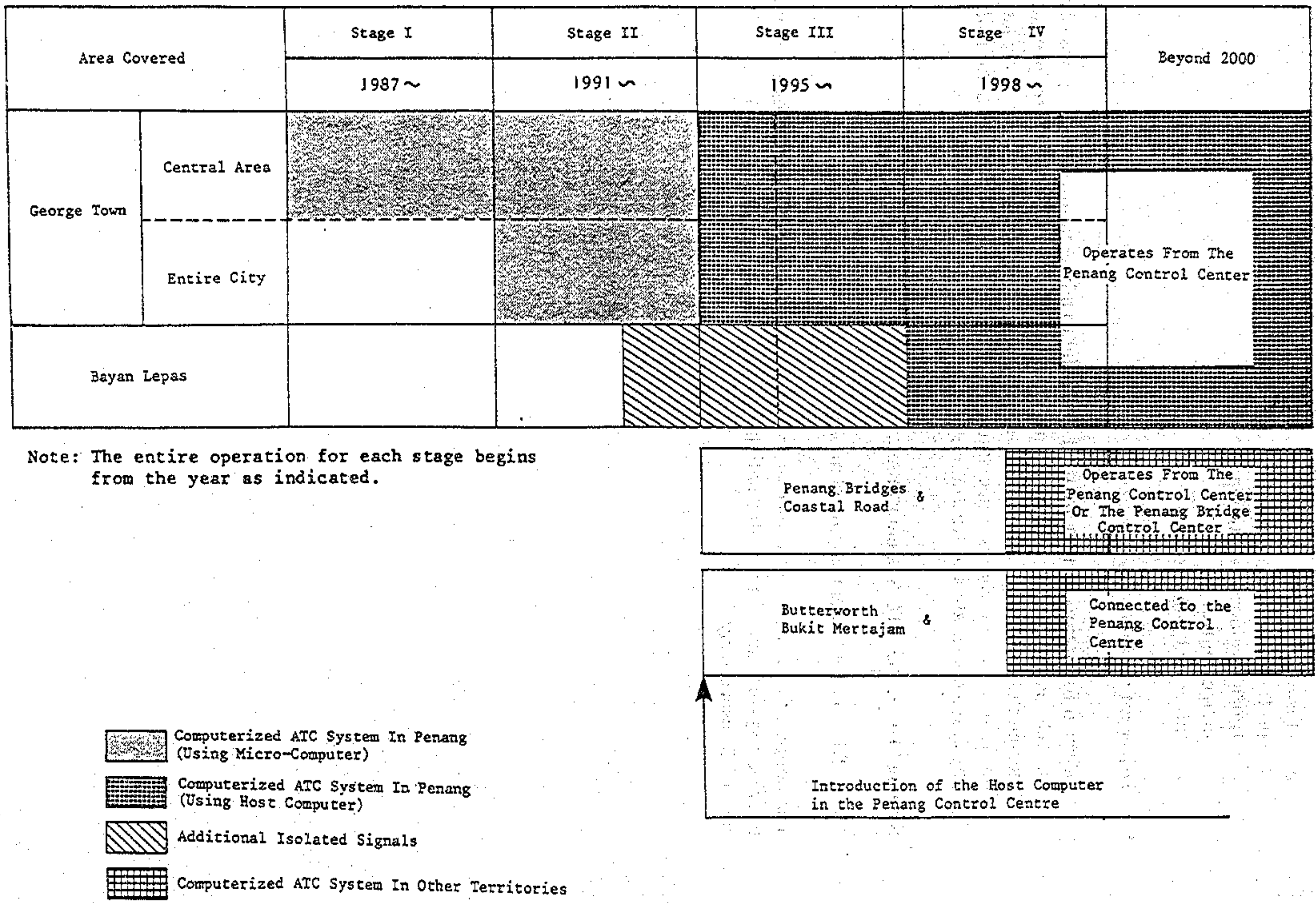


Figure 3.7.1 : Staging Plan of Traffic Control System

Table 3.7.1 : Staging Plan of Traffic Signal Control System

AREA COVERED		Stage I	Stage II	Stage III	Stage IV
		1987 –	1991 –	1995 –	1998 –
George Town	Central Area	Installation of computerized signals at 16 intersections	44 intersections to be controlled by computerized signals	29 intersections of high priority to be controlled by computerized signals	Signalization requirements will be examined along the course of the project and necessary actions will be taken
George Town	Entire City		If other intersections required to be signalized in Stage III, micro-type of local controllers available to be connected to the computer will be adopted	30 intersections of low priority to be controlled by computerized signals	
Bayan Lepas			5 intersections to be controlled by isolated signals, using the micro-type of local controller		Total 30 intersections to be controlled by computerized signals including 5 intersections installed in Stage II
Central Equipment		ATC Micro-Computer (Front-end processor) is introduced in the Control Centre		A host computer and a Front-End processor to be introduced in the Control Centre	A sub-station provided with a Front-End processor to be constructed in Bayan Lepas area
Foreseeable Events		Computerized ATC System in operation since April 1987		Opening of North Coastal Road	

Note : The entire operation for each stage begins from the year as indicated.

Table 3.7.2 : Staging Plan of Closed Circuit Television System

AREA COVERED	Stage I	Stage II	Stage III	Stage IV
	1987 ~	1991 ~	1995 ~	1998 ~
George Town	2 cameras and 2 monitor TV's	8 cameras and 8 monitor TV's	6 cameras and 6 monitor TV's	Necessary actions will be taken
Bayan Lepas				2 cameras and 2 monitor TV's
North Coastal Road and Penang Bridge				.8 cameras and .8 monitor TV's .Necessary actions will be taken
Butterworth & Bukit Mertajam				.Some cameras and monitor TV's .Necessary actions will be taken

Note: The entire operation for each stage begins from the year as indicated.

Table 3.7.3 : Staging Plan of Driver Information System

AREA COVERED	Stage I	Stage II	Stage III	Stage IV
	1987 ~	1991 ~	1995 ~	1998 ~
George Town			2 Changeable Message Signboards	. 3 Changeable Message Signboards . Introduction of a broadcasting system . Introduction of a mobile radio system
Bayan Lepas				2 Changeable Message Signboards
North Coastal Road				8 Changeable Message Signboards
Butterworth & Bukit Mertajam				Necessary actions will be taken

Note: The entire operation for each stage begins from the year as indicated.

3.8 Traffic Engineering Measures related to ATC System

This section introduces the traffic engineering measures related to the ATC System. It is important to implement these measures together with the ATC System in order to enhance its effectiveness.

3.8.1 Traffic Engineering Measures

A. Improvement to Intersections

An intersection is a point where roads cross each other and where the direction of traffic flow changes. Basically a good intersection design can be achieved in the following ways :

1. Construction of Simple Intersection

   As a general rule, the following measures should be taken at established intersections to ensure high capacity and safety.

   (1) avoid having five-leg intersections
   (2) roads should cross each other at right angle
   (3) avoid having two intersections too close to each other.

   Figure 3.8.1 shows typical examples on the simplification of complex intersections.

2. Provision of Additional Lanes at Intersection Approaches

   Additional lanes for turning at the approaches will increase intersection capacity and reduce traffic congestion. Figure 3.8.2 shows typical examples of the provision of several types of additional lanes for turning at intersection.

   For an intersection with a large turning movement, it is necessary to provide two right-turn lanes or two left-turn lanes. For example, at the intersection of Scotland Road/Western Road, it would be reasonable to provide two right-turn lanes on the north side approach of Western Road.

   In this city there are many small intersections along the primary and district roads at the crossings with minor roads and they are close to each other. Under these conditions, it is recommended that right-turn movements or parts thereof from major roads to minor roads or vice-versa be prohibited.

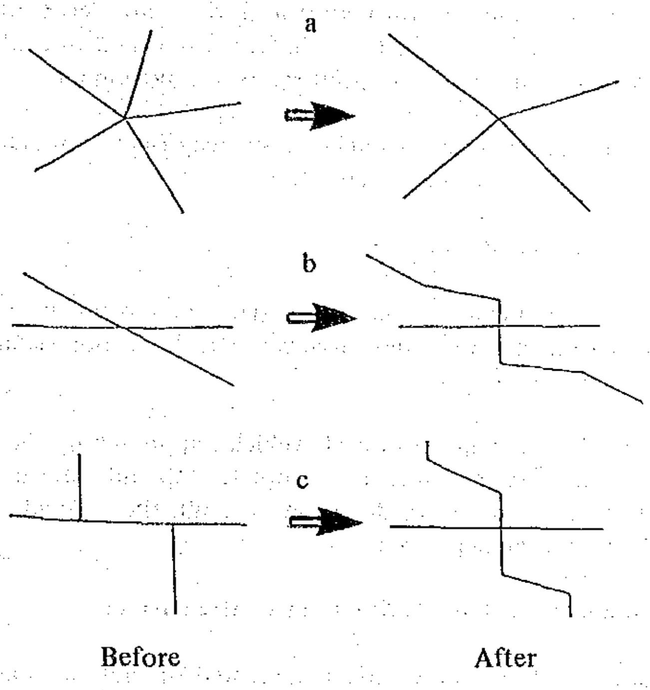


Figure 3.8.1 : Simplification of Complex Intersections

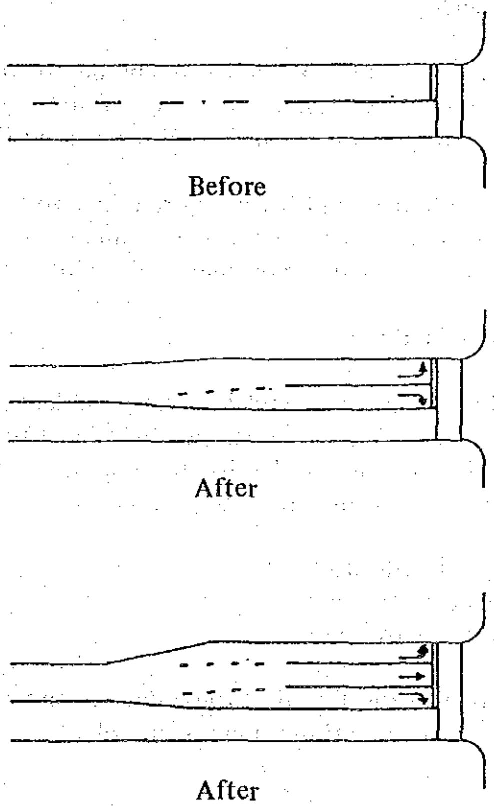


Figure 3.8.2 : Provision of Additional Lanes for Turning at Intersections

The most common turn-control devices are 'no-right turn' signs and symbol markings on the road. Safety islands and/or center dividers can be provided to physically prohibit right-turn movements.

One of the purposes of having a one-way operation is to prohibit turning to certain directions at intersections.

3. Signs and Regulations

It is recommended that stop signs and stop lines be installed on the approaches of minor roadways at their non-signalized intersection with major roadways.

These devices will require all vehicles approaching the intersection from the minor road to come to a complete stop and enter into the intersection only when it is safe to do so. As a result, they provide right-of-way to all vehicles on the major road.

B. Installation of Clear Lane Markings or Centre Divider

Lane markings should be clearly demarcated so that cars and motorcycles can follow the space allocated for them easily, especially at night and during heavy rain.

1. Centre Divider

Centre dividers along main roads should divide traffic flow absolutely into two separate directions and prohibit right-turn movements if necessary. It is useful when the following conditions prevail :

(1) adequate road-width with more than two lanes
(2) major roads with heavy traffic volume
(3) major roads which have many minor intersections

2. Centre-line Marking

Centre-line markings should be clearly marked on high-volume roads such as primary and district roads and some local roads. For clear visibility, it is desirable to use reflective thermo-plastic paint, and to install the following devices onto the painted centre-line :

(1) metal traffic studs
(2) traffic delineators
(3) traffic clatter-bars

This is due to the fact that these devices enhance visibility of the centre line under any conditions and are durable.

3. Lane Line-Marking

Lane line-markings should be used to separate lanes of traffic travelling in the same direction on multi-lane roadways or on wide roads, in order to ensure safety and orderly traffic flow. Such lane markings should also be used to provide outer lanes for bicycles and trishaws so as to separate them from the other vehicles.

C. Signal Control

Properly installed traffic signals will be effective in :

(1) Assigning right-of-way, facilitating traffic movement and increasing the traffic capacity of most intersections.

(2) Reducing certain types of accidents.

(3) Allowing substantial flow of traffic at a reasonable speed along a roadway.

(4) Providing safe pedestrian crossings on roads with heavy traffic.

(5) Enabling easy turning and crossing of vehicles at intersections.

The following measures are suggested regarding signal control :

(1) Roundabout intersections have less capacity for traffic flow than signalized intersections. Signal control has the ability to provide right-of-way for safe passage of crossing pedestrians.

Therefore, it is desirable to convert congested roundabout intersections into signalized intersections. However, it is important to maintain roundabout intersections which have sufficient intersection size, good landscaping, historical monuments and so forth; such as the roundabouts at Gelugor Road/Green Lane, Gurney Drive/Kelawei Road/Tanjong Tokong Road, Light Street/Beach Street, etc.

(2) In order to ensure safety for pedestrian, pedestrian crossing and/or signal should be provided at signalized intersection.

(3) To improve visibility of traffic light, it is recommended that the present obsolete lenses with 65 watt–250 volt screwed bulbs be replaced by new tungsten halogen projector lens bulbs and plastic acrylic lenses.

Also, mast arms for horizontal overhead display of the thirty (30) centimeters lens are recommended at large and busy intersections.

(4) Where traffic signal control is necessary for isolated intersections in the peripheral and out of urban areas, traffic actuated signal-control with four (4) or five (5) patterns of phasing time setting is recommended to achieve higher capacity.

Traffic signals should be linked to each other in a coordinated signal system whenever they are installed close to each other.

(5) Improved computer techniques make it possible to develop more effective progressive movements corresponding with the needs of the traffic situation.

(6) It is desirable to apply yellow and red flashing control at midnight when traffic volume is small in order to reduce delay and to avoid violation of signal rules.

(7) Finally, dimming of traffic signal lights will save energy consumption at night.

3.8.2 Geometric Improvement at Intersection in Stage II

The geometric designs of the intersections which are to be computerised in Stage II are illustrated in the Supplementary Volume : Drawings. The improvement costs of the intersections have been estimated too. Based on these data, the degree of improvement of intersections is classified into three (3) categories based on the improvement cost as shown below :

Major Improvement	:	Improvement cost more than M$50,000
Medium Improvement	:	Improvement cost between M$10,000 – M$50,000
Minor Improvement	:	Improvement cost below M$10,000

The number of intersection require major, medium and minor improvements are four (4), eight (8) and twenty-four (24) respectively. *

The improvement plan for the intersections in Stage II based on the above classification is shown in Figure 3.8.3.

3.8.3 Design Criteria for Phasing and Placement of Signal Faces in Stage II

A. Signal Phasing

1. Typical signal phasing scheme is depicted in Figure 3.8.4.

2. As a general rule, pedestrian crossings and pedestrian crossing signal lights should be installed at an intersection for the convenience and safety of pedestrians. However, its provision will inevitably increase delay time at intersections. In such cases, in order to give priority to pedestrian movement rather than the left turning vehicle movement, it is recommended that warning sign board "Caution : left turning vehicle give way to pedestrian crossing" should be installed to forewarn drivers of crossing pedestrians. These warning signs are only temporary measure as they will become redundant in the future after drivers become familiar with the rule. In particular, the provision of these signs is part of the campaign to educate the drivers. Such type of warning signs are recommended to be placed on three (3) or four (4) of the approaches at the following five (5) locations under Stage II where conflicts of left-turn vehicle movement with pedestrian movement are considered dangerous. These are:

   (1) Intersection No. 4 – Pitt Street/Chulia Street Ghaut

   (2) Intersection No. 16 – Bridge Street/Macallum Street Ghaut

   (3) Intersection No. 31 – Scotland Road/York Road/Batu Gantong Road

   (4) Intersection No. 46 – Pangkor Road/Burma Road

   (5) Intersection No. 74 – Jelutong Road/Perak Close/Tengku Road

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* Improvement costs for other intersections in Stage II are not estimated because either only pedestrian crossing are designed or the intersections are currently being improved.

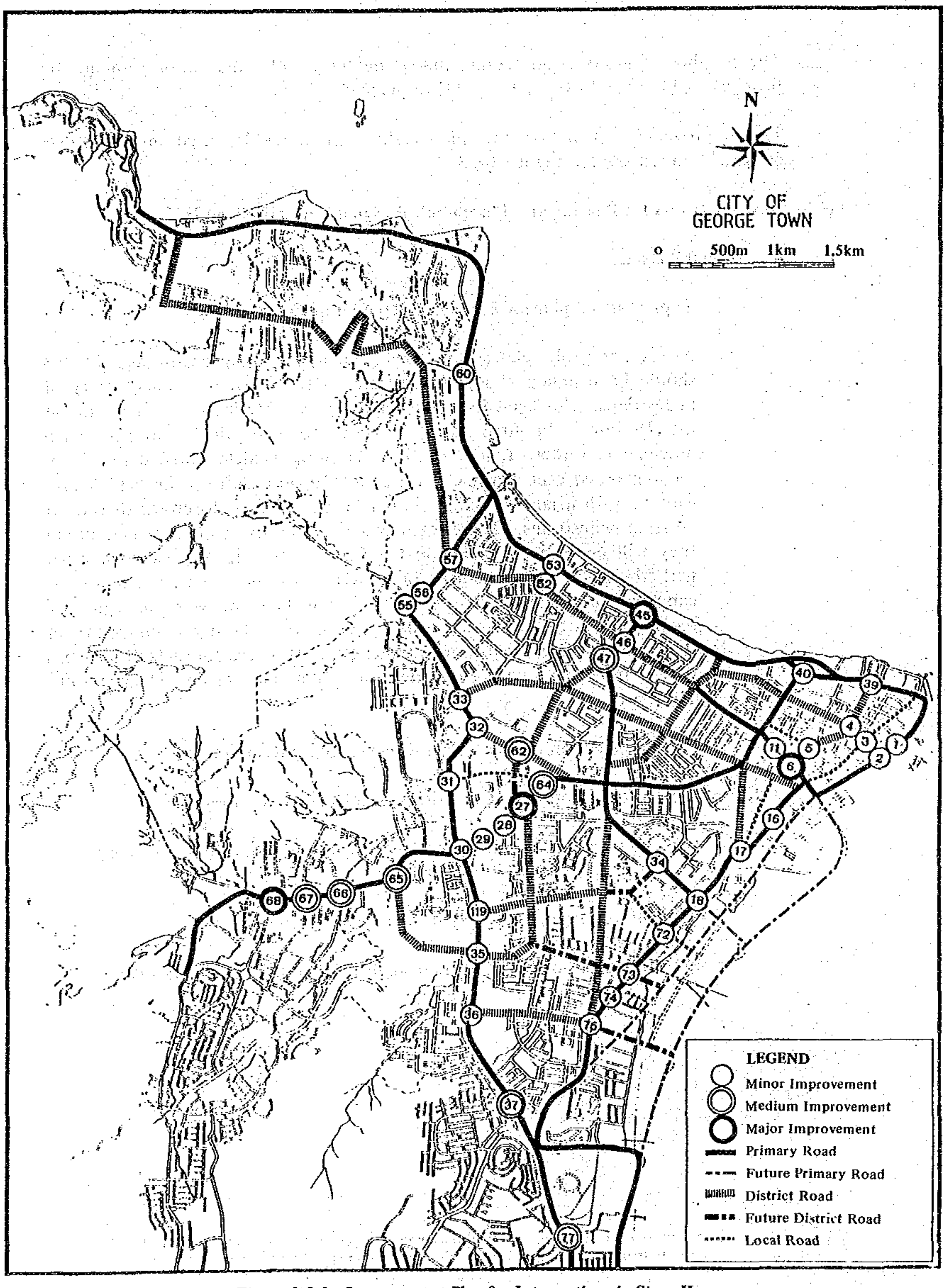
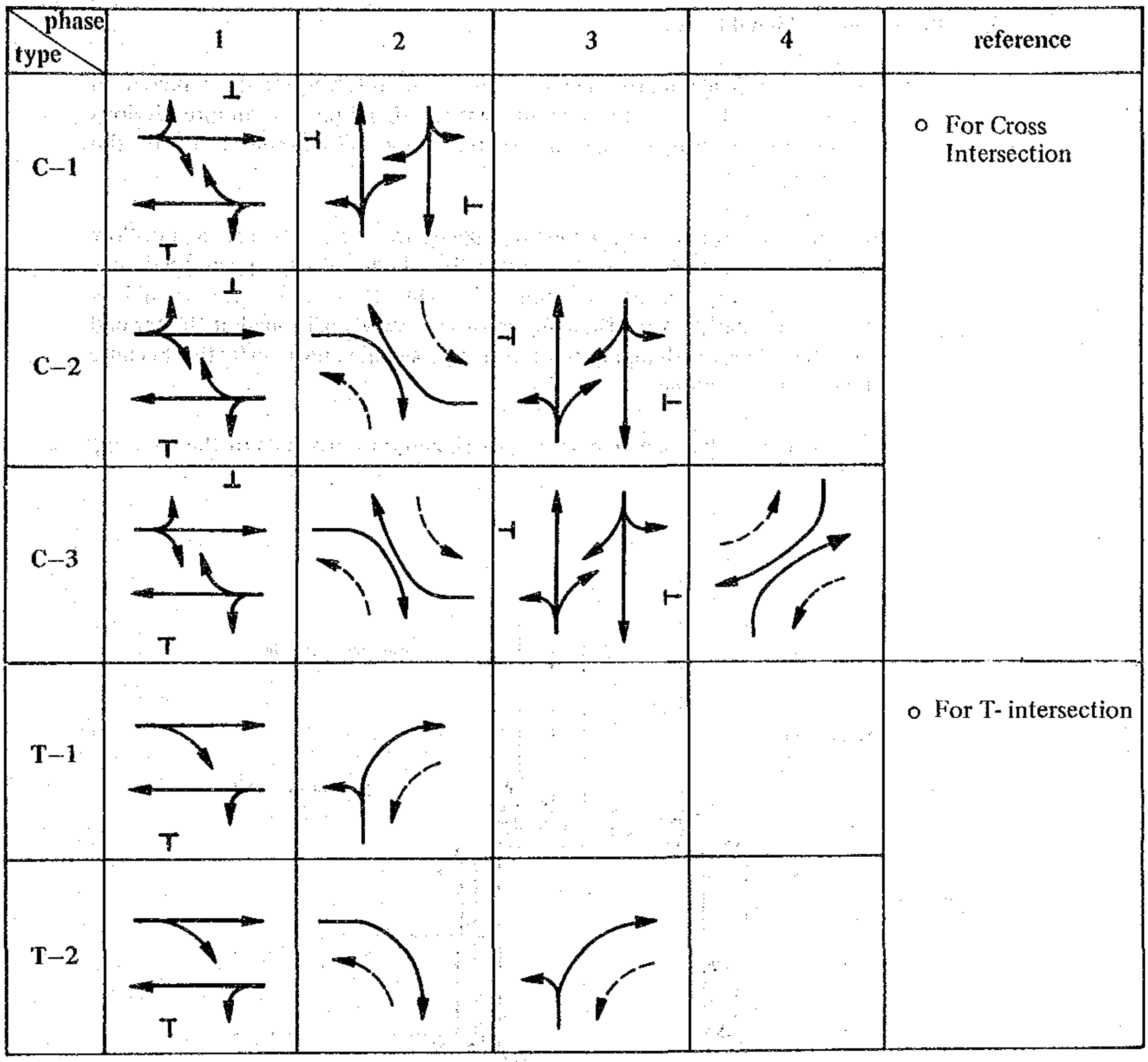


Figure 3.8.3 : Improvement Plan for Intersections in Stage II



Note : (1) In this Figures, Pedestrian movement phasing is not including

(2) Dotted lines with arrow are phases that can be permitted if there is left turn lane on approach.

Figure 3.8.4 : Typical Phasing Schemes

B. **Placement of Signal Faces**

1. The typical placementof signal faces at an intersection is depicted in Figure 3.8.5. It is most important that the signal faces at all intersections are positioned with utmost care so that they can be seen clearly by the on-coming drivers.

2. In principle, primary and secondary signals are positioned for each in-flow direction. A primary signal is normally a pedestal type positioned very near to the stop-line of the approach. On the other hand, a secondary signal is normally an overhanging mast arm type positioned at the far end stop-line. The overhanging mast arm type signal is more effective because of its higher visibility.

3. In principle, pedestrian signals are positioned on both ends of the crossing.

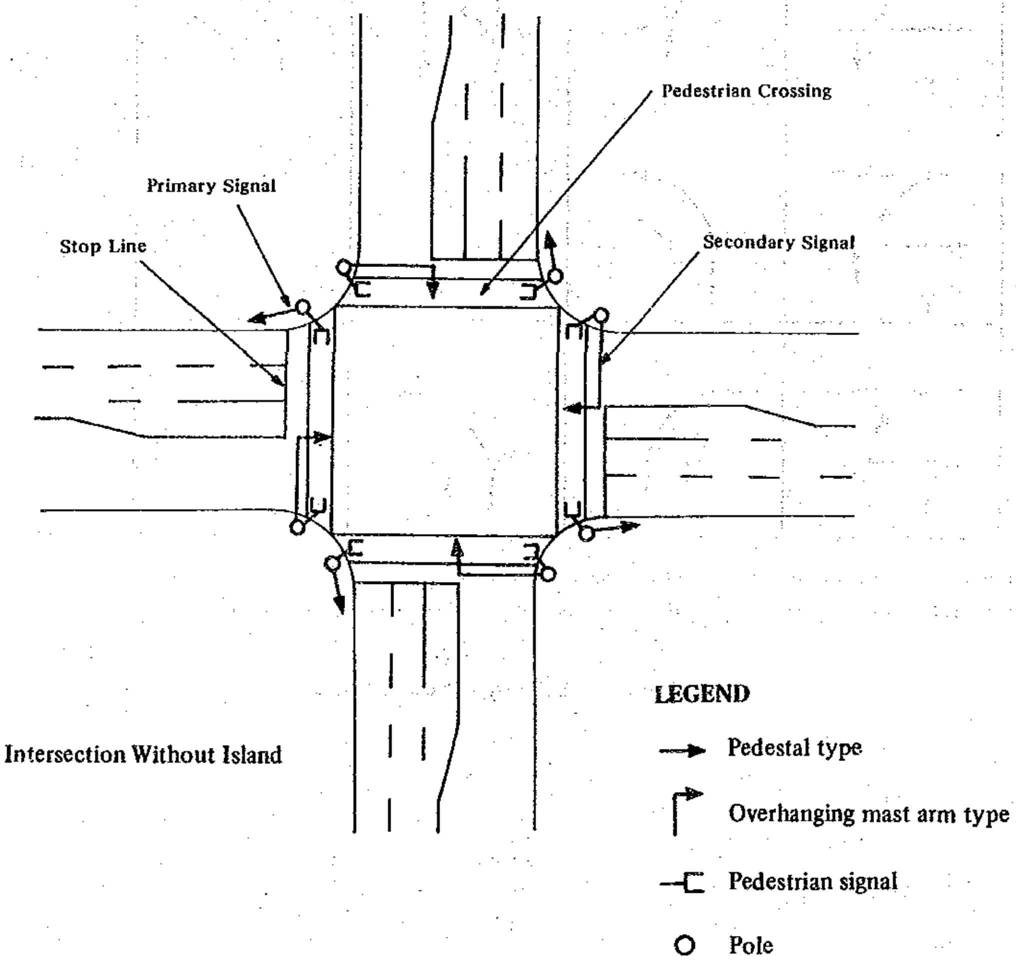


Figure 3.8.5 : Typical Placement of Signal Faces at an Intersection

4.0 CONCEPTUAL HARDWARE STRUCTURE PLAN

4.1 Most Computer System

A micro-computer has been installed in the Stage I system. This computer is developed for signal control including transmissions, and its capacity is sixty-four sets of signal controls.

Thus, additional computers will be requested to perform not only the function of the signal control system, but also several functions of other ATC sub-systems in the expansion plan.

Considering the reliability of the ATC system and several additional ATC sub-systems, a host computer system is recommended for the expansion plan as shown schematically in Figure 4.1.1.

If the host computer system is not introduced, the addition of micro-computers will entail the following problems :

(1) In the case of another micro-computer identical to the existing one introduced, the following problems will appear :

   (a) Synchronization between two micro-computer systems (or more) is required. The equipment will be costly and will have low reliability.

   (b) Management of the two systems is troublesome and complicated; it will result in mistakes by operator as well as responsibilities for the operator.

   (c) Reports are separately generated in the two systems.

(2) The addition of any other function to the micro-computer is difficult, because the micro-computer's performance is largely dedicated to signal control only.

   New functions to be added to the future system include :

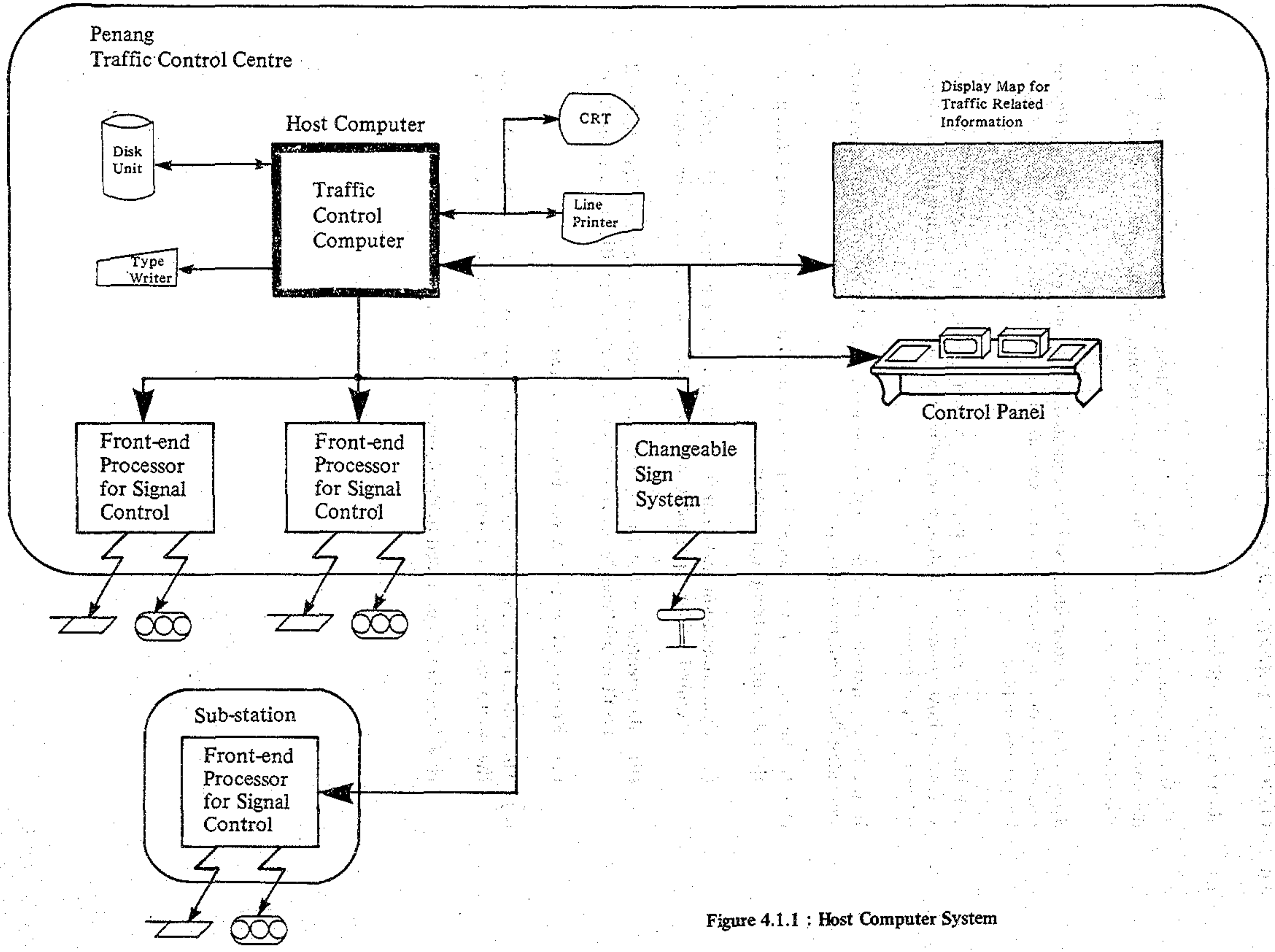


Figure 4.1.1 : Host Computer System

(a) Connecting the related systems such as driver information system, freeway surveillance and control system.

(b) Reinforcement of statistical report-generating function.

(c) Realisation of new ideas for traffic control.

(3) The programs in the micro-computer are written in assembler language, so that it will take a long time and a lot of money to develop any new programs.

(4) For a large scale ATC System, the aid of such machinery namely the CRT display, line printer, and mass storage is necessary to manage the system and to deal with a large quantity of data.

The solution to the above problems lies in the introduction of a host computer system.

4.2. Sub-station System

The accomplish the expansion plan, two alternative expansion concepts are considered :

(1) Installation of all additional front-end processors (or micro-computer) in the existing control centre (Direct Expansion Concept)

(2) Installation of part of additional front-end processors at indoor locations. (Sub-station Concept)

It is preferable to introduce sub-station concept (2) in the Penang System. The reasons are as follows :

(1) Breakdown of one part of the ATC system will only affect traffic flow in the area controlled by the system and not the whole Penang Island.

(2) Total length of the data communication lines will be quite short, as compared with the direct expansion concept, so that the rental cost for the lines will be cheaper.

(3) It is possible to hook-up to other traffic control systems such as the Coastal Road – Penang Bridge and Butterworth and Bukit Mertajam systems.

However, it is necessary to provide indoor space in a public building to accommodate the front-end processors and their related equipment.

4.3 Timing of Host Computer Introduction

The timing of host computer introduction is considered when the number of intersections to be controlled by computerised signals is sixty-five (65) or more because the micro-computer for Stage I system (or front-end processor) is capable of handling only sixty-four (64) signal controls. It is estimated that this will occur between 1991 and 1995.

After 1995, the North Coastal Road will be opened and connected to the Penang Bridge. It is expected that a surveillance and control system for these expressways including the relaying of information regarding traffic flow in George Town will be provided in order to enhance traffic safety and ensure smooth flow.

Thus, the host computer will be able to perform not only for the Penang ATC system, but also for the surveillance and control system for the North Coastal Road and Penang Bridge.

4.4. Traffic Control Centre and Sub-station

The control room for the installation of central equipment is located at the 13th floor of the KOMTAR Tower.

The present control room is not suitable for the expansion of the ATC system as it is too small and its ceiling too low.

Thus, it is necessary either to extend this room or to move to another site when a host computer is introduced and the scale of the system expanded.

In addition, for expansion of the ATC System, an indoor space in a public building in which a front-end processor will be installed in Bayan Lepas Area will be necessary.

4.5 Hardware Structure Staging Plan

Main hardware Structure Plan in each Stage is presented in Figures 4.5.1 to 4.5.3.

Four (4) major systems are provided for traffic control in Penang Island, namely signal control system, driver information system, CCTV system and statistical data collection system. Furthermore, the system will accommodate the expressway surveillance and control system and the traffic control system in Butterworth and Bukit Mertajam area.

The signal control system is mainly composed of a host computer and three (3) micro-computers i.e. front-end processors (FEPs); two FEP's for George Town and one FEP for Bayan Lepas. The FEP has a capacity of controlling sixty-four (64) traffic signals and one hundred (100) vehicle detectors. All FEPs are connected to the host computer via communication lines.

In addition, a micro-computer for driver information system will be necessary.

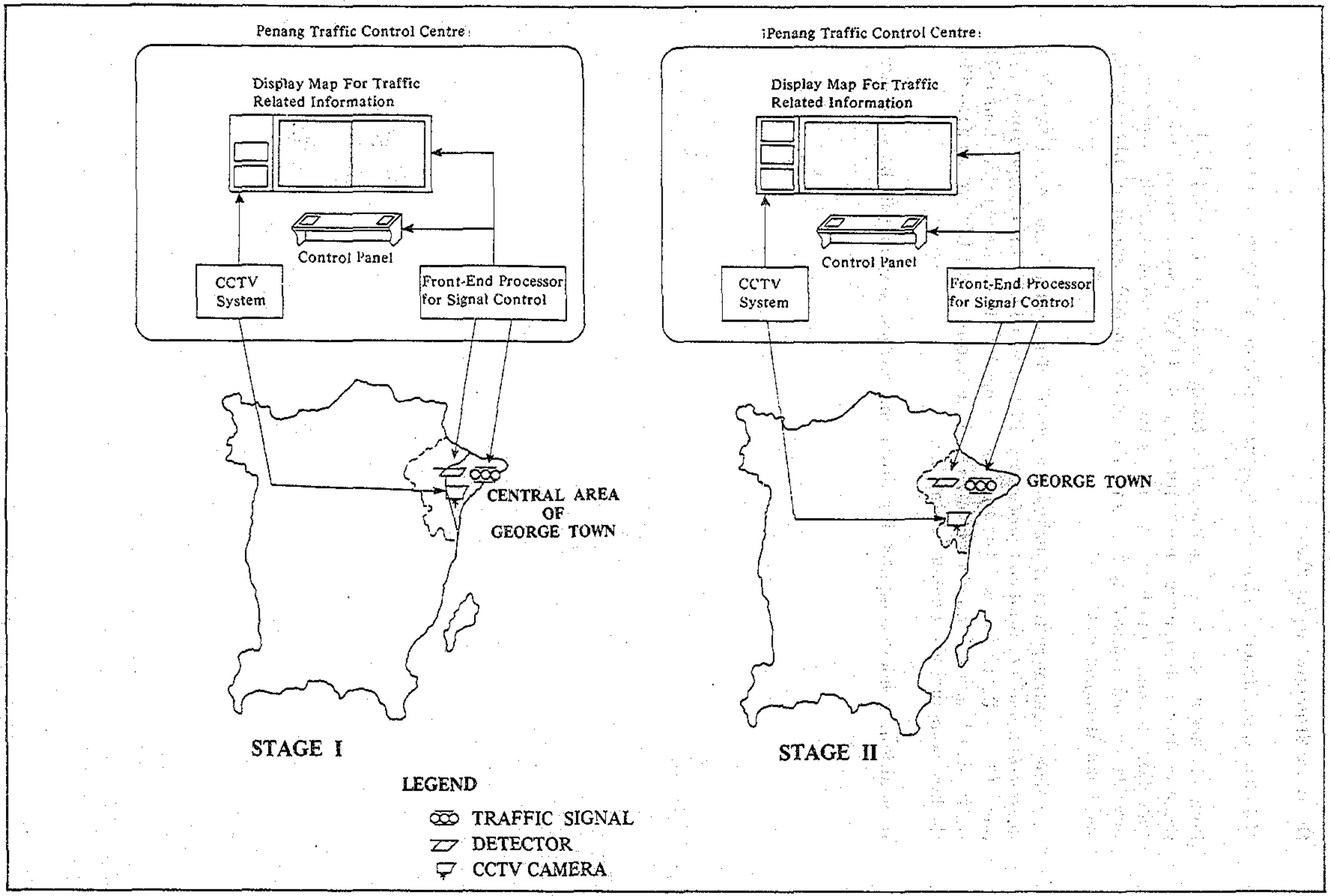


Figure 4.5.1 : Main Hardware Structure Plan in Stages I & II

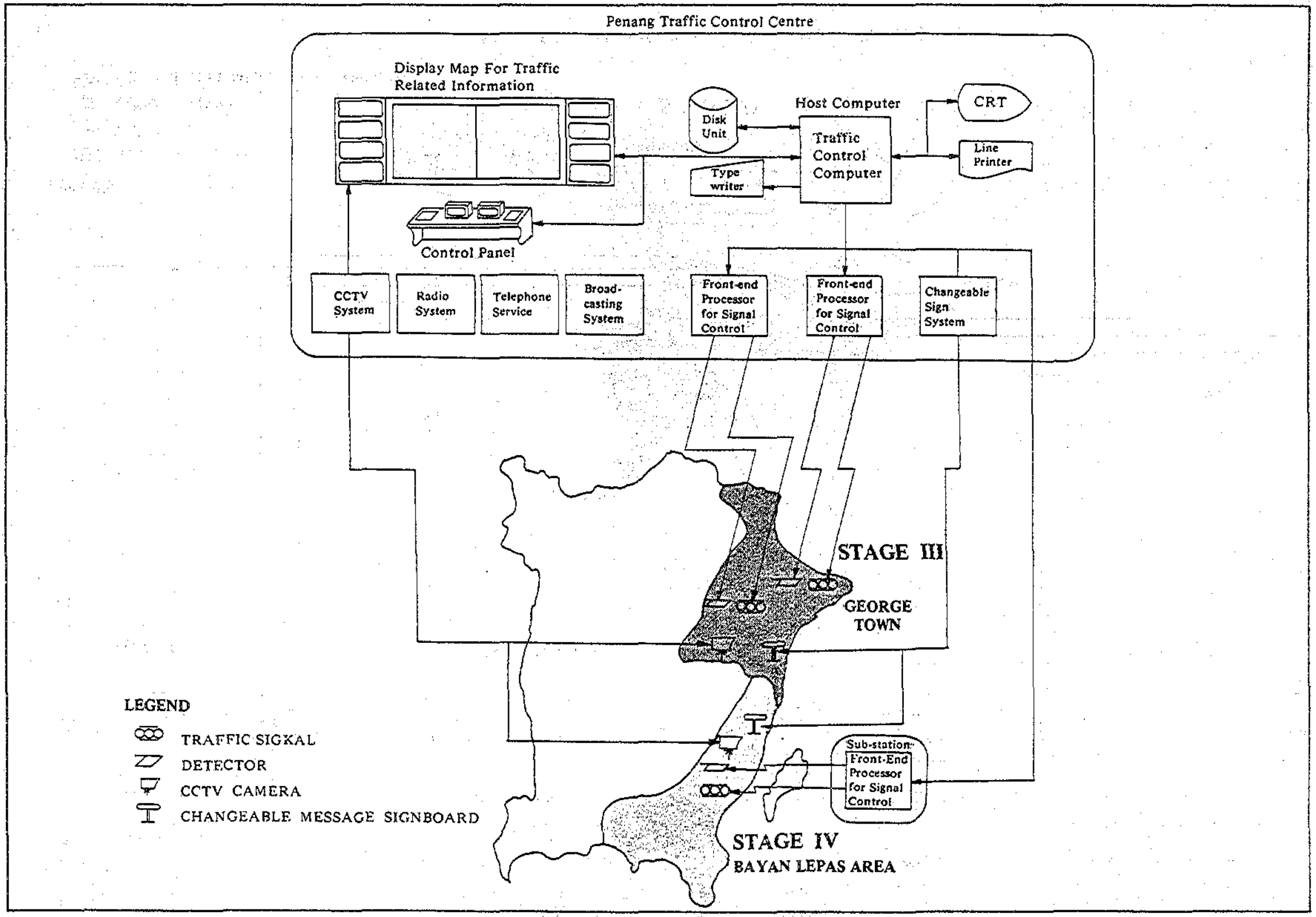


Figure 4.5.2 : Main Hardware Structure Plan In Stages III & IV

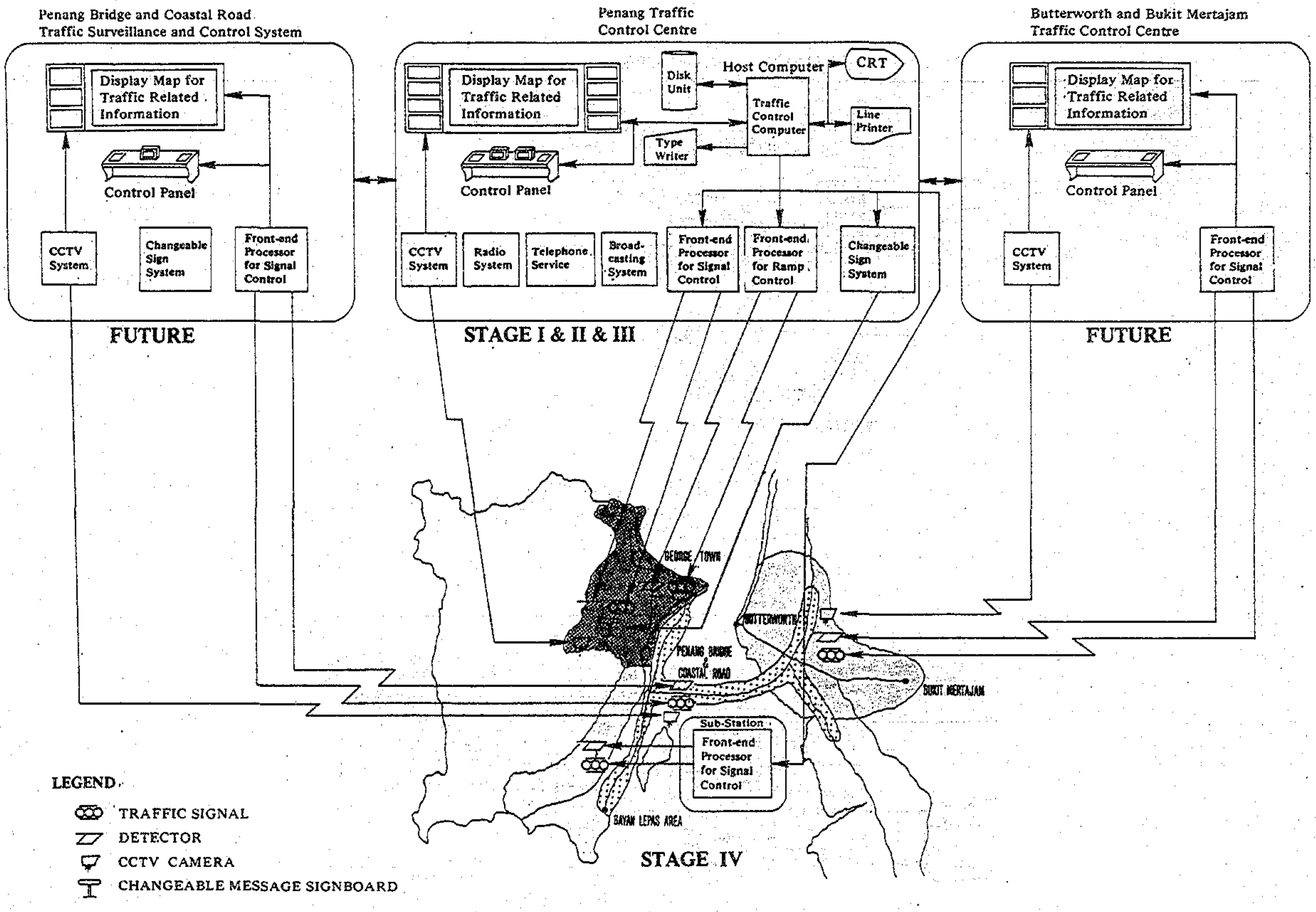


Figure 4.5.3 : Main Hardware Structure Plan in Future Stages

4.6 Management of Traffic Control Centre

The control centre which can be called the Penang Traffic Control Centre under the jurisdiction of the Director of Engineering Department, will consist of one central control centre and one sub-centre as described in the conceptual hardware structure plan. The central control centre will be located in the Engineering Department at KOMTAR and the sub-centre will be located in a government building in Bayan Lepas.

A. Functions of Control Centre

The central control centre and sub-station will assume the following functions and responsibilities.

1. Central Control Centre

(a) To monitor daily traffic conditions and to record continuously statistical data on the traffic conditions.

(b) To initiate special traffic counter-measures in response to road accidents, emergency vehicle usage (fire fighting, etc) parade on roads and other incidents.

(c) To make decision of the countermeasures to be taken to resolve problems on the control of congestion, etc and if necessary to coordinate with other agencies such as police aid services and maintenance crews.

(d) To supervise the overall functioning of all activities in the traffic control centre including those of the sub-station.

2. Sub-centre

(a) To monitor the traffic conditions in Bayan Lepas area and to rely these information to the central control centre.

B. Staff Requirement

The following qualified personnel will be required to operate the expanded ATC System and to discharge the responsibilities required of the control centre.

(i) Senior Engineer (Manager)

- One person who must be a well experienced personnel for traffic management and accident disposal.

- Regular duty (8 hours a day)

– Responsibilities

(Usual case)

- To examine the strategies and procedures already made to improve them to be more compatible with the situations.

(In an emergency)

- To make decision of the countermeasures to be taken after receiving the reports from the staff.

(ii) Traffic Engineer

– One person who must have more than three years experience on traffic engineering work after traffic engineering education at college or university level.

– Regular duty (8 hours a day)

– Responsibilities

  - To analyse the traffic data

  - To adjust the timing parameter

  - Planning of countermeasures to traffic problems

(iii) Electronics Engineer

– One person who must have more than three years of practical experience in related field after electronics education at college or university level.

– Regular duty (8 hours a day)

– Responsibilities

  - To monitor the operations of computer and other equipment

  - First-aid repairs,

  - Periodical inspection,

  - Improvement planning of system.

(iv) Operating, Engineers

– Three persons who must have more than one year experience in operating a similar computer system,

– 24 hour duty (2 or 3 shifts)

– Responsibilities

- To operate the computer system and to input changes to the system as directed by the Traffic Engineer
- To operate the control desk in order to monitor traffic conditions
- To receive messages through emergency telephone call and to confirm the situation in more detail
- To report what has been received to the engineers in charge
- To convey messages such as instruction or direction to other related agencies such as police, fire station, hospital, etc.

C. **Organisation of Staff in accordance to the Staging Plan**

As described in the proceding section, the ATC System will be expanded stepwised in accordance to the Staging Plan and the system will begin to function comprehensively with the introduction of a host computer in Stage III. Therefore, it will be possible to operate a control centre comprehensively in Stage III.

Considering the scale of the ATC System in Stages I and II, it will be necessary to have full-time operators only; the Senior Engineer who makes decision or other engineering personnels will be required only on a part-time basis seconded from the Engineering Department. In Stage III, a "Traffic Management and Control Unit" as an independant unit within the Engineering Department, Majlis Perbandaran Pulau Pinang will be necessary for the efficient and effective operation of the control centre. Then, this unit will have to employ full-time engineering staff. Therefore distribution of staff requirement in each stage is indicated below :

	Stage I	Stage II	Stage III	Stage IV	Stage V
Staff	(1987–1990)	(1991–1994)	(1995–1997)	(1998–2000)	(Beyond 2000)
Senior Engineer	0	0	1	1	1
Traffic Engineer	0	0	1	1	1
Electronics Engineer	0	0	0	0	1
Operating Engineer	1	2	2	3	3
Total	1	2	4	5	6

Note : A Traffic Management and Control Unit will be established in Stage III.

D. Budget for Control Centre

The budget for the operation of the control centre will consist mainly of wages for the required staff and the expenses for system maintenance. The maintenance of the system will be privatised to a specialist contractor.

5.0 APPRAISAL OF THE AREA TRAFFIC CONTROL (ATC) SYSTEM TO BE INTRODUCED

This chapter will deal with the appraisal of the ATC System to be introduced. Comparison is made here between the case with the ATC system and the case without it in terms of economic benefit and other non-quantifiable merits.

5.1 Economic Benefit from the Introduction of the Traffic Signal Control System (TSCS)

Benefit is derived from improvement in traffic patterns. This can be seen by the difference in delay time measured in traffic flow simulation by computer for the cases of 'with' and 'without' computerization.

The delay time can be converted to benefit in monetary value using the two aspects of time value and fuel consumption.

5.1.1 *Computer Simulation*

Several traffic flow models for signal control had been developed. These models can be classified mainly into two types : One is a tool for evaluation of traffic operation on street network (especially signal control) and the other is a tool for optimal signal parameter decision for coordinated signals.

The former class of models are represented by "UTCS–1" developed by FHWA in USA, and "MICSTRAN" and "MACTRAN" developed by the Research Institution of Police Department in Japan. The "UTCS–1" and "MICSTRAN" models are microscopic simulation models dealing with each vehicle movement, but they have limit of the computing time and memory range when simulating a wide-area road network.

"MACTRAN" is a macroscopic simulation model that simulates traffic flow on a road like liquid flow. However, most of this kind of models do not have a function of detector data simulation, so that the models are not capable of evaluating the effect on on-line signal control.

On the other hand, there are simulation models to determine the optimal signal parameters for the coordinated signals. The main models are "SIGOP", developed by FHWA in USA and "TRANSYT" by TRRL in Britain and are used frequently worldwide. This type of model describes the platooning behaviour of traffic flow, calculates the performance index of the network for given set of signal timing, and determines an optimization by a procedure which makes changes to signal timing and judges whether or not the performance index is reduced.

"SCOOT", "ASCOT", "UTCS" programs have been developed for efficient and effective real-time traffic control system. The objective is to calculate optimal signal parameters in on-line responding to the existing traffic conditions obtained from detectors and to update the parameters automatically.

However, these programs are adopted experimentally in real world situation.

A. Outline of the Simulation Model

A traffic flow simulation method developed by committee members of The Association of Traffic Control Facility in Japan has been adopted for application in this Study.

Reference reports of the simulation method are :

"Evaluation of Signal Control by Simulation Experiments" by Shinji Mukai, Masahiko Katakura and others in a lecture of Civil Enineering Planning Study in October 1986.

"Evaluation of Signal Control by Simulation Model" in the report by Association of Traffic Control Facility in Japan.

This simulation model has been developed mainly for the evaluation of coordinated signal control in strategies and timing.

The main characteristics of the model are:

(1) The model is a macroscopic simulation model, and the traffic flow is described as liquid flow of continuous flow to shorten the calculation time and to cover the wide-area road network.

(2) The model can output simulated traffic volume and occupancy on traffic detector which can be located at any place on a road link.

(3) The model deals with each car movement in traffic flow to detect arrival of car at traffic detector and to simulate right turning car movement at intersections. The program can convert car movement from continuous flow to discreet flow.

(4) The model considers short-term variation (or random) such as car arrival rate, saturation flow of intersection approach, and traffic density in congestion situation.

(5) The model considers spreading of platoon.

The following describes briefly this simulation model:

1. **Composition of the Model**

The model comprised (1) Sector of traffic signal control, (2) Sector of traffic flow and (3) Sector of traffic detector. Figure 5.1.1 shows the flow chart of the program.

2. **Description of Traffic Flow**

The traffic flow is dealt with on a link between intersections being divided into small blocks of unit length (The unit length is decided by the progressive speed or average speed). Traffic flow rate from a block to the adjacent downstream block is decided by interpretation of the existing vehicle number in both blocks.

The traffic flow movement from a link to another link (at intersection) is treated as follows:

. the traffic flow is categorized by directions before hand

. according to signal timing parameters, the categoried flow (for example, turning flow) moves to the downstream link if congestion is not present at the downstream link

. the treatment of right turning movement is different between the cases with or without right turning lane and also between the cases with or without arrow signal for right turn cars

In the case of without arrow signal for the right turning cars the gap acceptance criterion on the opposite traffic flow is adopted after converting from continuous traffic flow movements to each car movement.

3. **Treatment of Traffic Detector Information**

Detector information such as traffic volumes, headway and occupancy are output by the Detector Sector.

4. **Signal Control**

This simulation model is capable of treating dynamic programs of signal control timing such as split control, actuated control, etc., based on detector data output by the Detector Sector.

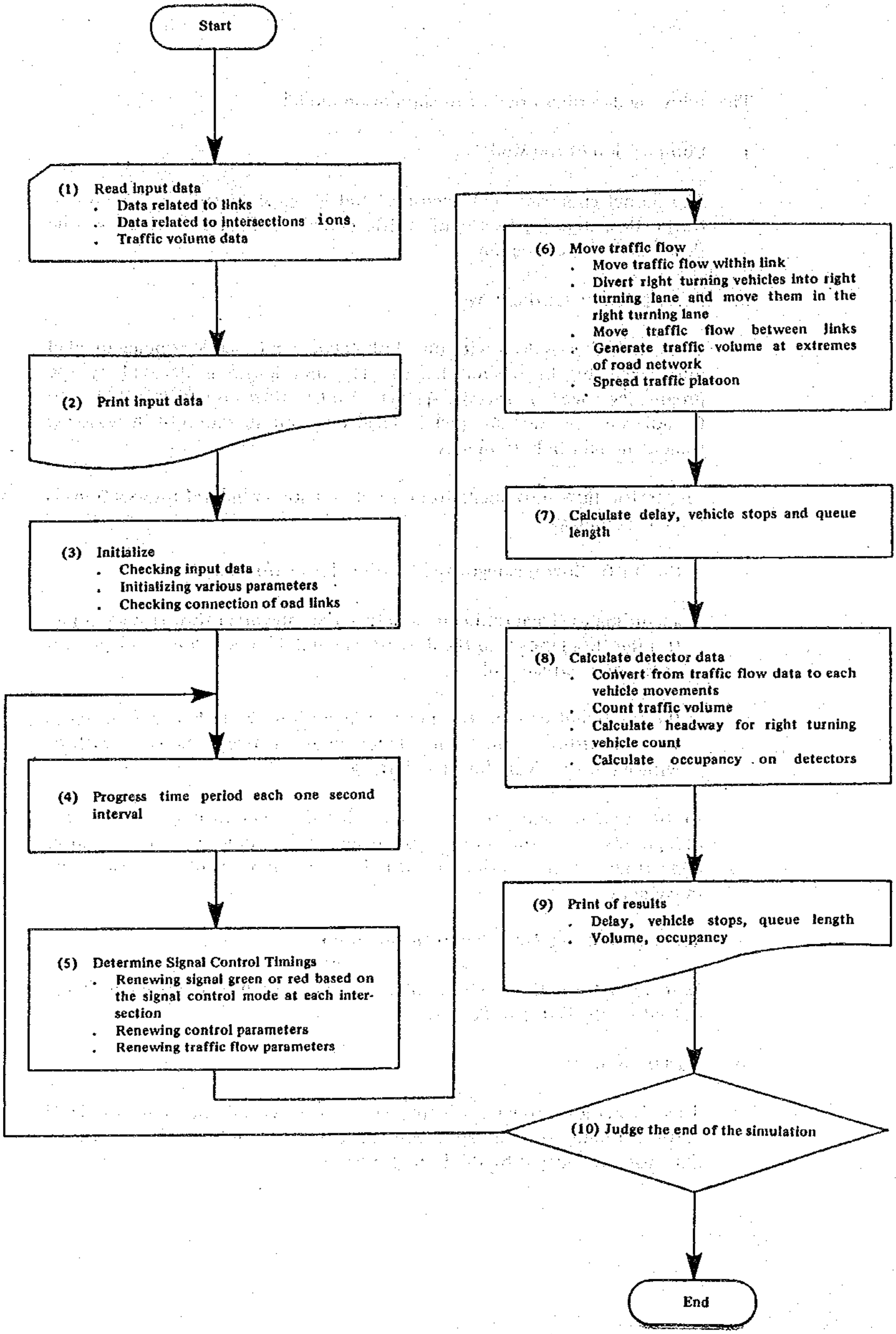


Figure 5.1.1 : Composition and Procedure of Simulation Model

However, in the trial, the signal control timing was input before hand using actual signal timings at intersections for no-improvement signal condition, and as for area control signal condition, the signal timings, which are most likely to be exhibited under the traffic conditions where the simulation are executed, were prepared before hand.

5. **Output results**

This model gives the following outputs at each approach of intersection :

. delay time and total delay time
. vehicle stops
. traffic volume
. occupancy on detectors
. queue length

B. **Simulation Cases**

The simulation area covers the following six (6) routes which include forty-five (45) major intersections in George Town.

Route		Number of Intersection
Route I	: Penang Road and Magazine Road	8
Route II	: Northam Road	3
Route III	: Perak Road and Anson Road	10
Route IV	: Bridge Street and Jelutong Road	7
Route V	: Ayer Itam Road	10
Route VI	: Green Lane	7
	Total	45

Figure 5.1.2 depicts the location map of the intersections covered in the simulation.

A total of twelve (12) simulation cases as shown in Table 5.1.1 was executed. This involved executing simulations of the situation at one morning peak-hour and one evening peak-hour in both cases of isolated and computerised signalisation according to existing (1986) and future (1990 & 1994) situations.

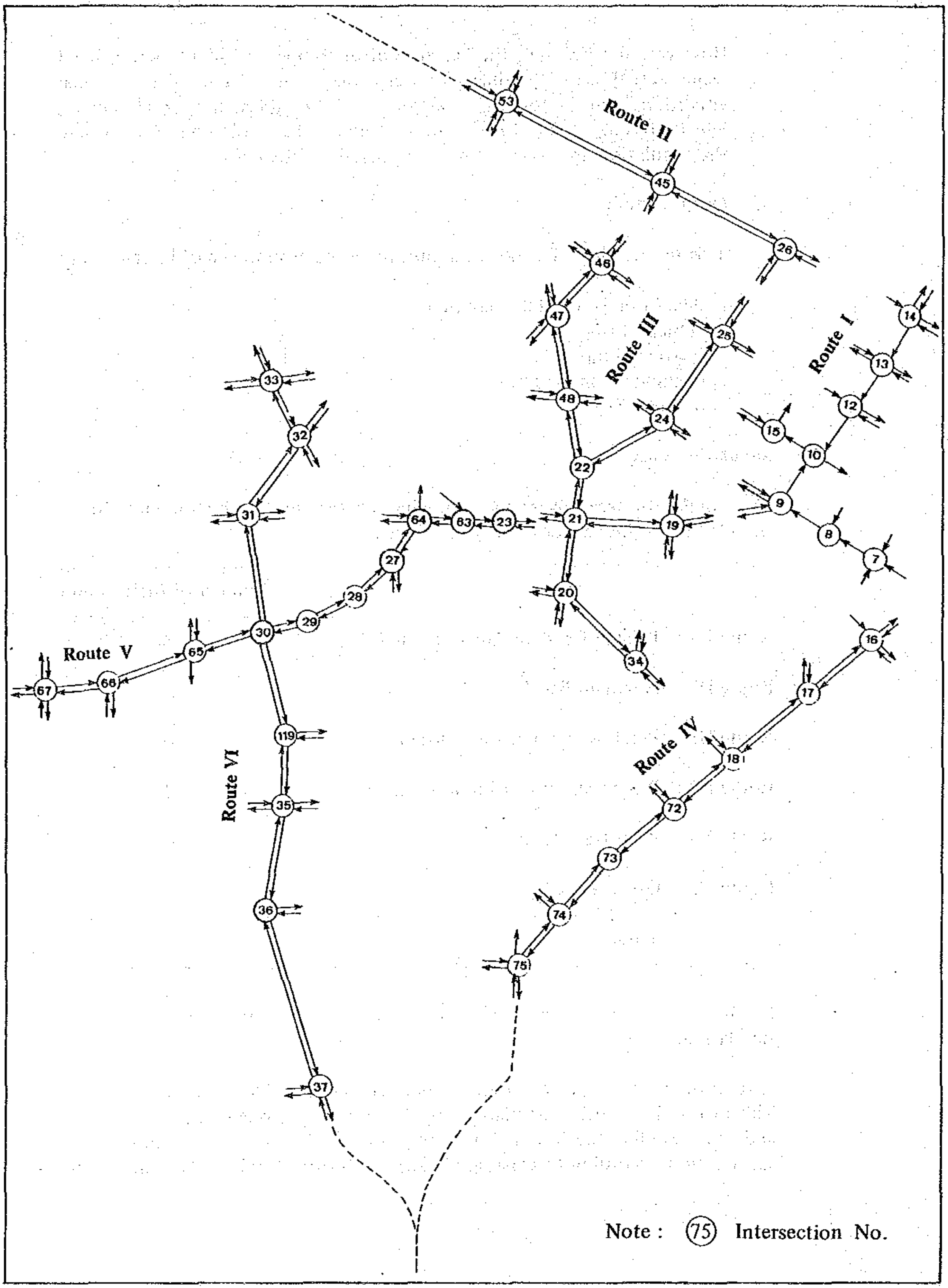


Figure 5.1.2 : Location Map of the Intersections Included in Simulation

Table 5.1.1 : Simulation Cases

Traffic Volume		Signal Operation	
		Without TSCS	With TSCS
Present (1986)	Morning Peak (1 hour)	No. 1	No. 2
	Evening Peak (1 hour)	No. 3	No. 4
Future (1990)	Morning Peak (1 hour)	No. 5	No. 6
	Evening Peak (1 hour)	No. 7	No. 8
Future (1994)	Morning Peak (1 hour)	No. 9	No. 10
	Evening Peak (1 hour)	No. 11	No. 12

In this exercise, the following conditions are assumed :

1. **1986 Situation**

   a. Geometric structure of streest and intersections

      The existing ones in 1986 are adopted, except in Ayer Itam Road/ Green Lane junction where the flyover which is under construction* is assumed to be functioning.

   b. Traffic volumes input

      Traffic volumes which were surveyed by the study team in September, 1986, were applied.

   c. Signal Timing

      In the case of 'without TSCS', existing timings were adopted.

      In the case of 'with TSCS', newly designed timing plans which are most likely to be exhibited under the traffic conditions where the simulation was executed were adopted.

* When the simulation was executed, the flyover was still under construction.

2. **1990/1994 Situation**

a. Geometric structure of streets and intersections

The same as those in 1986 situation were adopted.

b. Traffic volumes input

Traffic volumes which were projected in 1990 and 1994 by the study team were adopted.

c. Signal timing

In the case of 'without TSCS', existing timing were adopted.

In the case of 'with TSCS', newly designed timing plans which are most likely to be exhibited under the traffic conditions where the simulation was executed were adopted.

C. Result of Simulation

Simulation cases No. 1 and No. 3 reproduce the existing situation. The accuracy of the simulations is examined by a comparison with the traffic survey data.

Table 5.1.2 shows the comparison of delay time between the simulated result and survey data for eight (8) critical intersections. The table shows that although the differences for some intersections appear large when examined individually, the overall result for the eight (8) intersections reveal that compared to the survey data, the simulated delay time at morning and evening peak are 1.21 and 0.92 times respectively.

Next, Table 5.1.3 shows the comparison of delay time between simulated result and survey data for four (4) routes. Likewise, differences are observed when the routes are examined individually but on the whole, compared to the survey data, the simulated total delay time at morning and evening peak are 1.12 and 1.01 times respectively.

Two routes that is Route V : Ayer Itam Road and Route VI : Green Lane, have been left out in the above mentioned examination because at intersection No. 30, which is the intersection of Ayer Itam Road/Green Lane, construction work for a flyover was on-going when the simulation was executed.

Table 5.1.2 : Comparison of Delay Time Between The Results Of Survey And Simulation At Critical Intersections

Intersection		Morning		Evening	
No.	Name	Survey	Simulation	Survey	Simulation
21	Perak Road/Dato Keramat Road	379	418.6	787	547.5
9	Magazine Circus	186	230.8	403	249.6
10	Burma Road/Penang Road	160	122.1	174	187.0
74	Perak Close/Jelutong Road	124	222.9	235	196.4
75	Perak Road/Jelutong Road	117+	237.4	128+	258.4
18	Jelutong Road/Sg Pinang Road	52	24.6	127	168.7
19	Patani Road/Dato Keramat Road	52+	38.5	94+	177.7
20	Perak Road/Sg Pinang Road	61	70.7	158	154.1
	Total	1131	1365.6 (1.21)	2106	1939.0 (0.92)

\+ Delay time not including all approaches.

( ) Ratio of simulation to survey results.

Table 5.1.3 : Comparison of Delay Time Between The Results Of Survey And Simulation On Main Routes

Route		Number Of Intersection	Morning			Evening		
No.	Name		Survey (A) (hrs)	Simulation (B) (hrs)	(B)/(A)	Survey (A) (hrs)	Simulation (B) (hrs)	(B)/(A)
I	Penang Road and Magazine Road	8	435	358.7	0.82	747	685.1	0.92
II	Northam Road	3	26	26.0	1.01	55	21.9	0.40
III	Perak Road and Anson Road	10	670	718.4	1.07	1363	1336.5	0.98
IV	Bridge Street and Jelutong Road	7	417	633.0	1.52	686	822.3	1.20
	Total	28	1548	1736.1	1.12	2851	2865.8	1.01