5.6 Road Maintenance

5.6.1 Introduction

The purpose of maintenance and repair operations are to sustain the roads and associated facilities as initially constructed or as later improved, so that traffic safety, smooth traffic flow and comfort will be achieved on the expressways and highways.

The maintenance works can be classified as follows:-

1) Inspection

Inspections are performed to repair road and maintain them in such condition that no hinderance to traffic will occur.

2) Road Cleaning

Road cleaning involves removing dirt and trash from the road surface and various facilities as to keep the surface clean and avoid traffic obstruction.

3) Vegetation Control

Vegetation control consists of cultivating new growth, maintaining full-grown vegetation and renewing old and falling vegetation so that grass, plants and trees can fulfill their intended purposes of providing mental refreshment for drivers, creation of scenic beauty and conservation of environment.

4) Repairs

Repairs include repair of pavement, earth works, traffic control facility, bridge, tunnel, etc.

5) Maintenance of Road Fixtures, Fittings and Equipment

This item includes the daily inspection, maintenance and repair of buildings, machinery and electrical equipment as well as communication facilities.

Specifically for the establishment of a traffic control and management system master plan, only inspection and traffic control for road maintenance will be dealt with in this section.

5.6.2 Patrolling, Inspection and Reports

Daily patrolling along the expressway and highway is a basic but essential activity for maintenance work. This is to detect or identify those defects that may post a danger or serious inconvenience to users such as traffic accidents, spillage of bulk hazardous liquid material, major structural collapses, sink holes or major earth slips. As such, inspection must be carried out to correctly understand, estimate and evaluate road conditions and utilization patterns.

The three categories of road inspections that will be performed to repair roads and maintain them in such condition that no hindrance to ordinary traffic or others will occur are daily inspection, periodic inspection and extra inspections.

1) Daily Inspections

In principle, road patrol is performed once a day to conduct regular inspection of road conditions and to grasp utilization patterns.

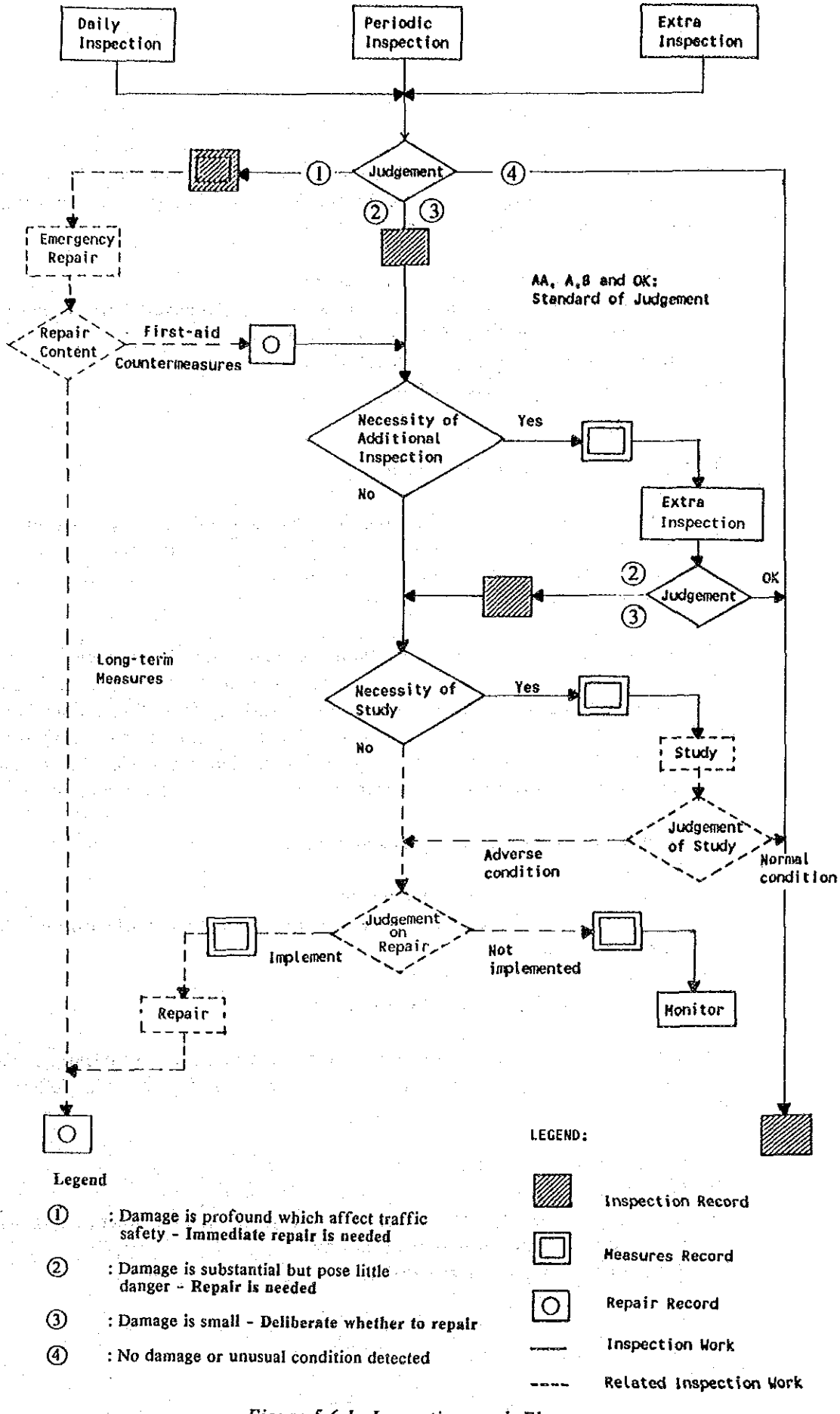
2) Periodic Inspections

Periodic inspection on foot is conducted on the nearest possible approaches to all structures including signs and road surface once or twice a year.

3) Extra Inspections

Extra inspections are performed when needed, such as during the rainy season, before and after the typhoon season and after concentrated heavy rains.

The findings obtained from the inspections must be recorded on an adequate format. The maintenance programme will be established based on the inspection reports. Figure 5.6.1 depicts the inspection work flow in terms of the coordination amongst inspection, study, repair and monitoring.



Legend

① : Damage is profound which affect traffic safety - **Immediate repair is needed**

② : Damage is substantial but pose little danger - **Repair is needed**

③ : Damage is small - **Deliberate whether to repair**

④ : No damage or unusual condition detected

Figure 5.6.1: Inspection work Flow

In 1988, Malaysian Highway Authority has prepared a Maintenance Manual for Expressway and Highway. Nonetheless, the following matters are recommended to make the manual more practical and efficient.

i) to identify the inspection item and its frequency;
ii) to establish the inspection record formats and their analysis method. For this purpose, road inventory data is very useful;
iii) organization set-up for the inspection works;
iv) preparation of inspection manual.

5.6.3 Traffic Control for Road Maintenance

Certain road maintenance activities require the closure of part of the expressway and thus create disturbances to the traffic flow. To minimize the possibility of accidents, traffic congestion and inconvenience to road users, road maintenance planning and appropriate traffic control are essential.

The objectives of road maintenance planning is to minimize disturbances to traffic flow such as the use of collective repair work method and finding suitable time period for repairs or maintenance like night time and holidays. While objective of traffic control for road maintenance is to provide information and warning to on-coming vehicles about maintenance work being carried out ahead, the common road maintenance work requiring systematic traffic control and regulation are:-

i) Overlay of pavement and pavement repairs
ii) Lane marking
iii) Road cleaning and vegetation control
iv) Traffic safety facilities maintenance (eg. guardrail, signboard cleaning, etc.)
v) Painting of bridges
vi) Erection and cleaning of noise barrier
vii) Others (like transmission cable work, etc.)

Similar to traffic regulation measures undertaken when accident occurs, traffic regulation measures undertaken for road maintenance may take the following form:-

i) Closure of road shoulders
ii) Closure of one lane
iii) Closure of one carriageway and diversion of traffic into the other carriageway to function as a two directional roadway
iv) Temporary reduction of speed limit

Figure 5.6.2 illustrates an example of a traffic control and regulation on an expressway requiring the closure of one lane for road maintenance work.

The above-mentioned Maintenance Manual prepared by MHA should include the traffic regulation measures undertaken for road maintenance.

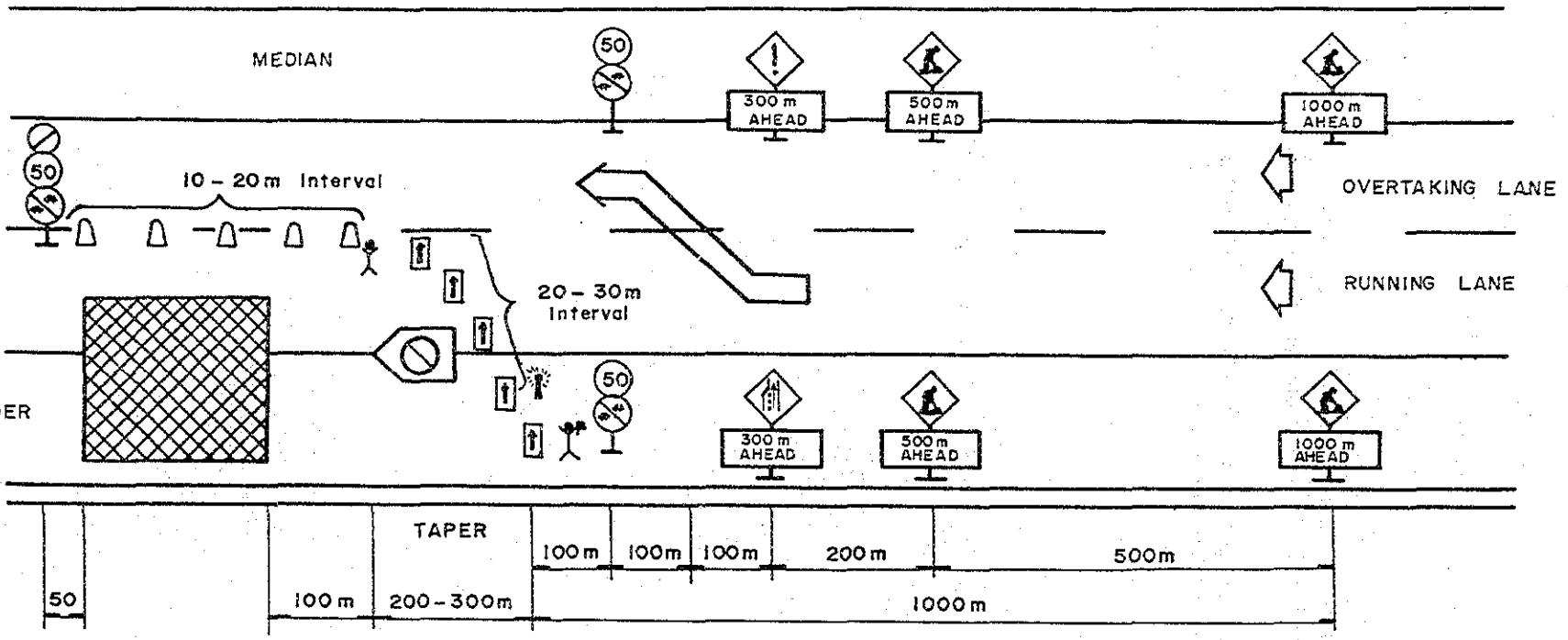


Figure 5.6.2: Traffic Control Requiring Closure of One-Lane for Road Maintenance

5.7 Traffic Safety

5.7.1 Scope of Traffic Safety

The traffic safety proposals cover mainly two basic functions, i.e. accident prevention and minimization of damages to road users and properties.

The three factors governing the occurrence of traffic accidents are:-

i) Traffic and road environment
ii) Road users
iii) Vehicles

Countermeasures against traffic accident must comprise measures both to prevent the occurrence of accident itself and to minimize the injuries of road users.

The component of traffic safety is shown in Figure 5.7.1. Basically, safety measures for accident prevention is illustrated in Nos.1 to 5 and minimizing damage by accidents is depicted in No.6 in the figure.

Accident analysis (No.7) is not directly related to these two functions but it is closely related to proposal of appropriate traffic safety plans and measures in the future.

The basic promotion of traffic safety can be conducted through 3E methods, that is Engineering, Enforcement and Education. However another E, that of Environment has been added to this approach due to the recent increase in the awareness of the role of environment on human behaviour. Engineering is responsible for highway design, construction, etc. as well as design of vehicle from the safety viewpoint. Enforcement is vital in ensuring smooth traffic flow and comply of traffic regulations. Education is useful in instilling consciousness, attitude, skills and knowledge of traffic safety.

The introduction of such a comprehensive approach can be expected to prevent accident and thereby enhance traffic safety.

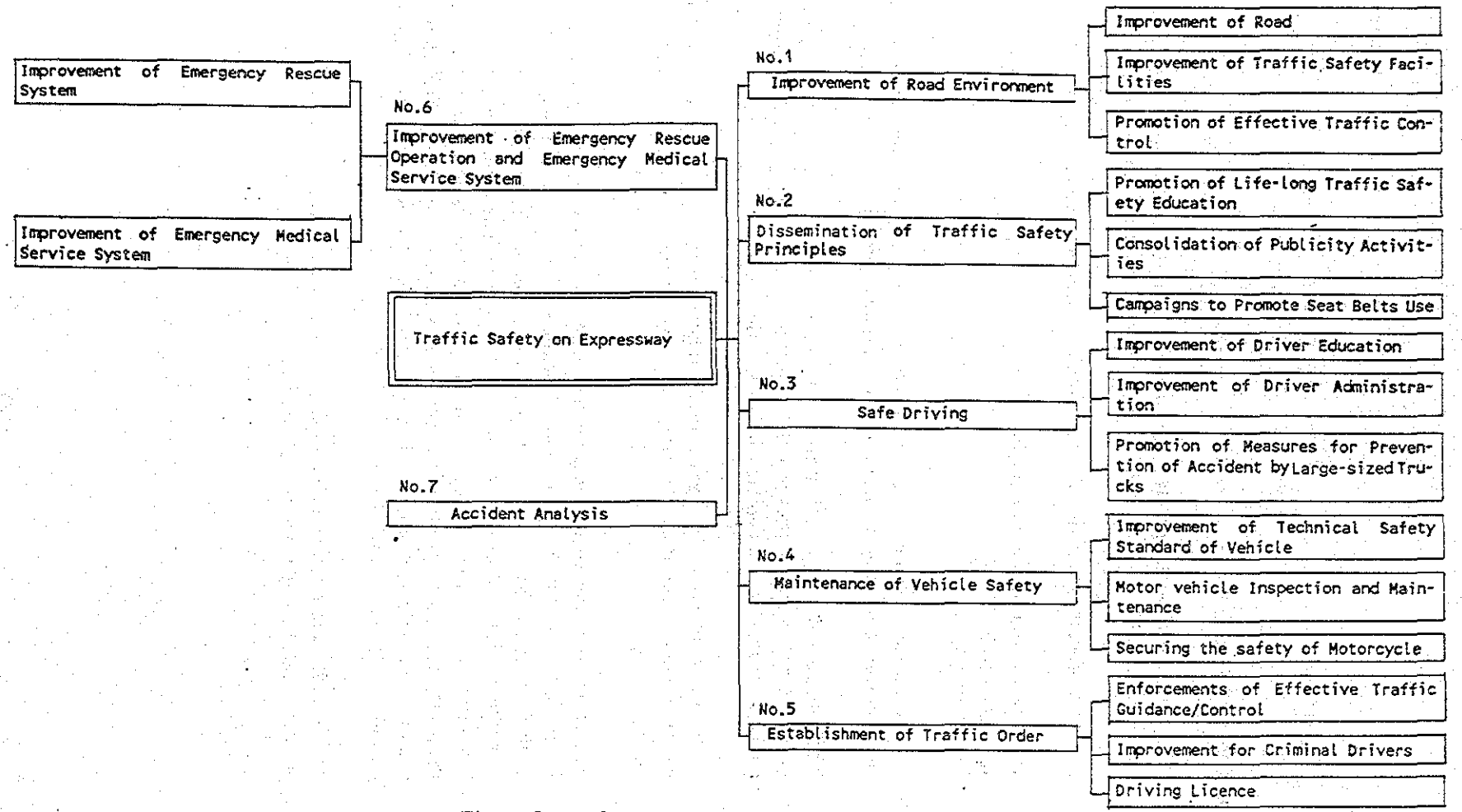


Figure 5.7.1: Component of Traffic Safety

5.7.2 Level of Traffic Safety

In enhancing traffic safety on expressway and highway, steps should be taken to introduce the components as depicted in Figure 5.7.1 individually and collectively.

Social and economic factors however are unlikely to permit easy application of every traffic safety measure simultaneously. As such, the selection of plans and its priority become very important tasks for road safety planners. Generally, the selection of improvement plans and its priority are determined by several steps based on the adopted definition of traffic safety level. At the early stages, basic and fundamental level of traffic safety measures can be introduced as the minimum level.

In determining the minimum level, the premise of B=f (P.E), where B = Behavior (Traffic behavior); f = Function; P = Person (Driver and pedestrian) and E = Environment (Road environment), is very helpful as it prioritizes the human activities and road environment. Accordingly, the level of traffic safety is established as follows.

The first level involves safety measures from the human viewpoint, i.e. psychological and physiological abilities of ordinary drivers. At this level, road environment are important aspects in establishing environmental improvement plans for traffic safety.

Accidents on expressway and highway usually occur when the man-machine system broke down. In case of drivers who are unfamiliar with safe driving due to lack of safety knowledge and improper attitude, corrective safety measures are required. This takes the form of safety education which is not only needed for drivers but also for other road users like pedestrians.

The second level of traffic safety is established on the premise of relief measures for traffic accident. The relief measures are related to several items such as driving licence system, vehicle maintenance system, insurance system, etc. These systems are closely related to the occurrence of accidents when the man-machine system broke down.

The final level of traffic safety is established on the premise of total safety whereby it is able to rectify both human errors or mechanical troubles.

Based on these three level of traffic safety, the first level is recommended to be the first step traffic safety measures for expressway and highway in Malaysia. Accordingly, the recommended traffic safety measures are:-

1) Improvement Plan of Safe Road Environment
2) Dissemination of Information on Traffic Safety and Safe Driving

In addition, it is proposed that the:-
3) Establishment of Accident Analysis and Reporting System

be carried out even though it is not directly related to human behavior on expressway and highway but nonetheless, it is closely related to traffic safety activities during accidents.

5.7.3 Improvement Plans for Traffic Safety

1) Improvement Plan of Safe Road Environment

On the improvement plan of safe road environment, the following major items are proposed:

(a) Improvement of Traffic Safety Facilities

i) To repair guard facilities and to avoid any unlawful invaders,
ii) To install efficient warning signs for the section of sharp curvature or steep vertical slopes,
iii) To improve sharp taper marking which warns drivers about reduction of soft shoulders on approach to bridges,
iv) To provide streamer (wind socks) at sections where cross wind occurs.

(b) Improvement of Road Design

i) To smoother sharp entry and exit ramps to interchanges or rest areas,
ii) To pave the soft shoulder for motorcycle

(c) Introduction of Minimum Speed Limit

Table 5.7.1 shows the existing and proposed speed limits for North-South Expressway and toll highways. A minimum speed limit of 50 kph is proposed for the motorways. The introduction of this minimum speed limit is however not timely at this moment as a large number of vehicles on the expressway are observed to have unsatisfactory conditions. When the level of vehicle conditions especially that of heavy vehicles can be upgraded and controlled with more stringent vehicle inspection in the near future, the minimum speed limit should then be introduced to enhance traffic safety.

Table 5.7.1 : Existing Expressway and Proposed Speed Limit on North-South Expressway and Toll Highways

Type of Vehicle	Existing Speed Limit (km/h)	Proposed Speed Limit (km/h)	
		High	Low
NORTH-SOUTH EXPRESSWAY			
Bukit Kayu Hitam-Jitra	90	70	-
Jitra-Gurun	110	110	50
Changkat Jering-Ipoh	110/80*, 65**	110/80*, 65**	50
Kuala Lumpur-Seremban	110	90	50
Seremban-Air Keroh	110	110	50
OTHER TOLL HIGHWAYS			
Senai Highway	90, 70, 50	90, 70, 50	-
Penang Bridge	80	80	-
Kuala Lumpur-Karak Highway	80/40**	80/40**	-

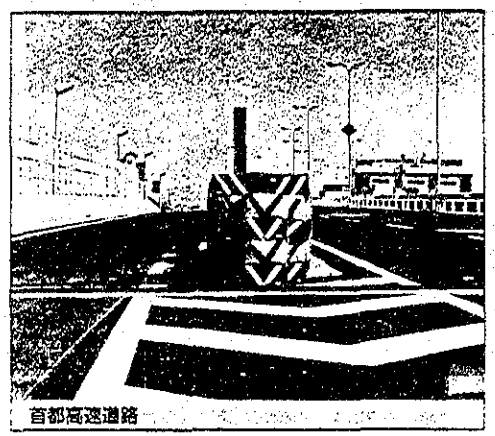
Note: * - Mountainous Section
** - Tunnel

The details of the improvement items for safe road environment inclusive of its implementation priority for expressway and highway are shown in Table 5.7.2. In addition, a detailed safety improvement plan of Karak Highway is shown in Appendix A.

Table 5.7.2: Improvement Items for Safe Road Environment

Expressway/ Highway	Section	Location	Provision of Facilities: Type	Provision of Facilities: Contents	Other Measures	Target Year
NORTH-SOUTH EXPRESSWAY	Bukit Kayu Hitam to Jitra	*Entire section			*Widen shoulder	○
					*Reduce maximum speed limit from 90 km/h to 70 km/h	◎
					*Classify as ordinary road	○
		*At-grade intersection	*Warning sign	*To warn about pedestrian crossing		◎
		*Nose of diverging end	*Guard cushion	*To channelize traffic into proper position and minimize injuries		○
	Jitra to Gurun	*Entire section	*Guard fence	*To prevent animals entering		◎
			*Pole	*To close opening at median		○
			*Warning sign	*To warn about flood		◎
					*Introduce minimum speed limit (50 km/h)	△
		*Nose of diverging end	*Guard cushion	*To channelize traffic into proper position and minimize injuries		○
	Meru-Menora Tunnel	*Entrance of tunnel	*Regulatory sign	*To prohibit overtaking		△
			*Marking	*To prohibit overtaking		△
		*Tunnel	*Guide sign	*To move km post sign away from fire extinguisher		◎
					*Change the Extinguisher Manual because of low legibility	◎
					*Check the lux at night time as it is too bright	○

Note: ◎ Implement immediately
○ Implement by 1995
△ Implement by 2005


首都高速道路

Guard cushion

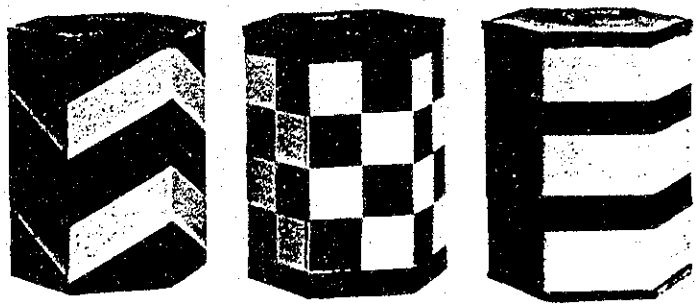
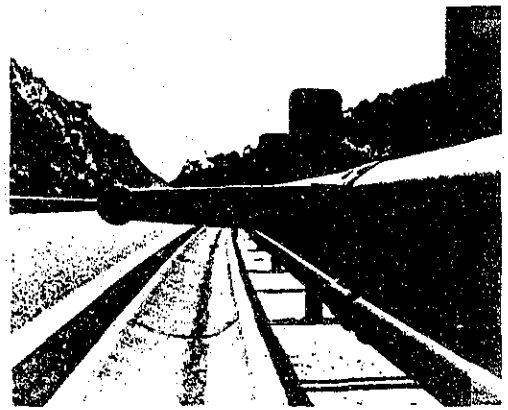


Table 5.7.2 (Cont): Improvement Items for Safe Road Environment

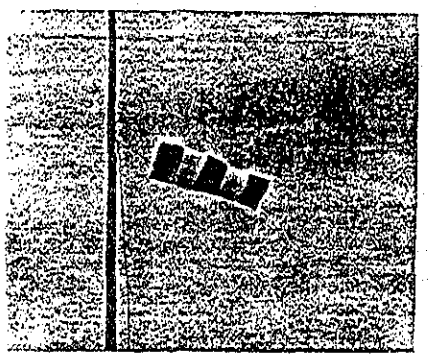
Expressway/ Highway	Section	Location	Provision of Facilities		Other Measures	Target Year
			Type	Contents		
NORTH-SOUTH EXPRESSWAY	Changkat Jering to Ipoh	*Entire section	*Guide sign	*To provide totalized distance unit (m,km)		○
					*Introduce minimum speed limit (50 km/h)	△
		*Bridge	*Side guider	*To guide traffic into proper position		○
		*93.0-96.4 km post	*Warning sign and Safety Gap Sign	*To warn about 'dozing' road (straight)		◎
		*100-102 km post	*Glare screen	*To repair broken screen		◎
		*104 km post	*Streamer (Wind socks)	*To warn about strong wind		◎
		*126-129 km post	*Warning sign and Chevron Delineator	*To warn about sharp curve (hair pin)		◎
			*Road lighting	*To produce satisfactory visual environment about sharp curve		○

Note: ◎ Implement immediately
○ Implement by 1995
△ Implement by 2005

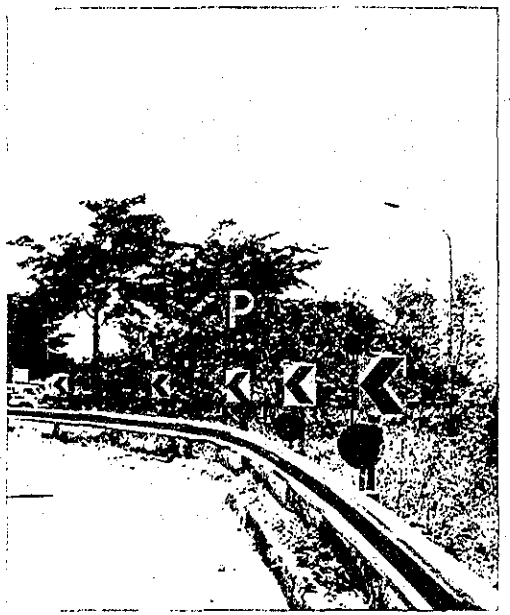
Side guider



Streamer



Chevron Delineator



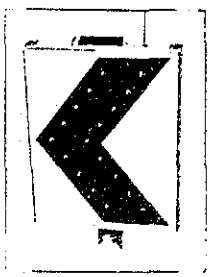


Table 5.7.2 (Cont): Improvement Items for Safe Road Environment

Expressway/ Highway	Section	Location	Provision of Facilities: Type	Provision of Facilities: Contents	Other Measures	Target Year
NORTH-SOUTH EXPRESSWAY	Kuala Lumpur to Seremban	*Entire section	*Guide sign	*To provide larger sign		○
			*Streamer	*To warn about strong wind		◎
			*Marking	*To provide wider marking		○
					*Pave soft shoulder for motorcycle	○
					*Pass regulation to prohibit two-seater motorcyclist	△
					*Reduce maximum speed limit from 110 km/h to 90 km/h	○
					*Introduce minimum speed limit (40 km/h)	△
		*18 km post	*Guide sign	*To provide totalized distance unit (m,km)		○
		*25.2, 30.6, 34.0, 41.6 km post	*Warning sign	*To warn about steep slope and sharp curve		◎
		*45.8 km post	*Guard fence	*To repair broken guard fence as animals was found strayed on shoulder		◎
		*50 km post			*Lengthen accelerating lane to petrol station	△
		*56.6 km post	*Warning sign and Chevron Delineator	*To warn about sharp curve		◎
		*62.1, 63.3, 63.8 km post			*Trim trees as they obstruct the viewing of guide sign	◎

Note: ◎ Implement immediately
○ Implement by 1995
△ Implement by 2005

Table 5.7.2 (Cont): Improvement Items for Safe Road Environment

Expressway/ Highway	Section	Location	Provision of Facilities		Other Measures	Target Year
			Type	Contents		
NORTH-SOUTH EXPRESSWAY	Seremban to Ayer Keroh	*Entire section	*Delineator	*To install at median as to help night time driving		○
			*Guard fence	*To prevent animals entering		○
					*Introduce minimum speed limit (50 km/h)	△
		*Approach to curves	*Road lighting	*To produce satisfactory visual environment		○
		*72.5 km post	*Warning sign and Chevron Delineator	*To warn about sharp curve		◎
		*79.4-79.9, 110.5-111.0 112.1-112.8, 113.1-113.9 123.2-123.6, 127.0-127.4 km post	*Streamer	*To warn about strong wind		◎
		*85.7 km post			*Lengthen accelerating lane to vista point	○
		*100-102 km post	*Safety gap sign	*To warn about safe vehicular speed gap		◎
		*126.2 km post	*Warning sign	*To warn about steep slope		○

Note: ◎ Implement immediately
○ Implement by 1995
△ Implement by 2005

Safety gap sign

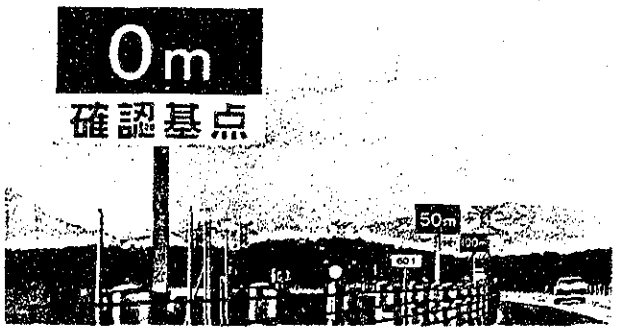


Table 5.7.2 (Cont): Improvement Items for Safe Road Environment

Expressway/ Highway	Section	Location	Provision of Facilities		Other Measures	Target Year
			Type	Contents		
TOLL HIGHWAY	Johor Bharu-Senai Highway	*Entire section	*Regulatory sign	*To set speed limit according to landuse		◎
					*Classify as ordinary road	△
		*At-grade intersection	*Warning sign	*To warn about pedestrian crossing		◎
		*Median	*Delineator	*To help night time driving		○
		*U-turn point	*Regulatory sign	*To prohibit U-turn		◎
	Penang Bridge				*Enforce prohibition of parked vehicle (to be conducted by police)	○
	Federal Highway				*Pave shoulder	○
					*Provide clearance between median and lane	○

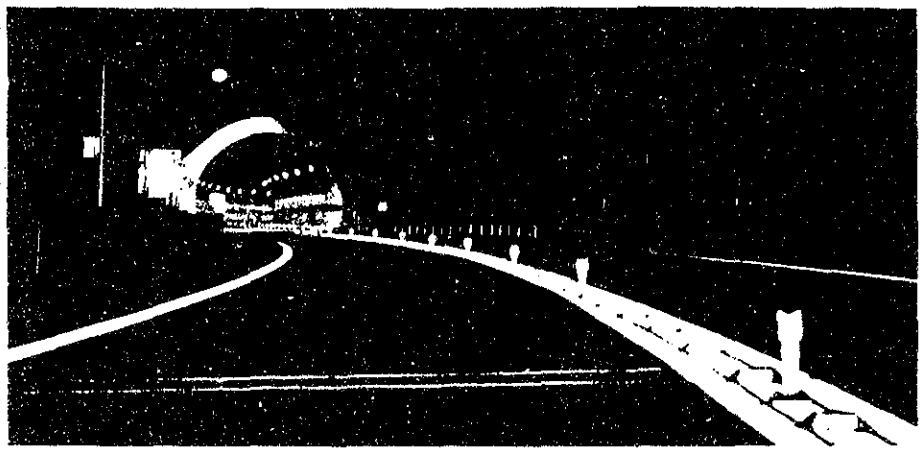
Note: ◎ Implement immediately
○ Implement by 1995
△ Implement by 2005

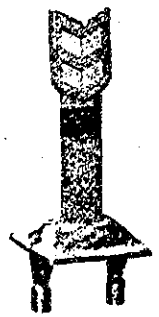
Table 5.7.2 (Cont): Improvement Items for Safe Road Environment

Expressway/ Highway	Section	Location	Provision of Facilities		Other Measures	Target Year
			Type	Contents		
TOLL HIGHWAY	Karak Highway	*Entire highway	*Road lighting	*To produce satisfactory visual environment		△
			*Marking	*To repaint lane and edge marking		◎
					*Pave shoulder	○
					*Pave climbing lane	○
		*Curve section	*Guardrail	*To safely redirect errant vehicle		○
			*Chevron Delineator	*To warn about sharp curve		◎
		*Vertical slope over 3%	*Warning sign	*To warn about steep slope		◎
		*Upstream and downstream of bridge	*Divider	*To regulate traffic into proper position		◎
		*500 m and 100 m from tunnel entrance	*Regulatory sign	*To warn about lower speed limit		○
		*Tunnel			*Provide motorcycle lane	○
		*Toll plaza	*Weighbridge	*To prevent overloading lorry entering	*Enforce regulation of overloading lorry	△
		*At each 5 km			*Provide emergency space	△

Note: ◎ Implement immediately
○ Implement by 1995
△ Implement by 2005

Divider





2) Accident Analysis and Reporting System

Accident analysis and reporting system is recommended as part of the safety proposals as it is essential for research into causes of accident which then enables the proposal of appropriate actions or plans. The improvement items which should be implemented immediately are illustrated in Table 5.7.3.

Table 5.7.3: Improvement Items for Accident Analysis and Reporting System

Accident Analysis and and Reporting System	Improvement Items
Preparation of Accident Analysis and Reporting System	Preparation of Highway Accident Investigation Sheet
	Establishment of Accident Reporting System
	Set-up of Accident Analysis Team

A sample of the Highway Accident Investigation Sheet can be found in the Operation Manual.

3) Dissemination of Information on Traffic Safety and Safe Driving

From the viewpoint of road users, the dissemination of information on traffic safety and safe driving are recommended as the second component of the safety proposals. It is divided into two aspects of traffic safety campaign and improvement of safe driving on expressway and highway.

a) Traffic Safety Campaign

For traffic safety campaign, the following items are proposed:

i) Public relation activities of MHA,
ii) Publicity of 'Expressway' to road users,
iii) Preparation of expressway map,
iv) Traffic safety campaign on expressway driving.

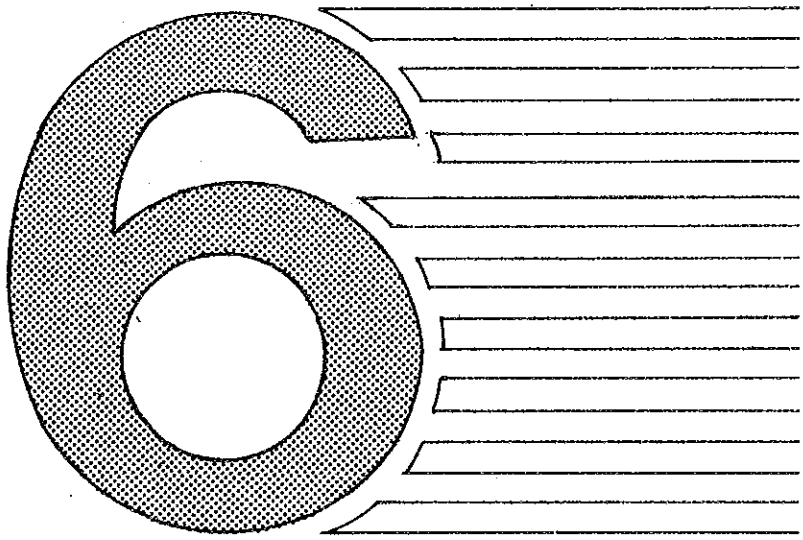
An example of the safety campaign is illustrated in the Operation Manual.

b) Improvement of Safe Driving

On the improvement of safe driving, the following items are recommended:

i) Guide book on safe driving,
ii) Introduction of safety guidance,
iii) Holding of traffic safety symposium,
iv) Other related activities by MHA.

CHAPTER



6.0 PRELIMINARY ENGINEERING DESIGN

6.1 Introduction

This chapter presents the preliminary engineering design for the traffic control and management system. The design is based on the premises of the master plan discussed in the previous chapter, which includes tasks and responsibilities of regional and maintenance offices, traffic management level, location of control centers, system functions and configuration, and installation standards for roadside equipment.

The final step of preliminary engineering design involves the preparation of drawings for the installation of various roadside equipment and communication cable, and communication network. In this chapter, however, specification and installation standard of each of the equipment are described in detail. Each section covers one equipment or sub-system. A total of 13 equipment and sub-system are presented in Section 6.2 through 6.14. The preliminary engineering design requirements elaborated here thus will provide the basis for the detailed design at the next stage.

6.2 Emergency Telephone

6.2.1 Introduction

Emergency telephone is a communication tool for the road users who need to contact the road management body for assistance in case of accident, car trouble or running out of fuel on the expressway and highway where no other means of communication is available. Emergency telephone system must be designed with the following requirements taken into account:

* Handling and operation of emergency telephone by the user must be simple and straightforward
* The system must be capable of automatically identifying the calling telephone without asking the caller.
* Communication between the calling telephone and receiver must be clear even under the great traffic noise.
* The system is capable of automatically recording communication between the caller and the operator on a tape with a time stamp.
* The system is capable of transferring a call from the receiving desk to the maintenance office, toll plaza, etc. when necessary.

Presently, emergency telephone system is installed on the North-South Expressway between the Seremban - Ayer Keroh section. New system proposed here is designed to be compatible with the existing system. The roadside telephones are retained in the new system, while the existing emergency telephone receiving desk at toll plaza will be replaced along with the new central equipment at the control center to be established at Ayer Keroh.

6.2.2 System Configuration

Emergency telephone system consists of roadside telephones along the expressways and highways, emergency telephone central controller, and emergency telephone receiving desk at the control center. Monitoring equipment is provided to the maintenance office to monitor the call from within its jurisdiction and to receive a call when it is not attended to by the operator in the control center due to multiple calls or malfunction of the equipment at the control center.

6.2.3 Type of Telephone Set

Basically, there are two types of emergency telephone set, one with a built-in speaker, a microphone and one or more push buttons to initiate a call, and another type with a handset same as the one provided to the ordinary telephone set. In the latter case, call is initiated automatically by lifting up the handset from the cradle. Functionally these two types are the same. The former type is already in use in Malaysia and is recommended to be used for the rest of the expressways and highways.

6.2.4 Installation Standard

1) Installation Interval

Emergency telephone is installed at a certain interval along the expressway or highway. For systems in other countries, the installation interval ranges from 200 meters in tunnel, 800 meters to 2 km along open air sections. If the interval is longer, the number of telephones required to cover a section of the expressway is obviously fewer thus reducing the total cost of the emergency telephone system. Drivers who need to use the telephone, however will have to walk longer distances to reach the nearest telephone. On the other hand, a shorter interval requires more telephone sets and thus higher total cost.

It must be noted, however, that cable and its installation cost is almost the same regardless of the interval as the cable must be installed along all stretches of the expressway or highway where emergency telephones are to be installed, and the difference in cost of center equipment is marginal.

The existing emergency telephone system between Seremban and Ayer Keroh adopts an interval of 2 km. This is regarded as too long as it takes fifteen minutes for a potential caller to reach the nearest telephone which is 1 km away in the worst case. An interval of 1 km is recommended in the proposed system.

Guide signs showing the direction of the nearest telephone must be installed at intermediate locations. An illuminated sign at each telephone location is desirable for easy identification at night. However, the illuminated sign requires power which is not easily available at most of the locations along the routes under study so that reflective sheet on the telephone housing is recommended as an alternative.

2) Installation Location

Two telephones must be installed at the same location on opposite direction to prevent drivers from trying to cross the expressway.

The following locations however must be avoided for installing the emergency telephone:

* Within 100 meter upstream and 50 meter downstream of a sign except overhang type sign,
* Within 100 meter of an over-bridge section.

The installation standards are shown in Table 6.2.1.

Table 6.2.1: Installation Standards for Emergency Telephone

Freeway	Installation Interval	Installation Location
Motorway/Expressway*1	1 km interval	At the same location on both sides in opposite direction
Karak Highway	1 km interval	On one side*2

Note: *1- Only applicable to certain sections of expressway where access to external environment is not available.
*2- It is sufficient as Karak Highway is a two-lane highway.

No emergency telephone is installed on Senai Highway and Federal Highway as the access to the outside of the road is easy along these routes.

6.2.5 Telephone Circuit Configuration

A variety of circuit configuration are in use from the simplest connection method of one circuit per telephone to the multiple party line configuration in which a group of 8 to 20 telephones share one or two common circuits. In the party line system, identification of the calling telephone at the receiving console must be made possible. Considering the low frequency of use, the multiple party configuration with a maximum of eight telephones per circuit is recommended. Additional circuit will be provided to each telephone for direct connection to the maintenance office. For this purpose, the roadside telephone is equipped with a key switch, through which the circuit can be switched to the maintenance office.

6.2.6 Operation

When a road user initiates a call by pressing the push-button switch on the telephone panel, an indicator on the graphic panel will flicker, chime sounds and schematic diagram of the calling telephone location is displayed on the CRT terminal to notify the operator of the call. By pressing appropriate key, conversation is possible between the caller at roadside and the operator in the control center. Tape recorder is provided to the system for the automatic recording.

At the console, capability is provided to enable the transferring of calls to other offices such as maintenance office or toll plaza for direct communication.

6.3 Vehicle Detector

6.3.1 Introduction

Vehicle detector is used to detect automatically the up-to-date traffic information such as volume, speed and congestion degree on the expressway and highway. Detector data are then processed collectively in a manner that traffic management officials can continuously monitor the traffic situation for prompt reaction in administering the necessary first aid countermeasures.

6.3.2 System Configuration

Vehicle detector system consists of vehicle detectors installed along the expressways and highways, detector data processor at the maintenance office and central computer system at the traffic control center.

6.3.3 Type of Vehicle Detector

There are two types of vehicle detectors being used widely, that is loop and sonic detectors.

1) Loop Detector

The loop detector is currently the most widely used means of vehicle detection because of its accuracy and flexibility. As such, it is recommended to be used on the Malaysian expressways and highways.

The loop detector generates an electro-magnetic field when a current is passed through a loop of wire. The iron component of vehicles will interrupt the magnetic field and this interference is detected by the electronics component of the detector.

The loop detector is capable of a broad range of vehicle detection. Loops can be designed to sense the presence of vehicles in addition to detecting the passage of a vehicle. Lane occupancy, speed, and volume can be determined from loop detector output signals. For measurement of accurate speed, two loops are placed at a certain fixed longitudinal distance, and the speed of an individual vehicle is calculated using detection time difference and the distance between the two loops.

Classification of vehicles into two types, large and small by vehicle length, is also possible by two loop installation, in which a vehicle is regarded as large if both loops detect a vehicle simultaneously.

This two-loops system is recommended for use on the Malaysian expressway and highways to obtain more accurate speed data and vehicle classification.

However, for installation of loop detectors, caution has to be paid against any possibility of the loop coil wire (which are installed under the pavement) being damaged or broken and influence of any nearby iron structure at the location.

2) Sonic Detector

The sonic detector transmits pulse beams of ultrasonic energy through a transducer towards the roadway. These beams are then reflected back, by the presence of a vehicle, to the transducer which converts them to electrical energy.

The sonic detectors are available with two methods of sensing head installation:

* Overhead type
* Side fire type

The detection accuracy of overhead type detector is higher than that of side fire type.

Unlike the loop detector, sonic detector can be applied at location with poor pavement condition or influence of iron structure.

6.3.4 Installation Location

Vehicle detector is mainly installed at all through lanes at representative location between interchanges for the sectional traffic volume and speed. In addition, detectors are installed to collect access and egress traffic volume at major interchanges. For the former purpose, loop is installed at about 500 meters upstream of off-ramp taper end, while loop at on- and off-ramp is placed at such place where less irregular running is expected.

For other purposes like congestion detection, detectors are placed at intervals of 500 meters, in the congestion prone area to detect the congestion or queue length. Table 6.3.1 summarizes the installation standards of vehicle detector at each management level.

Table 6.3.1: Installation Standards of Vehicle Detector

1) Motorway

Location / Level	Mainline	On & Off-ramp
Level 1	1 location between major cities	-
Level 2	1 location between ICs	Major ICs
Level 3	Recurrent congestion area	-

2) Expressway

Location / Level	Mainline	On & Off-ramp
Level 1	1 location between major cities	-
Level 2	1 location between major ICs	-
Level 3	Recurrent congestion area	-

3) Karak Highway

Location / Level	Mainline	On & Off-ramp
Level 2	1 location between toll gate and tunnel	-
Level 3	Recurrent congestion area	-

Note: The main functions of vehicle detectors in each level are as follows:

Levels 1 and 2 - to detect traffic volume and speed
Level 3 - to detect traffic congestion

6.3.5 Operation

Detection data of each vehicle passing over the loop sensor are transmitted in real-time mode from the detector unit at site to the detector data processor in the maintenance office. The data are processed into such five-minute traffic data as traffic volume of small and large vehicles, average speed, and occupancy rate. These processed data are then sent to the control center for monitoring and recording. In the maintenance office, traffic data are displayed on the monitor panel and printed on the typewriter, if necessary. In the control center, data are displayed on the graphic panel or on the CRT to help the operators in the center to grasp the traffic conditions, and stored on the magnetic tape for future analysis.

6.3.6 Specifications

1) Loop Sensor

a. Standard Size: 1.5 meter (longitudinal) x 2.0 meter (lateral).
b. Number of turns: 3 turns or more.
c. Burying depth: 60 - 100 mm below road surface.
d. Separation: Two loop coils will be placed 5.5 m (standard) apart.

2) Detector Unit

a. Number of loops: 6 loops maximum.
b. Speed: 1 - 160 Km/h.
c. Resolution: 2.3 meter (longitudinal).
d. Inductance range: 50 - 300 micro-henry.
e. Compensation: Automatic compensation against inductance variation within +/- 10 %.
f. Presence time: More than 5 min. for the inductance change of 2 %.
g. Interface with detector data processor:
   Data: Detection signal of each vehicle and malfunction of detector unit.
   Transmission method: FS-TDM.
   Number of channels: 18 channels/line.

3) Detector Data Processor

a. Unit time: 5 minutes or 1 hour.
b. Processed data:
   * Accumulated small car volume for unit time.
   * Accumulated large car volume for unit time.
   * Accumulated total volume for unit time.
   * Average occupancy rate for unit time.
   * Average speed for unit time.
c. Compensation for power interruption
   The processor shall be capable of holding the data correctly for 30 minutes in case of power interruption and resuming normal operation upon restoration of power.
d. Classification of vehicles
   Small < L = 6 m +/- 0.5 m < Large, where L: vehicle length.
e. Calendar and clock: Compensated for more than 3 hours.

f. Interface with transmission system

Following data for each direction shall be output to the transmission system:

* 5-minute volume of large car: BCD 3 digits.
* 5-minute volume of small car: BCD 3 digits.
* 5-minute occupancy rate: BCD 2 digits.
* 5-minute average speed: BCD 3 digits.

6.4 Weather Observatory Equipment

6.4.1 Introduction

Weather observatory sensors will be installed at the weather observation station along the expressway and highway to monitor the weather conditions with the purpose of preventing vehicle accidents due to the worsening of climatic conditions. Of the various sensors available, sensors for rainfall and winds which have great influence on the Malaysian expressway and highway are recommended and described here.

6.4.2 System Configuration

Weather observatory system consists of a rain gauge and an anemometer at the outdoor observation station and weather observatory panel with a dot recorder at the maintenance office. Functionally, weather data are sent from the observatory station or panel to the control center for further processing, monitoring and recording.

6.4.3 Type of Equipment

1) Rainfall Sensors

The sensor contains a water faucet measuring 200 mm in diameter and a turn-over liquid system to measure the quantity of precipitation. When the liquid measure turns over once with a rainfall of 0.5 mm to 2 mm, one electrical pulse is generated. From the number of pulses, the quantity of precipitation can be found. Normally, through use of the rainfall sensor, the following data are computed to monitor rainfall:

*precipitation for 10 minutes
*precipitation for 1 hour
*precipitation for 3 hours
*cumulative precipitation
*effective precipitation (during a given time)

2) Anemometer

Several kinds of anemometer are available but the propeller type anemometer is commonly used for the expressway and highway applications. For meteorological observation, anemometer is usually placed at a height where the wind is not affected by buildings nearby. For measuring the influence of

wind on moving vehicles at spots along the expressway and highway and for providing wind information to drivers, the anemometer is positioned at the height two to three meters above the ground. An AC synchronous generator or self-synchronous generator is used for the detection of wind direction, while a magnetic type alternating current generator is used for the detection of wind velocity. The output of both generators is in AC voltage and they are input to the averaging circuit to be converted into ten minute average. Averages are of the form of DC voltage which is then changed into digital signal by a AD converter for data transmission.

Range of measurement is usually 0 to 60 meters per second and 0 to 540 degrees for velocity and direction respectively. The wind resistance of the meter itself is necessary to be more than 70 meters per second.

6.4.4 Installation Location

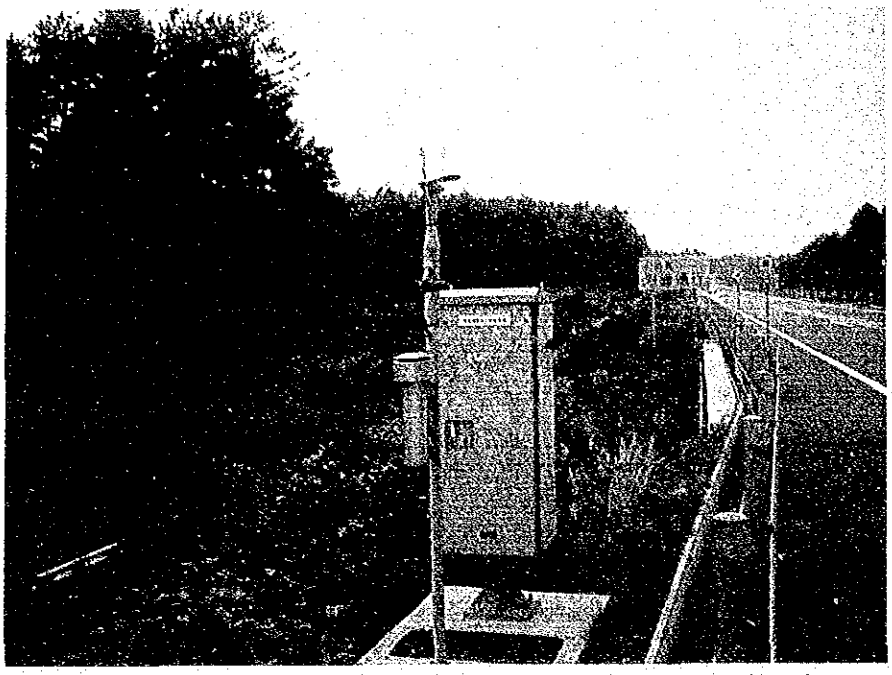
Weather observatory equipment are installed at the location where heavy rain or strong cross wind are frequent which may endanger traffic safety.

For Malaysian expressways and highways, rainfall sensors are recommended to be installed at locations where annual maximum rainfall exceeds 3000 mm or daily maximum rainfall exceeds 200 mm.

Based on these conditions, rainfall sensors together with anemometer are required at nearby areas of the following interchanges along the North-South Expressways.

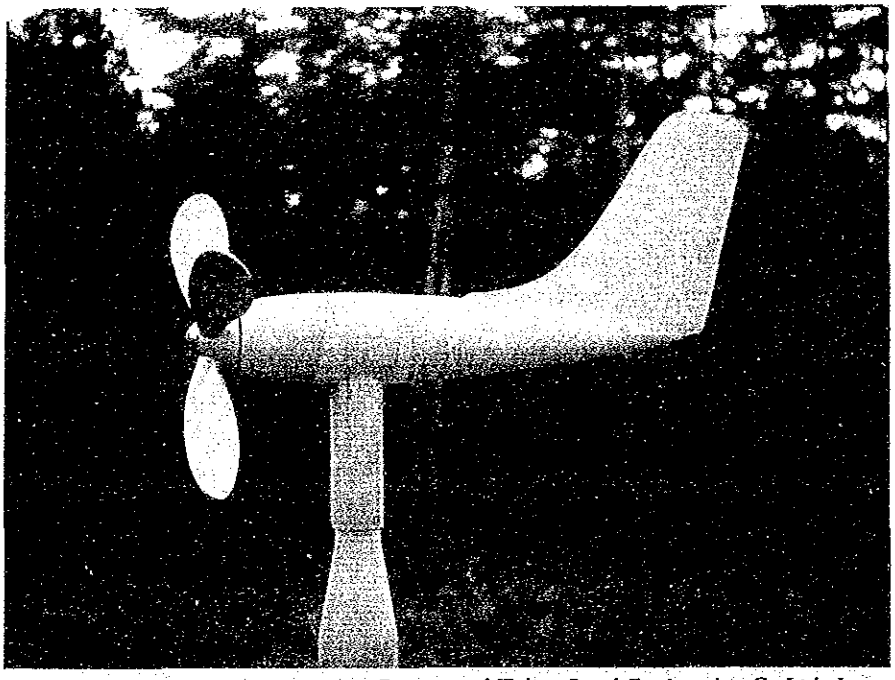
* Alor Setar Interchange
* Gurun Interchange
* Butterworth Interchange
* Taiping Interchange
* Ipoh Utara Interchange
* Gopeng Interchange
* Bidor Interchange
* Tanjung Malim Interchange
* Kajang Interchange
* Ayer Keroh
* Ayer Hitam Interchange
* Kulai Interchange

Because of its location in a mountainous region where landslide are prone to occur, rainfall sensor is required to be installed at one representative location on Karak Highway even though the rainfall does not exceed the above-mentioned values.



Courtesy of Tokyo Road Engineering Co.Ltd, Japan

Weather Observatory Station



Courtesy of Tokyo Road Engineering Co.Ltd, Japan

Propeller-type Anemometer

6.4.5 Specifications

1) Rain Gauge

a.	Type:	Turn-over liquid measurement type.
b.	Faucet diameter:	200 mm.
c.	Turn-over rainfall:	0.5 mm/turn-over.
d.	Output:	No-voltage contract output pulse of approximately 0.1 second width.

2) Anemometer

a.	Measurement range:	540 degrees, 0 - 60 m/sec.
b.	Generator:	AC synchronous generator or self-synchronous generator (wind direction). Magnet type AC generator (wind velocity).
c.	Output:	DC 0-3 V for 540 degrees. DC 0-3 V for 0-60 m/sec.
d.	Averaging time:	10 minutes.
e.	Accuracy:	Less than +/- 5 degree for 540 degrees. Less than +/- 5 % for 2-60 m/sec.

3) Weather Observatory Panel

a.	Recorder:	Dot recorder.
b.	Input:	DC current or voltage input.
c.	Alarm:	Alarm shall be output when measured data exceeds the preset threshold.

6.5 Closed Circuit Television System

6.5.1 Introduction

Although visual data provided by the closed circuit television (CCTV) system do not produce any quantitative data, they contain numerous unquantifiable information and the system enables operators to investigate traffic conditions in greater details at the center.

CCTV system in a traffic control and management system is used mainly for the following applications:

* Traffic flow monitoring
* Disaster prevention in tunnel
* Weather observation
* Others

CCTV system is one of the information collection tools and used to confirm the occurrence of congestion and other incidents in conjunction with the quantitative data obtained by detectors. It provides visual information, which is more intuitive and comprehensive than figures, and has proved to be an essential component in the traffic surveillance system.

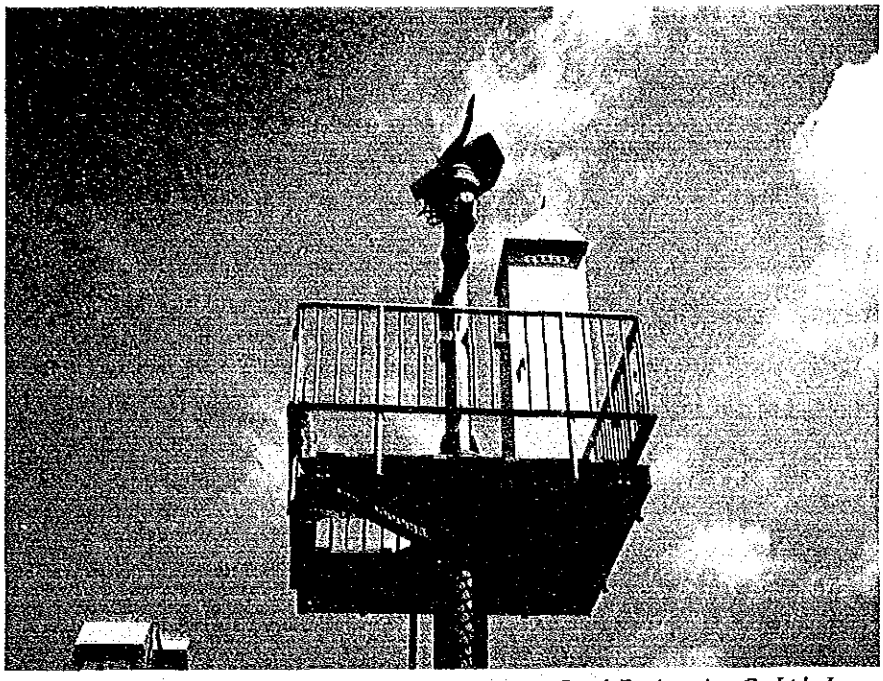
As one of the disaster prevention facilities, CCTV system in tunnel provides information on site situation and facilitates the effective execution of adequate countermeasures should an incident occur in tunnel.

In connection with weather observatory equipment, CCTV system is also used to evaluate the data sent from these equipment and to formulate the countermeasures. It is also installed at toll gate to monitor the toll gate operation.

These four applications are not mutually exclusive and in many cases a camera is installed for multiple purposes.

6.5.2 System Configuration

CCTV system consists of camera and camera controller at the site, slave remote control unit at the maintenance office and master remote control unit, operator console and monitor TVs at the control center. Transmission system with dedicated cable is required exclusively for connecting the site with the control center. Video signal taken by a camera is transmitted to the maintenance office and then to the control center over the optical fiber cable.



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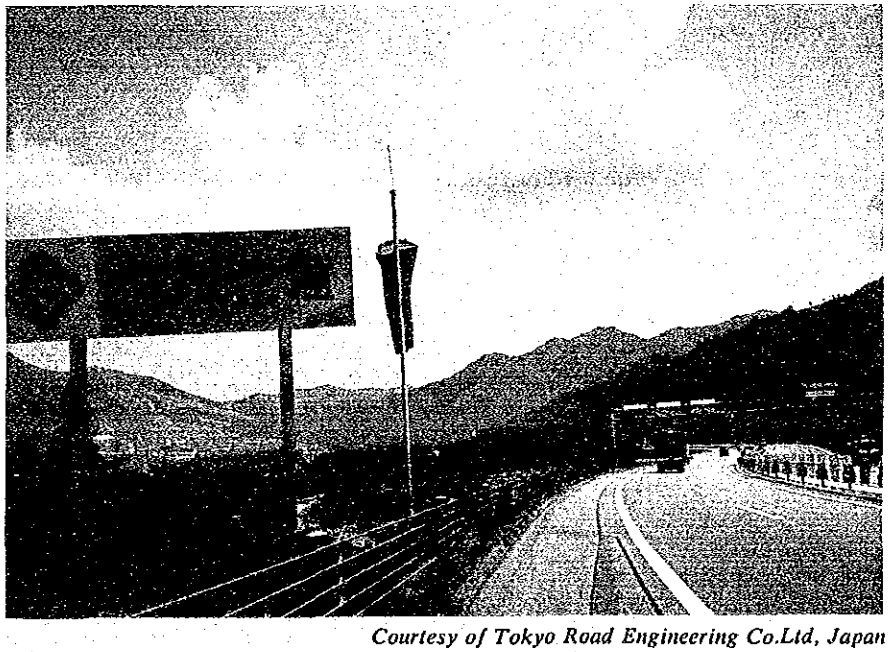
CCTV Camera



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Streamer

From the control center, command signals such as power ON/OFF, pan, tilt, zoom, telescope, etc. are sent to the camera controller. Video tape recorder with a time signal generator will be included in the central equipment for recording and re-playing the image data.

The camera in the tunnel is controlled from the tunnel control room while monitoring is possible at the maintenance office and the control center.

6.5.3 Installation Location

CCTV cameras are installed at the following strategic locations :

* Section or location where recurrent congestion is frequent or expected to occur. For the monitoring of traffic flow, in particular congestion, section of expressway or interchange in the vicinity of large city is a candidate, where congestion is frequent during peak hours or on specific days.

* In tunnel where emergency exit, ventilation system, or sprinkler system is installed.

* Section or location where incident or accident is prone to occur due to heavy weaving traffic, poor geometric design, frequent adverse weather condition, etc.

* Other places like toll plaza where monitoring of expressway operation is required.

Based on the above-mentioned considerations, a few locations have been identified on the study routes which require installation of CCTV. Table 6.5.1 presents the installation of CCTV camera on the study routes.

Table 6.5.1: Installation Location of CCTV Camera

Freeway	Route	CCTV	
		Location	No.
Motorway (at Stages 2 and 3)	N-S Expressway	Between Kuala Kangsar IC and Jelapang IC	1
		At Kuala Lumpur Utara Toll Plaza	1
		At Sungei Besi Toll Plaza	1
		Between Sungei Besi Interchange and Seremban Interchange	2
	New Klang Valley Expressway	Between Subang Airport Interchange and Bukit Lanjan Interchange	2
	Penang Bridge		2
	Total		9
Expressway (at Stage 3)	N-S Expressway	-	0
	Federal Highway (Subang Airport-Berkeley Roundabout)	Subang Airport Interchange	1
	Senai Highway	Johor Causeway	1
	Total		2
Highway (at Stage 2)	Karak Highway	Kilopost 30	2
		Western Toll Plaza	1
	Total		3

6.5.4 Specifications

1) Camera

a. Image taking device: 2/3 or 1/2 inch CCD
b. Minimum brightness of object: 5 lux.
c. Horizontal resolution: More than 350 at the center.

2) Lens

Zoom lens with auto iris function shall be used. Focal distance will be determined according to the conditions of each installation location.

3) Universal Head

a. Pan: More than +/- 170 degrees.
b. Tilt: + 15 degree or more.
- 60 degree or more.

4) Camera Controller

a. Video transmitter PFM-IM (Pulse Frequency
Modulation method: Modulation - Intensity Modulation).
Wave length: 1.3 micro-meter

b. Control signal receiver
Transmission system: Time division cyclic transmission.
Modulation method: Frequency Shifting.
Transmission rate: 1200 bits/s

6.6 Changeable Message Sign System

6.6.1 Introduction

Changeable message signs are visual communication facilities which are installed at strategic points on the expressway and highway to give the drivers such information as congestion, occurrence of accident, road condition and detour recommendation. The information (message) displayed at the terminal is set automatically by a computer or by manual operators.

6.6.2 System Configuration

Changeable message sign system consists of changeable message signboard and its controller installed on the expressway, highway and access road, slave remote controller at the maintenance office or tunnel control room, and master remote controller and operator console at the control center.

Changeable message sign at the tunnel entrance is mainly controlled from the tunnel control room. it is also controlled from the control center when necessary. Monitoring is possible at the maintenance office.

6.6.3 Type of Signboard

The signboard that is being widely used is categorized into two types; scroll type and matrix type.

1) Scroll Type

The viewing face of the scroll sign is formed by a continuous belt of flexible cloth or plastic material containing a number of message. The belt is stretched between two storage drums that are rolled until the desired message is displayed to the appropriate viewing position. If desired, a blank space may be left on the belt so that no message is visible when the belt is rotated to that position. In many cases the message belt is made of translucent material permitting back illumination.

Scroll sign may be applicable at entrance toll booth and displays traffic, road and environmental conditions on the expressway and the ramp-closure.

2) Matrix Type

This type of sign is applicable for large size sign on the mainline or access road because its viewing face is formed by a matrix arrangement.

This type of sign can be sub-divided into three types depending on the matrix element, that is Lamp (Light Bulb) Matrix, LED (Light Emitting Diode) Matrix, and Electro-magnetic Element Matrix.

a) Lamp (Light Bulb) Matrix

The viewing face of the lamp matrix display is formed by an array of incandescent bulbs for each message line. The array can either be a continuous field of bulbs or a fixed number of matrix modules. Typically, the number of message lines varies from one to four.

By independently controlling on or off state of each bulb, any messages or graphic symbols can be displayed. Messages can be displayed statically or flashed on and off. Messages change almost instantaneously when a new message is selected.

Because of the use of incandescent bulbs, this type has enough visibility under the bright daylight.

b) LED (Light Emitting Diode) Matrix

This type of sign is identical to the lamp matrix type except LED matrix is used in place of incandescent bulb. There are variations of LED layout. One type of signboard has a matrix of LED arranged four columns by four rows, which replaces one incandescent bulb. LEDs of two different colors, red and yellow, are used so that messages and symbols can be displayed in red, yellow or orange color.

Another type is made up of LEDs of the same colour and one LED replaces one bulb. Thus, the sizes of the signboard is much smaller than the lamp matrix type and only suitable for the toll booth.

Because of high density of LEDs, the former type of sign can display minute image than lamp matrix type. Use of LED also provide longer life and lower power consumption compared with lamp matrix type. Equipment cost, however is slightly higher than lamp matrix of the same size and the display is not as bright as the lamp matrix type.

c) Electro-magnetic Element Matrix

Disk matrix signs are similar to the lamp matrix with the exception that electro-magnetic elements rather than lamps are used to form the legend letters. The elements are made of plastic and take the form of disk, sphere or cube. A portion of the element is permanently magnetized. One side or face of the element is flat black to match the sign face background. Other sides which are used to form message letters are colored, usually in greenish yellow if disk or sphere is used, and red, white, and blue if the element is cube. Messages are displayed by electro-magnetically flipping appropriate elements from one side to the other.

This type of sign consumes power only when the display is changed and no power is consumed to maintain the display.

However, visibility may be inferior to that of lamp matrix because this type makes use of the reflection of incident light. Moreover during nighttime, light is necessary.

Out of these three types described above, lamp matrix type is recommended for the changeable message sign on mainline, access road and upstream of tunnel because of its lower cost and good legibility. For the changeable message sign at booth, where width is limited and signboard is seen by the drivers at short distance, LED type is recommended.

6.6.4 Message to be Displayed

The length of the message is limited physically by the size of display surface so that message must be short, concise yet comprehensible to road users. Besides, messages will be displayed in Malaysian Language only for the same reason although other languages are commonly used on information facility in this country.

1) Phrase

In general, a message consists of the combination of words and phrases describing location, cause and consequence as shown below within the limitation on the total number of letters set by the physical size of the signboard. As mentioned before, actual message will be in the Malaysian Language (see Operation Manual for the full range of messages recommended).

a. Location

Name of location such as:

* Interchange XXXX
* Next interchange
* Interchange XXXX - Interchange XXXX
* XX Km ahead

b. Supplemental phrase to location

Phrase to specify more in detail the location concerned such as:

* On-ramp
* Off-ramp
* Near
* Beyond

c. Cause of incident

Cause of incident such as:

* Accident
* Construction work
* Heavy rain
* Cross wind

d. Result of incident

Result of incident such as:

* Congestion
* Section closed
* Lane closed

e. Instruction

Instruction or suggestion to drivers such as:

* Exit here
* Use right lane
* Reduce speed

2) Length of Message

In general, longer message can convey more detailed information and message composition can be more flexible. As the size of the signboard becomes larger, however, longer time is required for road users to recognize and understand the message, which is not desirable for safety reason. Moreover the cost of the signboard and its controller will be higher. The size of signboard or the maximum length of a message must be, therefore, determined to be one that is long enough to express necessary information yet comprehensive to the road users.

A review of the interchange names and other words and phrases in the Malaysian Language to describe causes and consequences shows that the average and maximum length of phrases in each category is 9 and 15 letters, respectively. It must be noted, however, that two location names are used in a message if the section between two interchanges is to be specified. Based on these findings, the maximum length of message a signboard can display is set at about 50 letters, including blanks between words.

3) Size of Lettering

It is required that the message on the changeable message sign must be legible from a distance of at least 150 meters upstream of the sign for drivers to understand the displayed message and safely take action if necessary. To meet this requirement, a letter must be about at least 22.5 cm in height. Considering that the messages in Malaysian Language require relatively more letters than English, the size of a letter is set as 35 cm high by 25 cm wide. A letter of this size can be expressed by dot matrix of five horizontal dots by seven vertical dots at 50 mm interval in both directions. Proportional spacing of letters would be introduced so that the number of dots necessary to display some letters like "I" could be reduced.

4) Signboard Display Window Layout

Based on the discussion on the maximum number of letters and the size of a letter above, physical length of a message is calculated as more than 10 meters long assuming dot intervals of 50 mm. This required length is too long to put in one row. Messages are, therefore, to be shown in two rows instead, each having 25 letters. The same window layout but smaller dot interval will be adopted for the changeable message sign at toll booth to maintain design consistency even though it uses LED as the display element.

6.6.5 Installation Type

The following three types of installation are usually used on the expressway and highway:

* Overhead type mounted on a gantry structure.
* Overhang type attached to the arms stretched horizontally over the roadway from a roadside pole.
* Pedestal type mounted on a pedestal placed at the roadside.

Because the signboards are rather wide, the overhead type mounted on a gantry structure will be used for all changeable message signs except signs at toll booth.

6.6.6 Installation Location

Changeable message signs are installed at the following locations:

* On mainline of expressways and highways
* At tunnel entrance
* On access road leading to expressways and highways
* At toll booth

1) CMS on Mainline

The installation location of CMS on mainline is further classified into two types.

a) Upstream of off-ramp

Changeable message sign is installed at approximately 200 meters upstream of the end of decelerating lane of an off-ramp. The sign displays road and traffic information on the downstream section and enables drivers to decide either to proceed on the expressway and highway or to divert to the access road. If the downstream section is closed, the sign notifies the drivers of the closure and requires them to exit at the interchange.

b) Intermediate Location

The sign is intended to inform drivers of the road, traffic or weather condition ahead and urge them to drive accordingly. This type of sign is not used in the proposed system.

2) Tunnel Entrance

The sign is provided to tunnel of 150 meter or longer in length. The sign shows the abnormal condition in the tunnel and requests careful driving or prohibits the vehicles from entering into the tunnel. The sign is placed about 300 meters upstream of the tunnel entrance for the road with design speed of 80 km/h or higher and at 150 meters upstream for road of 60 km/h and lower. The sign may be used to display the general road and traffic information of the sections downstream of the sign location.

3) CMS on Access Road

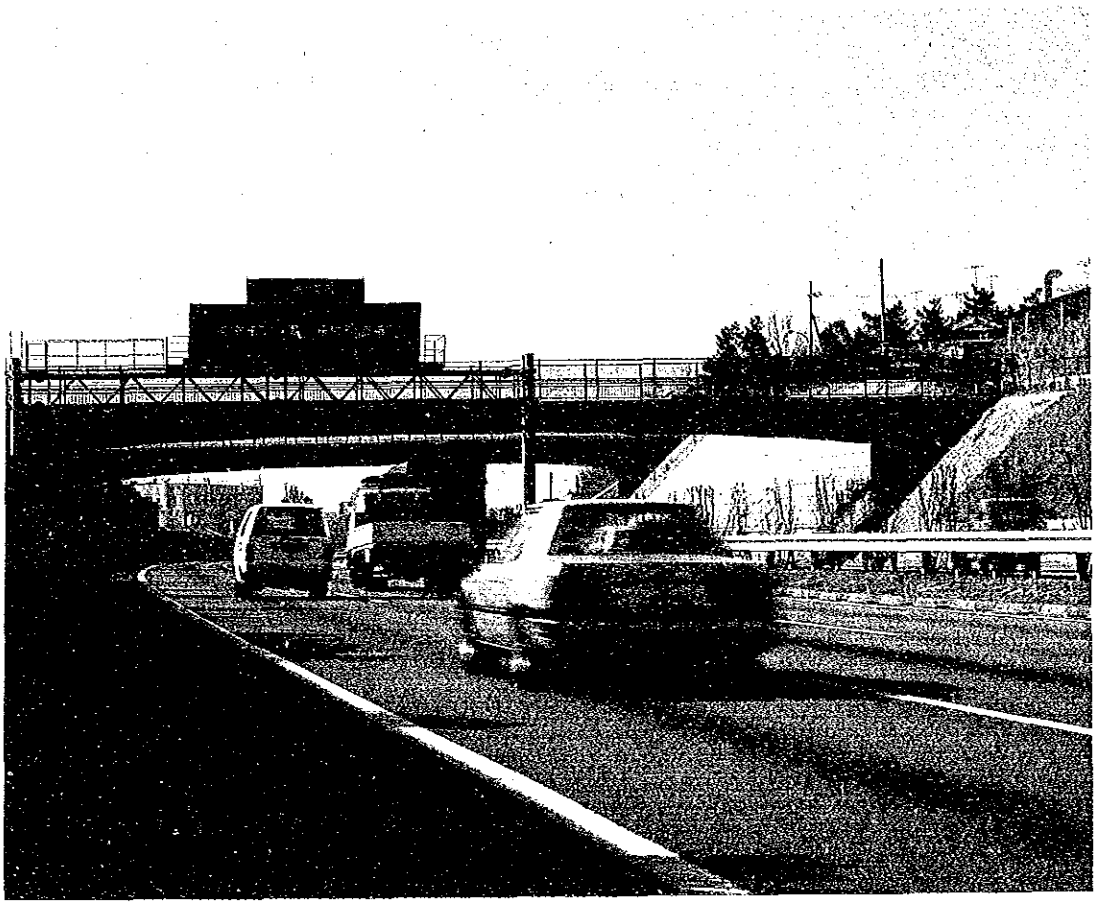
The purpose of the sign is to inform the possible users of the expressway and highway of the road and traffic condition on the expressway and highway in advance and assist them in selecting the route.

4) CMS at Toll Booth

The sign at toll booth is intended to inform the drivers of the road, traffic and weather condition on the expressway and highway. One sign is provided to every two booths.

This type of sign is recommended as simple and basic means of information dissemination on Malaysian expressways and highways.

Table 6.6.1 summarizes the installation standards of changeable message sign at each management level.



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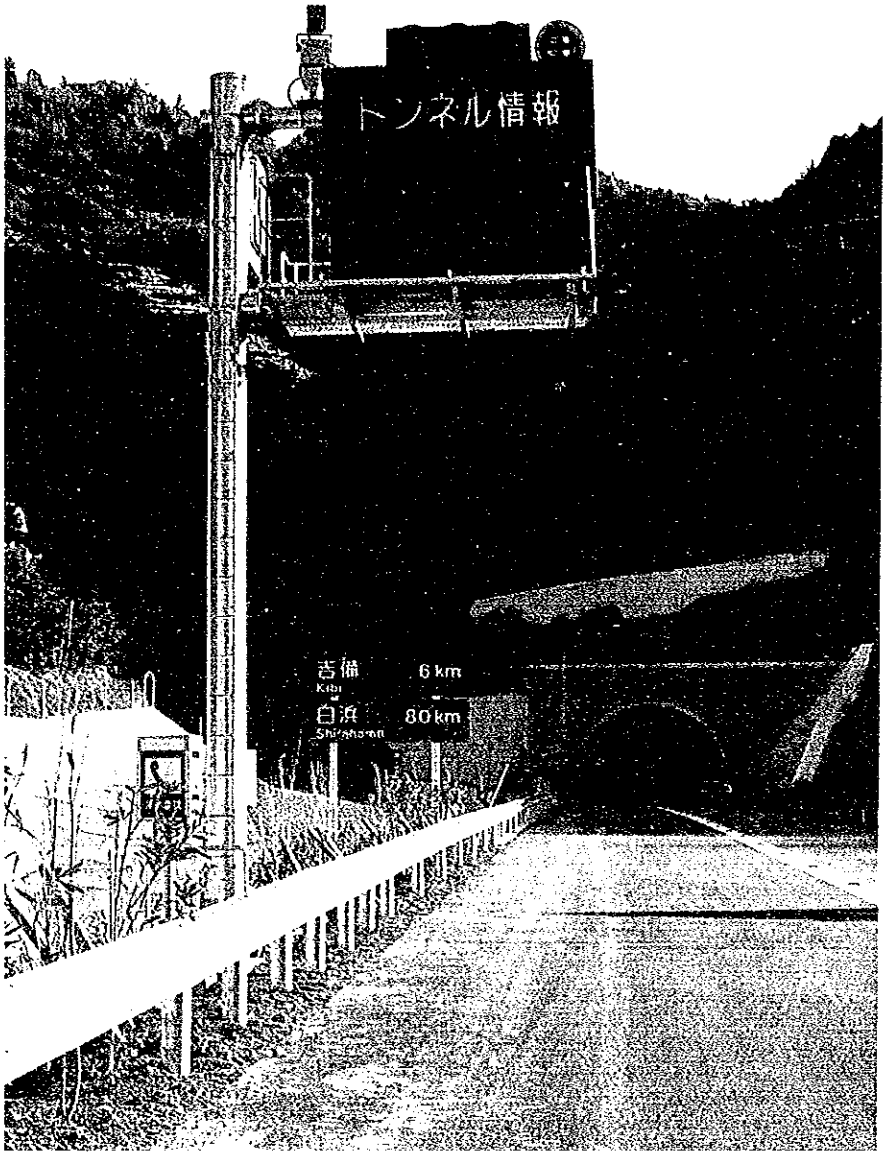
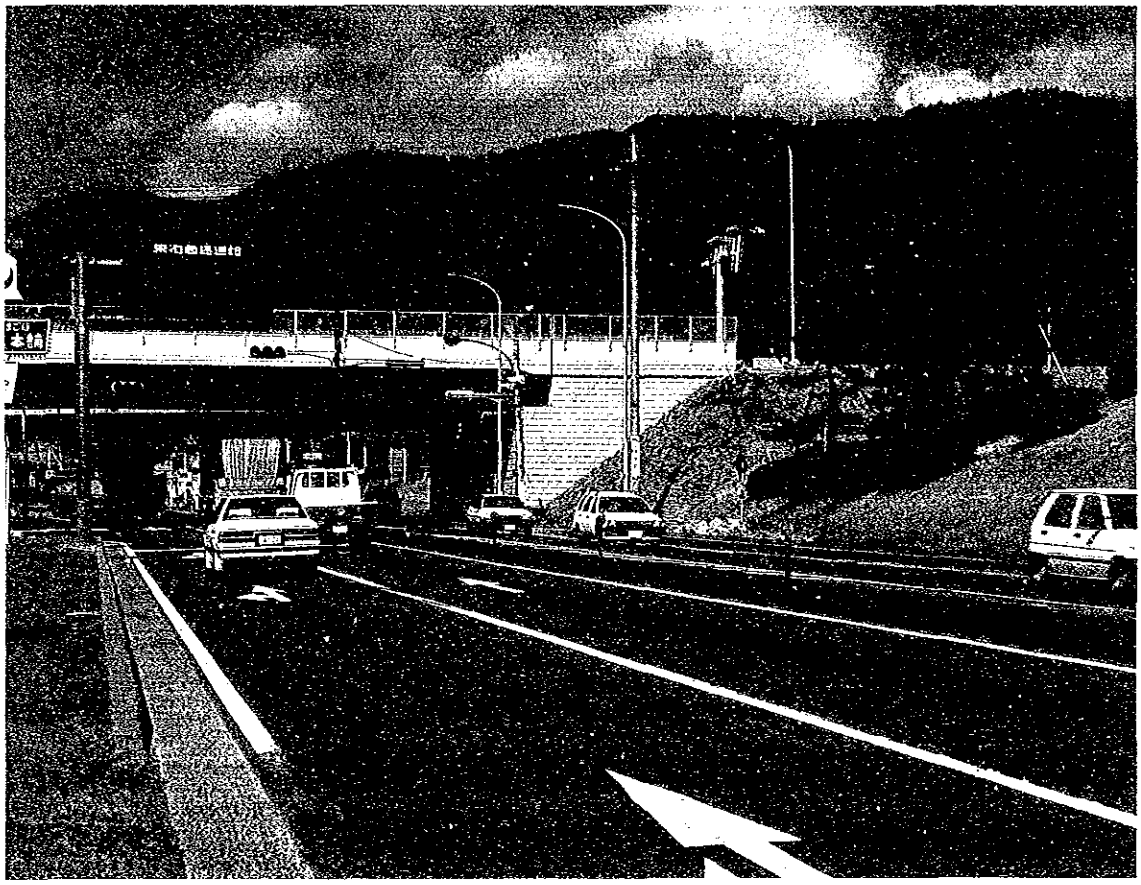
An Example of a Gantry Mounted Overhead Type Mainline Changeable Message Sign



Courtesy of Tokyo Road Engineering Co.Ltd, Japan

An Example of an Overhanged Type Tunnel Changeable Message Sign



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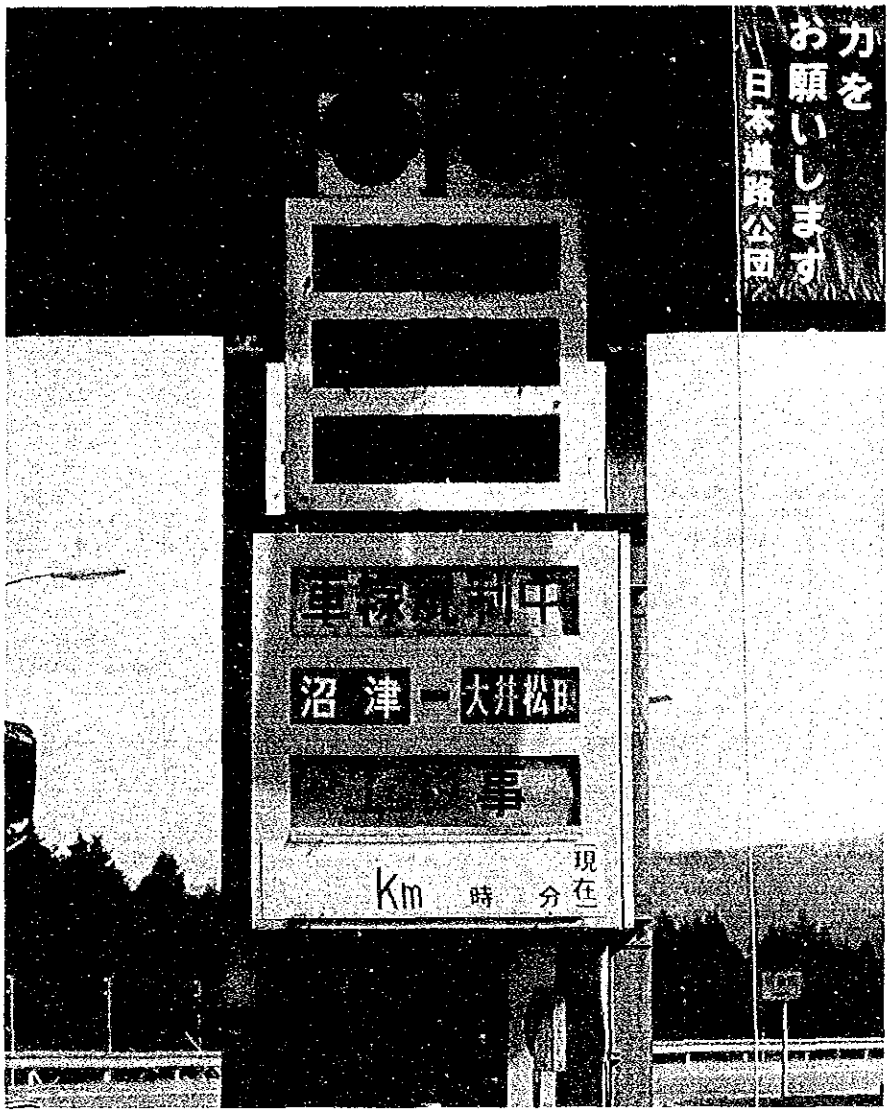
An Example of an Access Road Changeable Message Sign



Courtesy of Tokyo Road Engineering Co.Ltd, Japan

An Example of A Toll Gate Changeable Message Sign

Table 6.6.1: Installation Standards of Changeable Message Sign

1) Motorway

Location / Level	Mainline		Access Road	Toll Booth
	Upstream of Off-ramp	Upstream of Tunnel		
Level 1	IC located in major cities	Tunnel entrance		Entrance toll booth (1 sign/2 booths)
Level 2	Major ICs			
Level 3			Major access road	

2) Expressway

Location / Level	Mainline		Access Road	Toll Booth
	Upstream of Off-ramp	Upstream of Tunnel		
Level 1				Entrance toll booth
Level 2				
Level 3				

3) Karak Highway

Location / Level	Mainline		Access Road	Toll Booth
	Upstream of Off-ramp	Upstream of Tunnel		
Level 1		Tunnel entrance		Entrance toll booth
Level 2				
Level 3				

6.6.7 Operation Mode

Changeable message sign on mainline and access road is used for the general traffic control and management purpose and their operation is possible from both the control center and the maintenance office, while changeable message sign at tunnel entrance is installed as one of the disaster prevention equipment and its control is done at the tunnel control room. Several operation modes are provided to the control center and maintenance.

1) Changeable Message Sign on Mainline and Access Road

Changeable message sign on mainline and access road are normally controlled from the traffic control center. But it is also possible to operate them from the maintenance office when the traffic control center is not operative or when communication between the center and maintenance office is interrupted. Operation modes are summarized below.

From Traffic Control Center

* Control by event:
  Several CMSs are controlled collectively by the input data of event such as congestion or traffic regulation.

* Linked control:
  CMS on access road is linked to a CMS on mainline and controlled simultaneously with the mainline CMS.

* Control by section:
  Several CMSs in a section is collectively controlled and display the same message.

* Individual control:
  Each CMS is controlled individually.

From Maintenance Office

* Individual control:
  Only individual control is possible at maintenance office.

2) Changeable Message Sign at Tunnel Entrance

Changeable message sign at tunnel entrance is one of the disaster prevention equipment and has the following operation modes:

* Local automatic:
  In case of fire in tunnel, CMS is operated automatically by the fire detection system.

* Remote manual:
  Each CMS is controlled individually from remote location when traffic regulation is enforced by such event as construction work.

Linkage of CMS with fire detection system can be released manually by an operator at the tunnel control room. Under the latter mode, CMS is operated by an operator at the tunnel control room.

In addition to the operation modes mentioned above, CMS is provided with local manual control function which is activated through the operation panel incorporated in the local controller.

6.6.8 Monitoring

Displayed information on CMS is continuously monitored at the traffic control center, the maintenance office and the tunnel control room.

For the control of CMS, CRT display at the traffic control center is necessary. This is because their operation require observation of the current message on display and guidance to operator including the selection of an over-riding message from a multiple messages at one time, or selection of the items for the automatic linked control.

6.7 Changeable Speed Limit Sign

6.7.1 Introduction

Changeable speed limit sign is installed along the expressway and highway and used to inform drivers of the speed limit being enforced. The sign is capable of displaying two or three different speed limits in accordance with the command from the control center. Reduction of speed limit is required when the original speed limit is hazardous under the inclement weather condition.

6.7.2 System Configuration

Changeable speed limit sign system consists of changeable speed limit sign and its controller installed on a section of freeway at 2 Km intervals, slave remote controller at the maintenance office and master remote controller at the control center.

Changeable speed limit signs in a section, where same speed limit is applied at all times, are grouped into one control unit and controlled simultaneously, but the signs are monitored individually.

6.7.3 Type of Signboard

The following three types of sign are widely used:

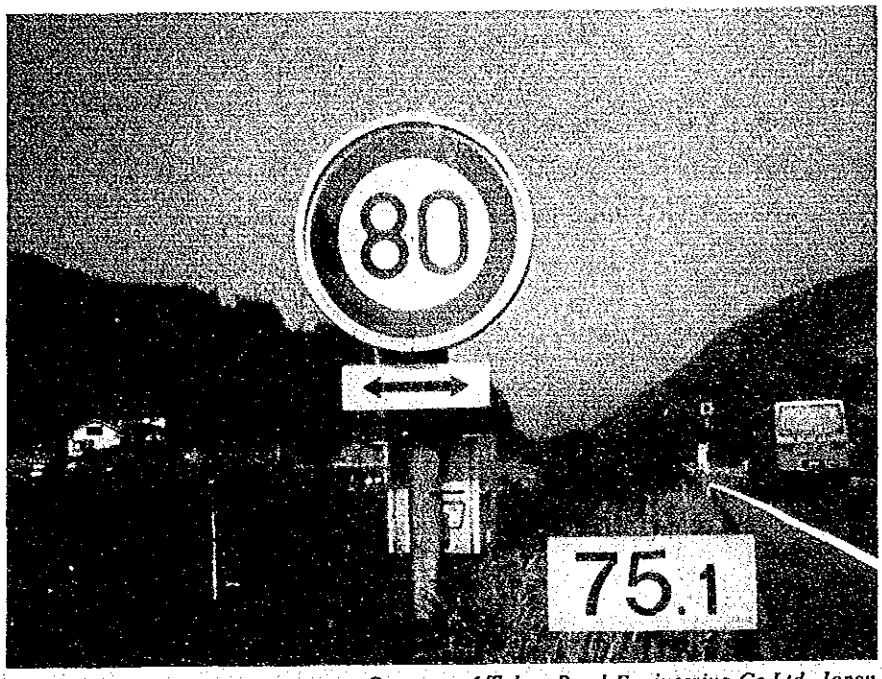
* Lamp matrix type
* Rotating disk type
* Fiber optics type

Lamp matrix type displays the figure by dots of lamps. This type has high visibility and easily recognized by drivers even under fog or heavy rain.

For rotating disk type, two or three disks with different speed limit painted on them are concentrically placed and speed limit in effect is shown by rotating the disk by a motor with the corresponding figure to the top of other disks. No energy is required to maintain the display.

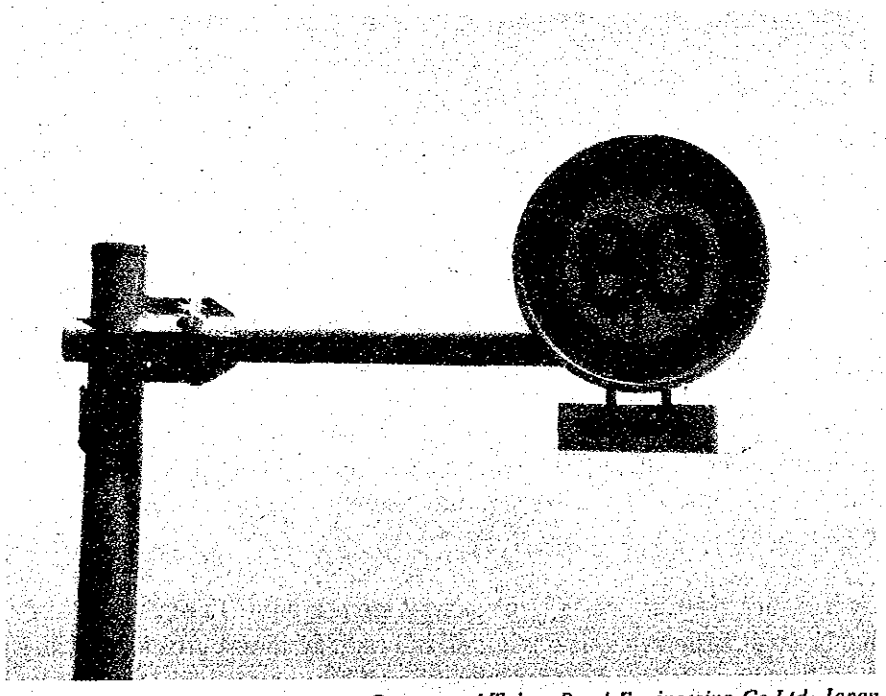
Fiber optics type disperses light energy from a point light source through fibre bundles that form symbols or figures and light from a source is guided to the sign surface to express two or three speed limits.

Rotating disk type is recommended from the viewpoint of cost and similarity in appearance with the fixed speed limit sign.



Courtesy of Tokyo Road Engineering Co.Ltd, Japan

The Rotating Disk Type Changeable Speed Limit Sign Mounted on a Pedestal



Courtesy of Tokyo Road Engineering Co.Ltd, Japan

Rotating Disk Type Changeable Speed Limit Sign Mounted on a Overhanged Pole

6.7.4 Installation Location

Changeable speed limit sign is installed at the section, where speed reduction is often necessitated by adverse weather such as heavy rain, and strong cross wind. Several signs are installed at the intervals of 800 meters to 2000 meters to cover the section, where speed limit reduction is required.

Besides, this sign is also installed at sections where the geometric design are found to be unsatisfactory. Based on these considerations, changeable speed limit sign is recommended to be installed along the Changkat Jering-Ipoh Section of the North-South Expressway.

6.7.5 Specifications

1) Changeable Speed Limit Sign

a.	Type of sign:	Rotating disk.
b.	Speed limit display:	No display, 80 Km/h and 50 Km/h.
c.	Manual operation:	Possible by handle.
d.	Changeover time:	Less than 20 sec.

2) Transmission System

a.	Configuration:	1:N.
b.	Transmission system:	4-wire Half-duplex transmission system.
c.	Transmission method:	Time division cyclic transmission.
d.	Transmission rate:	50 bits/sec.

6.8 Radio Broadcasting

6.8.1 Introduction

Radio broadcasting is one of the most common means of information dissemination. It utilizes the broadcasting station run by other agency or company, thus the system can be realized with a small amount of investment.

Radio broadcasting booth is constructed in the control center and connected to the outside broadcasting station through the telephone line. Announcer at the control center obtains traffic-related information through the wall map, CCTV monitor, CRT terminal, etc. and broadcasts timely and accurate information periodically between ordinary radio programmes. Drivers receive traffic information through the ordinary car radio which acts as a driver information tool.

6.8.2 System Configuration

As radio broadcasting system of traffic information makes use of the existing broadcasting system, only a microphone and a transmitter to the broadcasting station are necessary and provided to the control center.

6.9 Highway Radio

6.9.1 Introduction

Highway radio is one of the information dissemination devices on the expressways and highways. It utilizes the conventional car radio as the information receiving device thus eliminating the necessity of additional equipment on the vehicle side. It uses high-end of the AM band frequency not used by broadcasting radio station but can be received by car radio. It provides information, usually more in detail compared with the message shown on changeable message sign, in the form of voice so that drivers' sight is not disrupted to obtain information.

Another advantage of the highway radio over changeable message sign is that more than one message can be conveyed to the drivers at a time.

6.9.2 System Configuration

Highway radio system consists of message editor, operator console and controller at the control center, monitor and supervisory equipment at the maintenance office, guide sign, transmitter and antenna on the expressway and highway and car radio.

6.9.3 Type of Antenna

Antenna is selected among directional antennas of slit coaxial cable or parallel two-wire induction line, or non-directional vertical antenna based on the area covered, ambient noise level or antenna location. Each antenna has the following features:

1) Slit Coaxial Cable

Slit coaxial cable is applicable to the linear section such as on mainline or at ramps and the unnecessary radiation outside of the expressway is kept minimum due to steep attenuation of electric field strength as the distance away from the cable. This type of antenna is also superior in aesthetics and not susceptible to the road work as the cable is buried underground beneath the median. Proposed system adopts the slit coaxial cable.

2) Parallel Two-wire Induction Line

This type of antenna is also applied to the linear section, where not enough electric field strength is obtained by slit coaxial cable due to bridge or elevated section. The line is installed at the shoulder above the ground so that it is subject to damage by car accident or maintenance work. Appearance is also a problem.

3) Vertical Antenna

This type of antenna has no directivity and is adopted to cover the certain area such as service area, parking area or junction of two expressways.

6.9.4 Length of Service Section

Highway radio system is provided to a section of expressway for certain length to ensure the reception of the message by the road users. The length of service section is determined by both the length of message and vehicle speed. According to a study, message should not be longer than 40 seconds and must be repeated three times for the listener to receive the message at least two complete cycles. Assuming the maximum vehicle speed of 110 Km/h, the length of service section is calculated as 3.7 Km.

6.9.5 Message Preparation

Message to be provided will be prepared by the following three steps:

* Collection of information to be provided;
* Composition of message text;
* Synthesizing the message by voice synthesizer.

Various incident information such as type of incident, severity, cause, traffic regulation, degree of congestion, suggested action, etc are input to the message editing equipment and message text will be produced using pre-stored words, phrases and sentence patterns. The message text is then fed to the voice synthesizer and converted to the voice information.

Message must be easily understood and recalled by the road users. A combination of three simple information, or one complicated information plus one simple information is the maximum volume of information that can be conveyed by one message of 40 seconds long.

6.9.6 Guide Sign

In order to inform the road users of the highway radio system, three guide signs will be installed at 1 Km upstream of service section, at the starting point of the section and at the ending point. The sign will be inner illuminated type and lighted when the system is in operation.

6.9.7 Installation Location

Highway radio system will be installed at upstream of an interchange. However, as the system is capable of providing information to the users in both directions through the antenna installed at the length of 3.7 Km, actual installation location will be at a section between two interchanges. Section between Kajang interchange and Bangi interchange is selected as a location for highway radio.

6.9.8 Specifications

1) Transmitter
   a. Frequency: 1620 KHz.
   b. Power: 10 watts/50 ohm unbalanced.
   c. Modulation: Amplitude modulation.

2) Antenna
   a. Type: Slit coaxial cable.
   b. Impedance: 50 ohm unbalance.

6.10 Transmission System

6.10.1 Introduction

Transmission refers to the transfer of information from one location to another. In a traffic control and management system, transmission system consists of three layers or tiers as described below.

* Trunk line transmission system
* Local line transmission system
* Access line transmission system

Trunk line transmission system links regional offices and maintenance offices and transmit bulk of voice and data signal, and in some cases video signals through high speed transmission channels over long haul which can be up to several hundreds kilo-meters.

Local line transmission system provides multiple transmission channels between the nodes established at 10 to 20 Km interval and collects voice and data signals to a trunk line transmission station that is usually set up at every maintenance office.

Access line transmission connects the facilities and equipment in offices and roadside to a node for local line transmission. Transmission distance is short and normally less than 20 Km.

Figure 6.10.1 illustrates the hierarchical composition of transmission system.

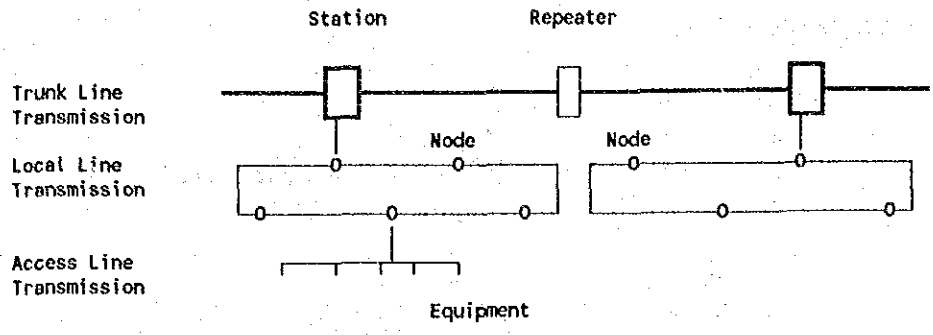


Figure 6.10.1: Transmission System Hierarchy

As video signal transmission requires a wide band-width of the channel, different transmission technology is adopted for transmitting such a signal to the trunk line transmission station.

In this section, trunk line, local line and video transmission is studied using Kajang -Ayer Keroh section of North-South Expressway as a representative section. After the type and number of channels in the section is estimated, trunk line and local line transmission methods are compared from the technical and economical vies points.

6.10.2 Trunk Line Transmission

Various trunk line transmission technologies are available and they can be divided into two groups, analog method and digital method. Because of the limitations such as short transmission distance and repeater interval, inferior quality, lack of technical prospect in future, analog method is not recommended.

In terms of transmission media, transmission system is classified into two group; wired system and wireless system. Three types of cable; balanced pair cable, coaxial cable and optical fiber cable are used for trunk line transmission. Wireless system employs radio transmission at the frequency range of 2 to 8 GHz.

Three alternatives for the trunk line transmission system are compared to select the most suitable system. The results of comparison are presented in Table 6.10.1. As shown in the table, optical fiber transmission system has become the standard for the long haul transmission and is recommended for the Malaysian expressways and highways too. Different standards, however, have been specified for PCM hierarchy in Japan, North America and Europe. If no transmission traffic other than for expressway control and management is added, 100 M (90 M in North American standards and 120 M in Europe) system is deemed appropriate for the

section with video signal transmission, while 32 M system for the section without video signal transmission.

Cost comparison of the three systems in the table is prepared for the section of Kajang-Ayer Keroh on the North-South Expressway as a representative section. The number of channels are first estimated based on the number of equipment in the proposed system. Configuration of each system is then designed to accommodate the required number of channels. In the case of optical fiber transmission, video signal is multiplexed with telephone channels. In metallic cable and micro wave systems, however, video signal transmission is separate from telephone circuits. Cost of each system is estimated for equipment, cable and installation work and results are shown by relative magnitude of the total cost.

A carrier terminal station will be installed at each maintenance office, which normally covers about 70 to 90 km of expressway and highway. Toll office, service area, parking area, and roadside facilities in the coverage area of the maintenance office is connected to the carrier terminal station through local line transmission system.

Table 6.10.1: Trunk Line Transmission System

System	Cable Type	Signal Type	Transmission method	Capacity	Repeater Interval	Quality	Cable[2]	Relative System Cost[3]	Remarks
Metallic Cable System		Balanced Pair	Telephone (1.5M)	DP-1.5M	24 ch	2 Km	Fair	PEF	1.49 . Not suitable for long haul transmission . Susceptible to induction due to use of metallic cable
		Video	ITV-4M	1 ch	2 Km	Fair	PEF		
Optical Fiber System		Optical Fiber	Telephone	32 M[1]	480 ch	40 Km	Good	SM	1.00 . Suitable for long haul transmission . Longer repeater interval . Not susceptible to induction
			100 M	1,440 ch	40 Km	Good	SM		
			400 M	5,760 ch	40 Km	Good	SM		
		Video	32 M	1 ch	40 Km	Good	SM		
			100 M	3 ch	40 Km	Good	SM		
			400 M	12 ch	40 Km	Good	SM		
Micro Wave System	Micro Wave	Telephone	6G (200 Mb/s)	2,880 ch	50 km	Fair		1.3[4]	. Suitable for long haul transportation . Quality is affected by rain . Number of video signal circuits is limited
		Video		2 ch	50 km	Fair			

Notes: 1) Hierarchy is different for Japanese, North American and European standards.
2) PEF: Formed Polyethylene Cable;
GI: Graded Index Optical Fiber Cable;
SM: Single Mode Optical Fiber Cable.
3) In case they are applied to the section between Kajang and Ayer Keroh
4) When 6 Mb/s system is used for video signal, if 32 Mb/s is adopted, relative cost is 3.0

6.10.3 Local line transmission system

Local line transmission system covers the section of about 70 to 90 km in length, which is the recommended length of route coverage of a maintenance office. The following three methods are candidates for local line transmission.

* Optical digital loop 32M-DLN (optical fiber cable)
* Digital transmission (DP-15.M) (metallic cable)
* Analog transmission T-12SR (metallic cable)

Table 6.10.2 presents the comparison of the three transmission systems. Recent development of digital transmission combined with the use of optical fiber cable has made it possible to use Local Area Network (LAN) type of system in traffic control and management system along the expressway and highway. Optical digital loop system has many advantages like better transmission quality, capacity, longer transmission length without repeater and lower cost when compared with analog system using metallic cable. Digital loop system is recommended for the Malaysian expressways and highways.

6.10.4 Access line transmission system

Access line transmission system connects terminal equipment such as emergency telephone, CCTV camera, vehicle detector and changeable message sign installed along the expressway and highway to the nearest node. Various transmission methods will be used for each type of equipment, but most of them use the frequency band of 300 Hz to 3400 Hz.

6.10.5 Video Signal Transmission System

Video signal transmission methods being used are summarized in Table 6.10.3. In video transmission, system using coaxial cable has been replaced by the optical fiber system, which is also recommended. In a practical application, more than one methods are often adopted depending on the distance and number of channel to be transmitted.

Table 6.10.2: Local Line Transmission System

System	32M DLN	DP 1.5M	T-12 SR
Outline of System	System using optical fiber cable in which input of any type of information at any point of cable is possible within the area. A comprehensive network with the maintainability and reliability.	Transmission between two points at the distance of less than 100 Km using metallic cable and PCM multiplexing. Data transmission is made through MODEM. No supervisory function is provided.	A transmission system between two points at the distance of less than 100 Km using metallic cable and FDM multiplexing. Data transmission is made through MODEM. No supervisory function is provided.
Maintainability	System is placed under the monitoring of network supervisor and detection of malfunction and separation of erroneous parts are made automatically.	Reliability may be improved by adding switcher and monitoring system. But short repeater interval will lessen the reliability.	Reliability may be improved by adding switcher and monitoring system. But short repeater interval lessens the reliability. Development of monitoring system is difficult.
Expansion	Alternation and expansion is possible without adding core and affecting the system in operation. Addition of channels is easily made by adding interface.	Alternation and expansion may need additional cable and repeater and affect the system in operation. Capacity per channel is limited and new cable may be needed.	Same as DP-1.5M
Capacity	480 ch/loop	24 ch/sys	12 ch/sys
Reliability	System itself has RAS and capable of coping with malfunction of equipment and cable.	System does not have countermeasures against malfunction. Additional supervisory system is required and reliability is inferior to DLN.	System does not have countermeasures against malfunction. Additional supervisory system is required. Only signal level is monitored and the reliability is low.
Transmission Quality	Because optical fiber cable and digital transmission are adopted, not affected by electrical induction, and high speed and long haul transmission are possible. Maximum transmission distance: 600 Km Repeater interval: 25 Km	Limitation on transmission distance due to the use of balanced pair cable. Bit error rate is lower than DLN. Maximum transmission distance: 100 Km Repeater interval: 2 Km (0.9mm PEF cable)	Susceptible to electric induction and noise due to balanced pair cable and analog transmission. Transmission quality is inferior. Maximum transmission distance: 100 Km Repeater length: 12 Km
Compatibility with trunk line transmission system	Compatible with both digital and analog interfaces. Optical cable for trunk line and local line and metallic cable can be accommodated in one composite cable.	Only analog interface is possible so that quality deteriorate as number of links increases. Composite cable with trunk line is not possible.	Only analog interface is possible. Both analog transmission noise and quantifying noise affect the quality. Composite cable with trunk line is not possible.
Relative cost	1.00	1.42	1.58

Table 6.10.3: Video Signal Transmission System

System	Capacity	Method	Repeater 1)	Quality 2)	Cable	Remarks
ITV-4M	1 ch	Analog	2 km	S/N drops at every repeater link	PEF 2W	a) Not economical as many repeaters are required for the maximum of 50 km transmission b) Employs established technology and no development is expected
D-1M	1 ch	Analog	5 km (0.85) 10 km (1.3)	- ditto -	GI 1c	a) Item a) above applies b) Applicable to short distance transmission
PFM-1M	1 ch	Pulse Frequency Modulation	15 km (0.85) 20 km (1.3)	- ditto -	GI 1c	a) Longer repeater length compared with analog method b) Applicable to short distance transmission c) Must adopt analog interface so that quality deteriorates by repetition
PCM-100M	1 ch	Digital	15 km (0.85) 30 km (1.3)	- ditto - Does not deteriorate if digital repeating is adopted	GI/SM 1c	a) Item a) above applies b) Applicable to short and medium length transmission c) Can be connected to trunk line through digital interface
32MDPCM	1 ch	Digital Pulse Code Modulation	30 km	- ditto -	- ditto -	a) Item a) above applies b) Uses signal compression and advantageous when number of available channels is limited c) Applicable to trunk line
PCM-400M	4-5 ch	Digital Multiplexing	20 km	- ditto -	SM 1c	a) Item a) above applies b) Economical for independent system
PCM-100	3 ch	- ditto -	15 km	- ditto -	GI 1c	a) Accommodates 3 channels of 32MPDM

Note: 1) Figure in parenthesis is wave length in micrometer
2) PEF - Formed Polyethylene Cable
GI - Grade Index Optical Fiber Cable
SM - Single Mode Optical Fiber Cable

6.10.6 Cable

1) Trunk and Local Line Cable

The single mode optical fiber cable is recommended for trunk line cable. The cable has a small core diameter that allows only single mode (an axial ray) of light to travel through the fiber. This produces no pulse dispersion and offers wide band width. Optical fiber cable is also recommended for local line transmission system. GI type cable is suitable for local line. Design standards for trunk line cable are summarized in Table 6.10.4.

Table 6.10.4: Design Standards for Optical Cable

	Trunk Line		Local Line
	F-32 M	F-100M	32M-DLN
Transmission Rate			
Station	32.064 Mb/s	97.728 Mb/s	32.768 Mb/s
Outside	64.128 Mb/s	111.689 Mb/s	39.3216 / 32.768 Mb/s
Capacity	480 ch/sys	1440 ch/sys	500 / 480 ch/sys
Cable	SM	SM	GI
Maximum Distance	300 Km	300 Km	640 / 1320 Km/loop
Bit Error Rate	$< 10^{-9}$/300 Km	$< 10^{-9}$/300 Km	$< 10^{-9}$/640 or 1320 Km
Wave Length	1.3 micro-meter	1.3 micro-meter	1.3 micro-meter
Output Power	> -2 dBm	> -6 dBm	> -4.5 / -2.5 dBm
Minimum Receivable Power	> -38.5 dBm	> -39.0 dBm	> -41.0 /-36.5 dBm
Allowable Loss	36.5 dBm	33.0 dBm	36.5 / 33.5 dBm
Connector Loss	1.4 dBm	2.5 dBm	2.0 dBm
Cable Margin	3.3 dBm	2.4 dBm	3.3 dBm
System Margin	3.0 dBm	3.4 dBm	3.0 dBm
Cable Loss	28.8 dBm	24.7 dBm	28.2 / 25.2 dBm
Repeating Interval	47 Km	40 Km	30 / 28 Km
Unit Cable Loss	0.61 dB/Km	0.61 dB/Km	0.9 dB/Km

2) Access Line Cable

Colour coded polyethene insulated subscriber's cable (CCP cable) is commonly used for access line. In the case of metallic cable, transmission distance is limited by two factors; attenuation by loss and current decrease by resistance. Maximum transmission distance is summarized below.

a. Limitation by loss

Type of Circuit	Allowable Loss	Maximum Transmission Distance CCP-AP 0.9	CCP-AP 0.65
Exclusive Telephone	6.5 dB	8.0 Km	5.6 Km
Emergency Telephone	8.0 dB	9.9 Km	6.9 Km
Command Telephone	10.0 dB	12.3 Km	8.6 Km

b. Limitation by Resistance

Type of Circuit	Allowable Resistance	Maximum Transmission Distance CCP-AP 0.9	CCP-AP 0.65
Exclusive Telephone	900 ohm	15.5 Km	8.0 Km
Emergency Telephone	900 ohm	15.5 Km	8.0 Km
Command Telephone	600 ohm	10.3 Km	5.3 Km

c. Maximum transmission distance

Type of Circuit	Maximum Transmission Distance CCP-AP 0.9	CCP-AP 0.65
Exclusive Telephone	8.0 Km	5.6 Km
Emergency Telephone	9.9 Km	6.9 Km
Command Telephone	10.3 Km	5.3 Km

Allowable loss for the access line transmission of roadside equipment to the nearest node has larger margin than that for telephones so that metallic cable design is dictated by telephone system.

As shown above, CCP cable having copper wire diameter of 0.90 mm is suggested. The number of pairs in a cable is 20 to 60 pairs depending on the number of circuits needed at each section taking 50 percents of spares into account.

When utilizing two cables at the same stretch, "composite cable" combining optical fiber and metallic cable has recently been adopted so as to save installation cost. Thus it is recommended for use on the Malaysian expressways and highways.

As power is not easily available at most of the terminal equipment location, power cable will be laid along the expressways and highways from the power receiving points to the terminal equipment.

6.10.7 Standby Route

A standby route must be secured for trunk line transmission to attain the higher reliability of the system. Ideally, another optical fiber cable is buried along the expressway and highway at a portion different from that of the original optical fiber cable. If the original cable becomes inoperative, circuits are switched to the standby route automatically at the station. Significant cost increase by the additional cable and its installation work, however, make this method impracticable.

Another method, which is recommended, is to provide additional cores to the optical fiber cable as standby and use them when necessary. This method works when a core is damaged but not effective when the cable is totally damaged.

6.11 Radio System

6.11.1 Introduction

Radio communication system facilitates the communication between the radio control desk at the control center and the maintenance office mobile unit travelling on the expressways and highways. Patrol cars will be equipped with the mobile unit and communication with the center is possible all the time. Toll gate and other manned station will also be provided with the device to backup wired telephone.

6.11.2 System Configuration

The system consists of the radio control equipment installed at the control center and the maintenance office, base station equipment including an antenna at the base station, and mobile units to be installed on the patrol car and patrol motorcycle. Portable radio unit is also included in the system.

6.11.3 Base Station

All base stations belonging to the same control center will have the same frequency for communication with the mobile unit. On the other hand, mobile unit will be equipped with two frequencies; one is the frequency of the control center to which it belongs and another that of the adjacent control center.

Base stations will be established to cover the entire stretch of the routes. Location of the base station is determined by the wave propagation characteristics but selected from the following locations:

* Maintenance office
* Control center
* Interchange, toll plaza and tunnel
* Service area and parking area
* Other necessary location

6.11.4 Radio Equipment

1) Frequency

Frequencies of 400 MHz band is recommended as it is already approved for use on the toll roads.

2) Communication method

Press and talk method is recommended for the following reasons:

* Less number of frequencies are required.
* Equipment is simpler than other types.
* Capable of monitoring the conversation of other mobile unit.

3) Quality

Signal to noise ratio (S/N ratio) must be more than 25 dB with the standard modulated wave at all locations along the route. The standard modulated wave is a wave, the frequency of which is shifted 1.5 KHz against the input of 1 KHz. The S/N ratio of 25 dB corresponds to the conversation quality of Merit 4, in which conversation is clear with small amount of noise.

4) Redundancy

Transmitter and receiver at the base station must be of duplex construction to attain high reliability. The changeover between operating unit and backup unit will be automatic but the control from the traffic control center or the maintenance office will be possible.

5) Power supply

The base station equipment must be provided with batteries which are capable of maintaining the power for 3 hours when the station is provided with a generator and 6 hours if not, when the power is interrupted.

6.11.5 Propagation Test

Propagation characteristics of the wave between the base station and the mobile unit is complex as obstacles which cause diffraction or reflection of wave normally exist. In addition, the height of mobile unit antenna is only 1.5 to 2 meters above the ground so that the receiving level is easily affected by the surrounding geometric condition, structures and trees. To secure the stable communication through the radio system, receiving level at all points must be higher than the required level. The receiving level is first estimated by calculation and then propagation test must be conducted.

6.12 Telephone System

6.12.1 Introduction

In a traffic control and management system, the following three telephone systems are normally provided:

* Private branch exchange telephone system
* Command telephone system
* Emergency telephone system

Emergency telephone system has already been discussed in details in section 6.1, and therefore in this section, the other two telephone systems are described.

6.12.2 Private Branch Exchange Telephone System

As an expressway and highway management involves organizations and offices scattered along the entire expressway and highway, efficient communication between various locations must be provided. Particularly, in case of a severe incident, securing of communication channel is vital for executing countermeasures and in this sense subscriber's telephone system provided by Syarikat Telekom Malaysia (STM) is neither adequate nor economical. For this purpose, in-house telephone system or private branch telephone system covering all the offices is required. The system makes use of the communication system to be established for the entire stretch of the expressway and highway so that single closed telephone network within the expressway and highway management body can be realized.

The system consists of digital exchange of various capacity placed at headquarters, regional office, maintenance office, toll gate, etc. and telephone sets. Data terminals such as facsimile, and videotext can also be connected to digital exchange. Conception of the system is illustrated in Figure 6.12.1.

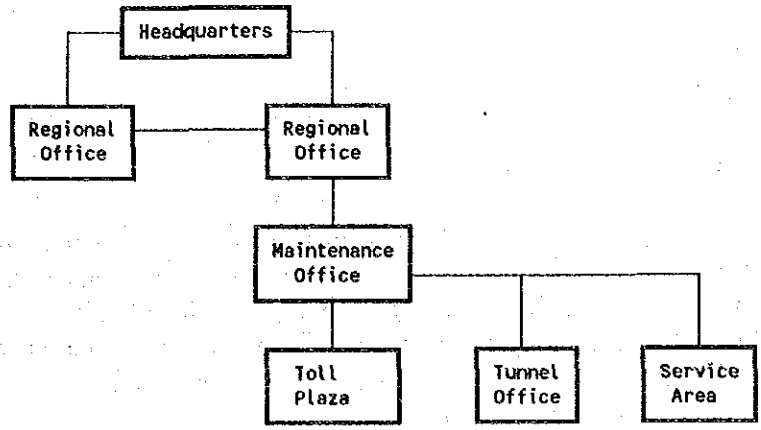


Figure 6.12.1: Private Branch Exchange Telephone Network

6.12.3 Command Telephone System

It happens quite often in an expressway and highway management that the same information on an incident must be transmitted from a location to several places like maintenance office, toll gate, etc. The ordinary telephone system of one to one communication method is not suitable for the dissemination of information from one source to plural receivers. Command telephone system is intended for this purpose.

The system consists of the command issuing telephone installed at the regional office and the control center and the command receiving telephone placed at maintenance office, toll gate, service area, etc.

Offices are grouped by type such as maintenance office or toll gate, or by section. Command is issued through the command issuing telephone after a group of receivers is selected. The receiving telephone is provided with a speaker, through which command or information is pass on to the staff at the receiver end. Confirmation lamps on the issuing telephone are turned on when the confirmation button on the command is pressed indicating the receipt of command.

6.13 Central Computer System

6.13.1 Introduction

Many of the data processing executed in the control center is performed by a central computer system. This is because of the fact that the cost of providing special equipment for each function generally exceeds the cost of a whole system requirement.

6.13.2 Functions

Information Collection

Fundamental functions of the central computer system is to collect various information concerning not only traffic but also other related information such as weather, construction work, events, etc. These information is gathered by means of such equipment as vehicle detector, weather sensor, emergency telephone, and CCTV. Some of the information are automatically collected by equipment, while others are input by operator.

Terminal Equipment Control

The computer system automatically or in accordance with a command input by an operator, controls roadside facilities such as changeable message sign or changeable speed limit sign.

Man-machine Interface

Various data are displayed on a display terminal in characters or in graphic form. It provides all the information that the computer system has, including traffic and incident data, and system operation upon request by an operator and assist them understand the current expressway and highway condition or organize countermeasures when necessary. Report to be displayed on a display terminal include but not limited to:

* Current or historical traffic volume on through lane, on-ramp and off-ramp
* Occupancy rate or congestion level
* Weather condition
* Operational status of changeable message sign
* Operational status of changeable speed limit sign
* Incident information
* Status and data from other traffic control and management system
* System status including equipment malfunction

A graphic display panel will be installed in the traffic control center to provide an overall visual presentation of the expressway and highway condition by lamp and other display elements, automatically or manually. The following information is likely to be displayed on the graphic display panel:

* Congestion
* Incident
* Regulation
* Expressway or highway condition
* Changeable message sign operation
* Changeable speed limit sign operation
* Emergency telephone

Countermeasures Formation

Part of countermeasures formation is undertaken by the computer system. For example, message to be displayed on changeable message sign or broadcasted through highway radio will be prepared automatically by the system based on the incident information stored in the system. Messages are issued to the roadside facilities automatically or after confirmation by the operator.

Reports

Reports are printed through printer as records of traffic data and system operation. Reports are output either periodically or in response to an operator's request.

Recording

Operational data and traffic data are recorded on a mass storage device in a specified format as record and for future analysis.

Operation Monitoring

The computer system monitors the operation of the system itself and equipment connected to it including roadside facilities. If any abnormality is detected, it is recorded by the monitoring system, and an alarm signal is issued when the fault is serious.

Data Communication

The computer system performs on-line data exchange with other traffic control and management systems through data channel. Database in each system will be mutually accessed and traffic and incident information will be exchanged.

6.13.3 Hardware Configuration

Central computer system consists of central processing unit (CPU), peripherals such as magnetic disk, magnetic tape unit, printer and CRT display, graphic display panel, control desk and interface units for connection with central controller for changeable message sign and detector data processor.

Figure 6.13.1(1) and (2) depict the hardware configuration of a control center and sub-center respectively while Figure 6.13.2(1) through (3) illustrate the control center and sub-center layout plans.

The estimated memory size by usage of the central processing unit for the traffic control center and the maintenance office are shown in Table 6.13.1

Table 6.13.1: Memory Size of CPU

Item	CPU at Control Center	CPU at Maintenance Office
Operating System	240 KB	240 KB
System Area	60 KB	90 KB
Console and Graphic Display Panel Processing Program	10 KB	60 KB
Display and Input Data Buffer	20 KB	20 KB
CRT Processing Program	85 KB	60 KB
Buffer Area	60 KB	120 KB
Total	475 KB	590 KB

Note: KB: Kilo Byte

The size of the external memory unit which store the various programs, parameters and data is estimated as follows:

Table 6.13.2: Size of External Memory Unit

Item	Control Center	Maintenance Office
Operating System	1,500 KB	100 KB
Main Memory Buffer Area	500 KB	100 KB
Display and Input Data Buffer	800 KB	100 KB
CRT Screen Data Area	950 KB	200 KB
Total	3,750 KB	500 KB

Note: KB: Kilo Byte

It should be noted, however, that these are sizes needed for storing the programs and data only and do not include the working margin. The actual sizes to be provided must be at least two or three times larger than the figures.

6.13.4 Software Configuration

The size and speed of the computer requires a high degree of sophistication in its operation. This means that software to be used must be carefully designed to have the attributes of efficiency and user-friendly.

The term "software" applies to all the programs that are written for a computer. It can therefore be defined as the internal programs or routines professionally prepared to simplify programming and computer operations. These internal programs fall into several categories, the totality of which facilitates the efficient use of the computer. These are the operating system, utility programs and application programs. The last two are controlled by the operating system.

1) Operating System

The operating system has a real-time processing function for multiple processing of main memory resident programs and non-resident programs in an efficient manner. All system resources such as main memory, input/output ports, and external mass storage devices are managed by the operating system.

2) Utility Programs

Utility programs are designed to facilitate the efficient use of computer system and normally include the following programs:

a) File management utilities
b) Database management utilities
c) Compiler and assembler
d) Debugging tools
e) Main memory utilities
f) Utilities for auxiliary storage
g) Communication utilities
h) House keeping utilities

3) Application Programs

Traffic surveillance and control functions are performed by application programs, which consist of the following:

a) Detector data processing routine
b) Weather data processing routine
c) Changeable message sign control routine
d) Changeable speed limit sign control routine
e) Man-machine interface routine
f) Statistical processing routine
g) Report producing routine

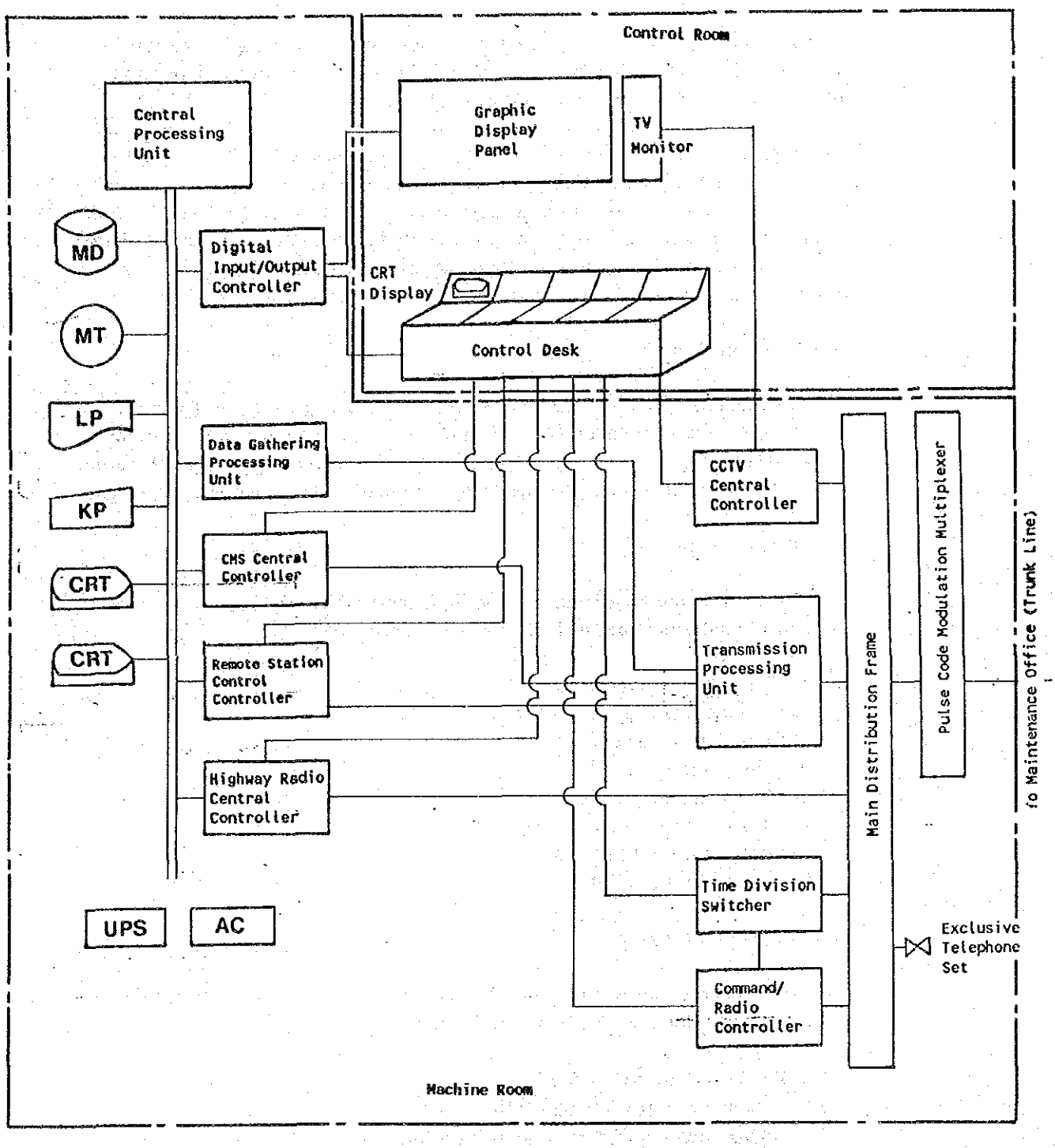


Figure 6.13.1(a): Hardware Configuration of Control Center

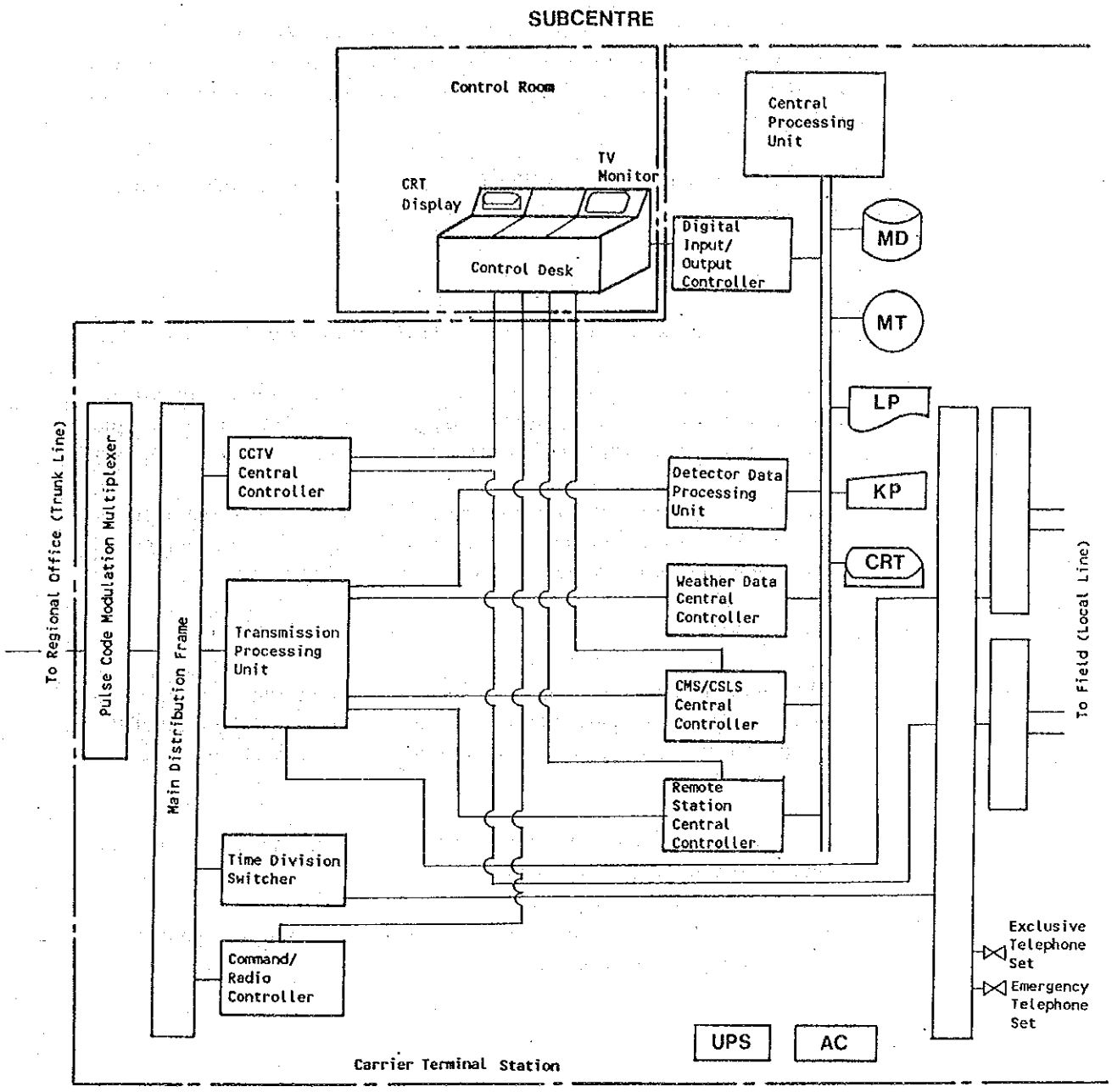


Figure 6.13.1(b): Hardware Configuration of Sub-center

6.13.5 Traffic Control Center Layout

In laying out the equipment in the traffic control center and the sub-center in the maintenance office, the function of each equipment, equipment operation by the operator and the inter-connection between the equipment must be carefully considered.

The layout of monitor panel and control console must be designed considering the following factors:

1) Monitor Panel

   a. Display items must be highly visible and easily recognized by the operator;

   b. Displays and indicators must be arranged such that their contents are easily scanned by the operator. Both the angles of elevation and depression must be within 30 degrees;

   c. The size of monitor panel must be within the sight angle of the operator (120 degree). Height of the panel must not be more than 2.7 meters and width must be 10 to 15 meters. It must be placed in an arc.

2) Operator Console

   a. The operator console must have a work area not larger than the size of 1.8 meters wide by 0.75 meters depth and should not obstruct the sight of the graphic display panel by an operator, whose eye level is about 1.2 meters above the floor.

   b. CCTV monitors must be place in such a way that they do not obstruct the sight of the graphic display panel.

The equipment layout plans of the traffic control center and sub-center are illustrated in Figure 6.13.2(a) through (c).

Traffic Control Center at the Regional Office

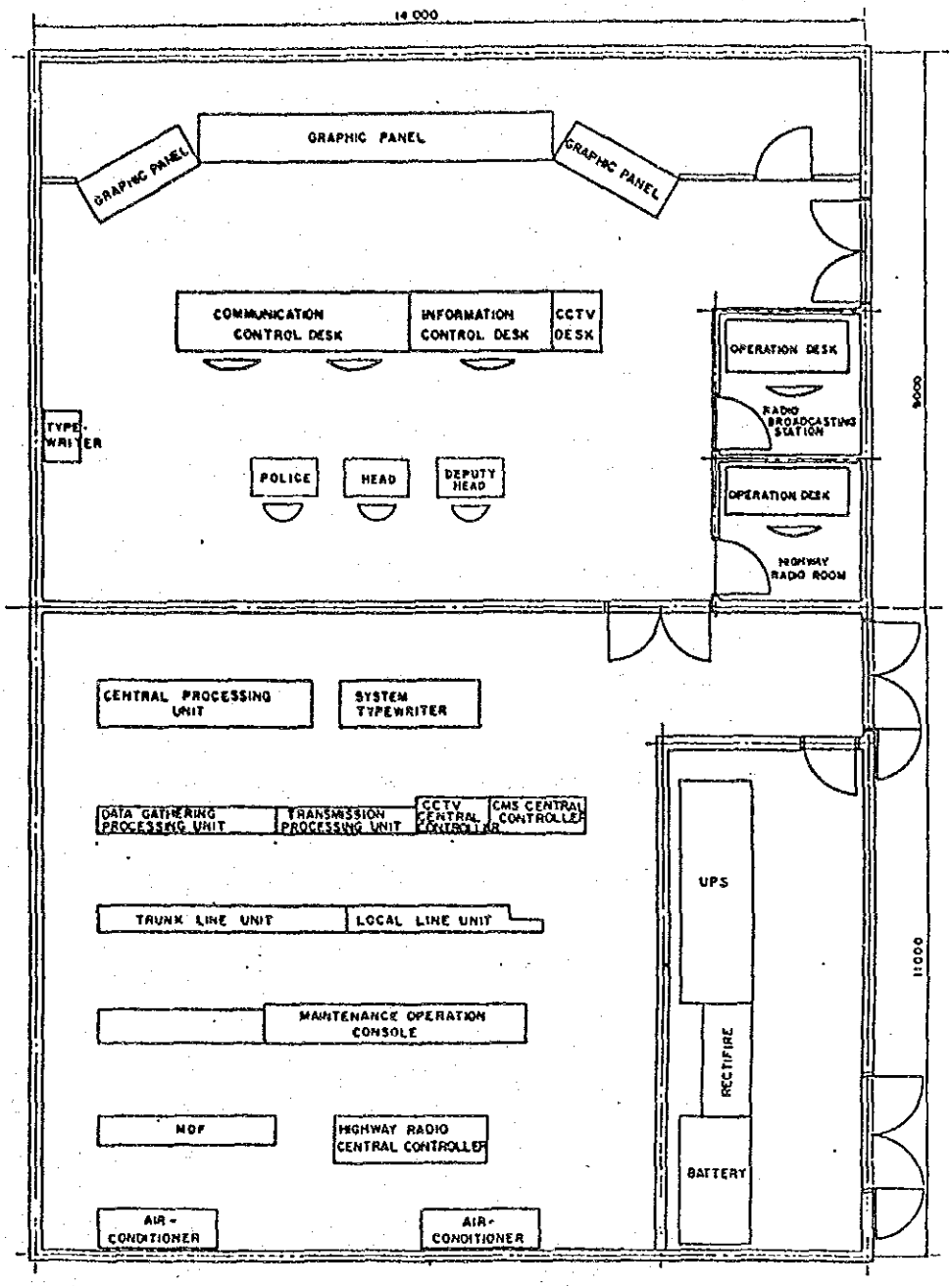
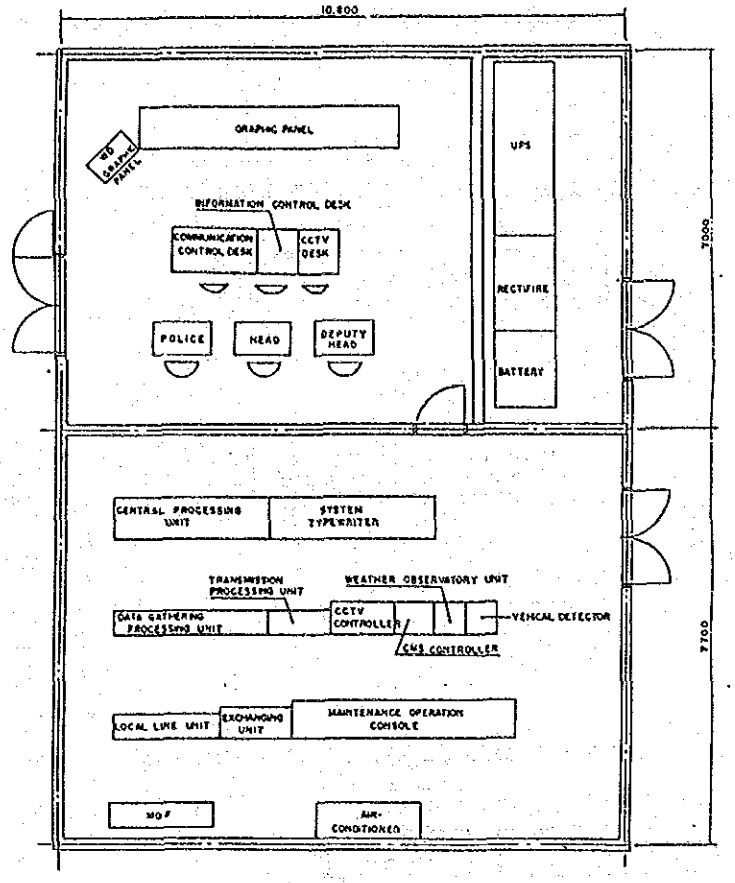


Figure 6.13.2(a): Control Center Layout Plan

Traffic Control Center at Genting Maintenance Office



Traffic Control Center at Penang Bridge Maintenance Office

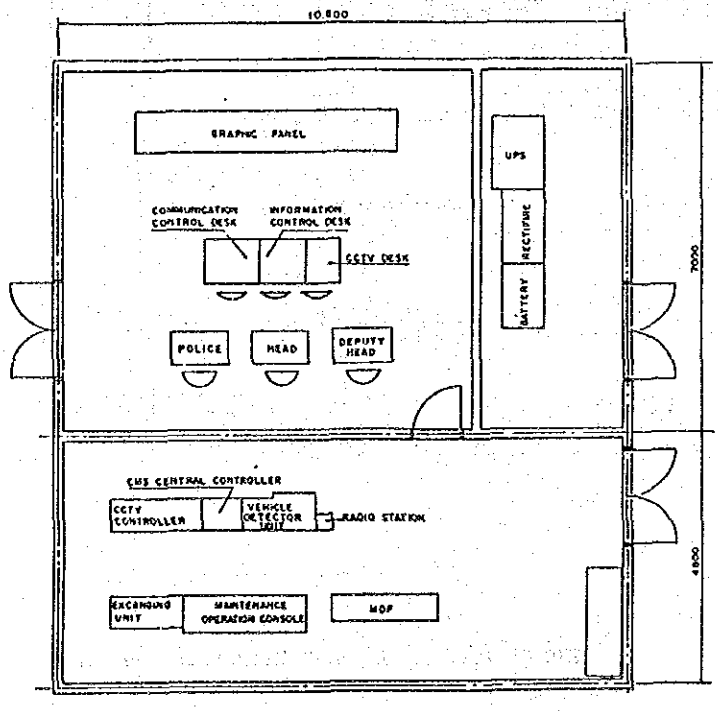
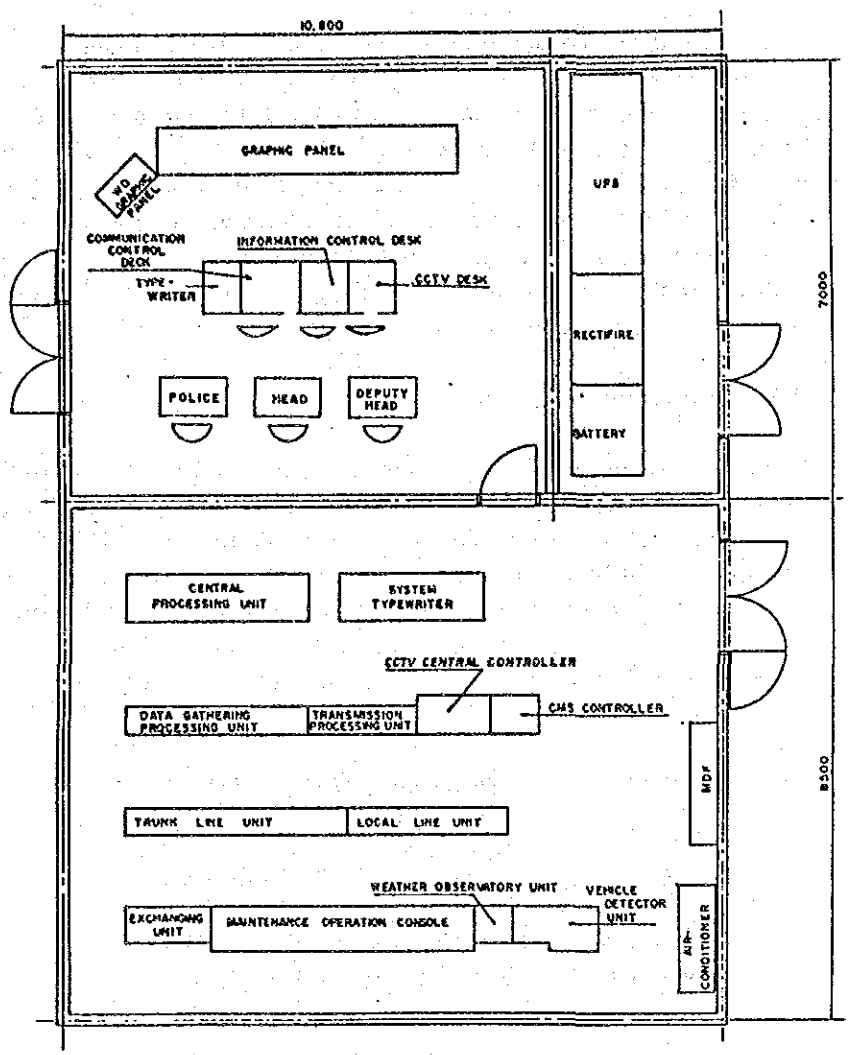


Figure 6.13.2(b): Sub-center Layout Plan

Traffic Control Sub-center at Maintenance Office



Toll Plaza Office

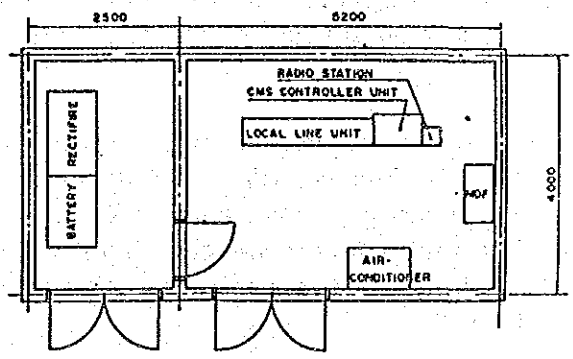


Figure 6.13.2(c): Sub-center Layout Plan

6.13.6 Environmental Conditions

The control center is divided into three sections; a control room, a machine room and a power room (see Figure 6.13.2). The control room in the control center, where the operation of the system is performed by the operators, is the focal point of the traffic control and management system. As such, the room must be separated from the noise and heat sources and its colour and lighting must be well coordinated in order to ensure efficient operation of the system. Various equipment such as computer, transmission devices are to be placed in the machine room. Power room accommodates the power supply equipment like uninterruptible power supply, rectifier and battery.

1) Air-conditioning

Control room and machine room must be air-conditioned to provide suitable environmental condition for the operators and equipment. Although some equipment operate within the broad temperature range, the reliability of the equipment will be enhanced at the constant temperature. Air-conditioning system must be designed taking the heat value of both equipment and operators into consideration. Temperature control of these rooms must be independent as the requirements are different as shown below.

Table 6.13.3: Environmental Condition

Room	Temperature	Relative Humidity
Control Room	25 +/- 3 degree	60 % +/- 10 %
Machine Room	21 +/- 2 degree	20 - 80 %

2) Lighting

Lighting plays an important role in the operation of the system and must be designed to create efficient and comfortable working condition for the operator.

Light sources must be placed in such a way that light reflected by the graphic display panel or CRT screen will not be directly seen by the operator. Illumination of the control console must be bright enough for operator to operate switches or to record the operation. But the different in illumination between graphic display panel and control console must be kept small to avoid the fatigue of eyes.

Window facing outside is suggested for control room to bring in the natural light, which gives the operator the sense of time. Following illumination is suggested:

Table 6.13.4: Suggested Illumination

Average illumination of control room	700 - 1,500 Lux
Graphic display panel	200 - 600 Lux
Control console	380 Lux
CRT screen	350 Lux
Machine room	200 Lux

6.14 Uninterruptible Power Supply

As the traffic control and management system relies on a computer system that operates on a 24-hour basis, a continuous and stable power supply is paramount at the traffic control center and the maintenance office. Uninterruptible power supply system consists of a generator, a constant voltage and constant frequency power supply, a changeover switch, batteries and rectifier.

Under normal condition, the power supply system receives commercial power and supplies power to the equipment through a stabilizing circuit. Should an interruption occur, power is supplied from the batteries until the generator has started and reached a steady state. The changeover switch is provided to switch over automatically between commercial power and the generator.

Capacity of the power supply system is determined by the power consumption of all surveillance and control equipment at the control center, power for air conditioning system and emergency light, and allowance for future expansion. Smaller system is provided at carrier terminal station to maintain the transmission system when commercial power is interrupted.

Power for roadside facilities is directly supplied by commercial power and no backup power is provided for economic reason.

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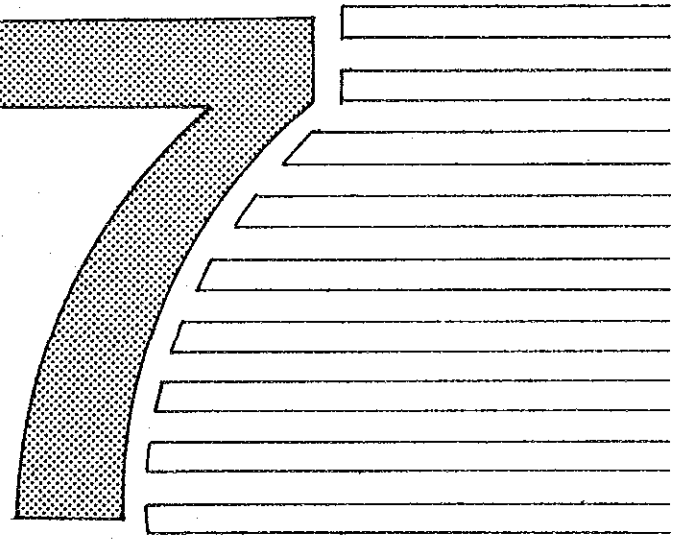

7.0 COST ESTIMATE

7.1 Introduction

The cost for the proposed system, estimated in 1989 price in Malaysian Ringgit, consists of two elements, construction cost and operation cost. The construction cost is further divided into equipment cost and installation work cost. Construction cost estimated is the direct construction cost and does not include such indirect costs as tax and duties for imported equipment and materials, detailed design cost, supervising cost and other project management costs. Local cost of labor and locally available materials are reflected in the estimation of the installation work cost.

7.2 Construction Cost

7.2.1 Cost Item

The construction cost is estimated in accordance with its system configuration, which includes the following items:

1) Information Collection System

* Emergency Telephone
* Vehicle Detector
* Weather Observatory Equipment
* Closed Circuit Television (CCTV)

2) Information Dissemination System

* Changeable Message Sign
* Changeable Speed Limit Sign
* Highway Radio

3) Information Processing System

* Central Processor
* Peripherals
* Graphic Display Panel
* Software

4) Communication System

* Trenching, Conduit and Cable
* Trunk Line System
* Local Line System
* Exchange
* Radio System

It should be noted that this construction cost does not include costs of office building, control center, air-conditioning system, and generator.

7.2.2 Equipment Cost

Unit cost of the equipment is estimated based on cost information from available sources in foreign countries such as Japan, USA, etc. as these equipment are not available in Malaysia and would have to be imported.

The equipment cost is therefore first estimated in foreign currencies and then converted into Malaysian Ringgit. Consequently, this cost is subject to fluctuation in exchange rate of Malaysian Ringgit against the currency of the supplier's country.

7.2.3 Installation Work Cost

Installation work cost consists of labor cost, material cost and miscellaneous cost. The estimation of the labor cost is based on the amount of work estimated for the installation, testing and adjustment if any. Local labor cost is adopted for unit labor cost as most of the work will be carried out by local laborers but 30 percent is added to the estimated direct labor cost as the cost of foreign supervisors.

Most of the materials for installation work will be imported as they are not available in this country and foreign cost is assumed. If the material is available locally such as handhole, concrete and gravel, they are treated as a local cost component. PVC conduit is an exception, which is found to be more costly here than in Japan so that it is included in the foreign cost.

Conduit work including digging, conduit laying and backfilling may be included in the road construction cost for the newly constructed section as such works are part of the overall road construction work. In this estimate, however, all conduit work is included.

System construction cost is presented in Table 7.2.1 for each route and maintenance office by sub-system, and in Table 7.2.2 by stage.

Table 7.2.1: Construction Cost Estimates by Sub-System

Unit: M$'000

Route/Section	Length (km)	Information Collection System	Information Dissemination System	Information Processing System	Communication System	Total	Per km
NORTH-SOUTH EXPRESSWAY							
Alor Setar	96.7	3,054	1,284	4,182	22,602	31,122	322
Butterworth	76.4	2,928	1,353	4,182	19,893	28,356	371
Taiping	91.4	3,929	3,612	4,182	22,036	33,758	369
Ipoh	87.6	3,688	2,424	17,391	24,389	47,892	547
Tanjung Malim	90.3	3,900	970	4,182	22,209	31,260	346
Kajang	75.9	7,104	8,147	4,182	19,507	38,939	513
Ayer Keroh	97.3	2,402	1,083	17,391	24,866	45,743	470
Air Hitam	83.5	3,771	1,083	4,182	19,770	28,806	345
Skudai	59.1	2,667	1,197	4,182	14,367	22,413	379
SENAI HIGHWAY	28.0	1,182	290	0	0	1,472	53
NEW KLANG VALLEY EXP.	53.6	5,136	3,637	9,040	13,223	31,037	579
FEDERAL HIGHWAY	15.0	970	832	0	0	1,802	120
Sub-total	854.8	40,730	25,911	73,096	202,862	342,600	401
PENANG BRIDGE	14.0	2,228	1,528	5,015	4,367	13,137	938
KARAK HIGHWAY	46.8	2,586	662	5,015	12,758	21,020	449
Sub-total	60.8	4,813	2,189	10,029	17,126	34,157	562
Total	915.6	45,544	28,101	83,125	219,988	376,758	411

Notes: 1) New Klang Valley Expressway includes 16.6 km of N-S Expressway (Rawang-Bukit Lanjan section).
2) Length of Karak Highway is the stretch between toll plaza.

Table 7.2.2: Construction Cost Estimates by Stage

Unit: M$'000

Route/Section	Length (km)	Stage 1	Stage 2	Stage 3	Total
NORTH-SOUTH EXPRESSWAY					
Alor Setar	96.7	29,242	1,197	682	31,122
Butterworth	76.4	0	28,032	324	28,356
Taiping	91.4	0	31,832	1,926	33,758
Ipoh	87.6	146	46,260	1,486	47,892
Tanjung Malim	90.3	0	30,774	486	31,260
Kajang	75.9	27,039	3,702	8,198	38,939
Ayer Keroh	97.3	44,461	1,282	0	45,743
Air Hitam	83.5	0	28,300	506	28,806
Skudai	59.1	0	21,426	986	22,413
SENAI HIGHWAY	28.0	290	667	515	1,472
NEW KLANG VALLEY EXP.	53.6	0	27,641	3,396	31,037
FEDERAL HIGHWAY	15.0	0	1,286	517	1,802
Sub-total	854.8	101,178	222,398	19,023	342,600
PENANG BRIDGE	14.0	9,756	2,400	981	13,137
KARAK HIGHWAY	46.8	19,080	1,940	0	21,020
Sub-total	60.8	28,837	4,340	981	34,157
Total	915.6	130,015	226,738	20,004	376,758

Notes: 1) New Klang Valley Expressway includes 16.6 km of N-S Expressway (Rawang-Bukit Lanjan section).
2) Length of Karak Highway is the stretch between toll plaza.

7.3 Operation and Maintenance Cost

Operation and maintenance cost of the system is estimated for each maintenance office. The operation and maintenance cost includes the following items:

1) System Operation Staff Salary

This item is the total salary of staff engaged directly in the operation of control center and sub-center. An operation on a 24-hour basis with three staff shifts is assumed.

2) Electricity

Electricity is consumed by both center and roadside equipment. Power consumption of each type of equipment is first determined and then total power consumption is calculated for the entire system. Power rate adopted in calculating the cost is LLN's Tariff E3 - high voltage peak industrial use for the central equipment and Tariff G - public lighting/street lighting for field equipment.

3) Maintenance of System

System maintenance cost consists of labor, vehicle, spare parts and miscellaneous expenses. It is assumed that maintenance work is undertaken by a maintenance company on a contract basis.

4) Patrol Squadron Expenses

These expenses include staff salary, depreciation and operating costs of cars and trucks, and tools and devices carried by car and truck.

All operation and maintenance costs will be incurred in local currency except the cost for the spare parts which will be imported from the manufacturer's country.

Estimated operation and maintenance cost at stages 1, 2 and 3 in 1989 price is shown in Table 7.3.1 and breakdown of the operation and maintenance cost at stage 3 is presented in Table 7.3.2.

Table 7.3.1: Annual Operation Cost at Each Stage

Unit: M$'000

Route/Section	Length (km)	Stage 1	Stage 2	Stage 3
NORTH-SOUTH EXPRESSWAY				
Alor Setar	96.7	1,446	1,530	1,571
Butterworth	76.4	0	1,501	1,512
Taiping	91.4	0	1,605	1,735
Ipoh	87.6	5	2,638	2,722
Tanjung Malim	90.3	0	1,549	1,566
Kajang	75.9	1,487	1,641	1,904
Ayer Keroh	97.3	2,473	2,534	2,534
Air Hitam	83.5	0	1,470	1,488
Skudai	59.1	0	1,146	1,196
SENAI HIGHWAY	28.0	21	193	208
NEW KLANG VALLEY EXP.	53.6	0	1,660	1,845
FEDERAL HIGHWAY	15.0	0	131	149
Sub-total	854.8	5,482	17,598	18,430
PENANG BRIDGE	14.0	1,044	1,151	1,200
KARAK HIGHWAY	46.8	1,284	1,364	1,364
Sub-total	60.8	2,328	2,515	2,564
Total	915.6	7,810	20,113	20,994

Notes: 1) New Klang Valley Expressway includes 16.6 km of N-S Expressway (Rawang-Bukit Lanjan section).
2) Length of Karak Highway is the stretch between toll plaza.

Table 7.3.2: Annual Operation Cost at Stage 3

Unit: M$'000

Route/Section	Length (km)	Operation	Electricity	Maintenance	Patrol Squadron	Total	Per Km
NORTH-SOUTH EXPRESSWAY							
Alor Setar	96.7	26	250	1,100	196	1,572	16.3
Butterworth	76.4	26	260	1,030	196	1,512	19.8
Taiping	91.4	26	328	1,185	196	1,735	19.0
Ipoh	87.6	157	469	1,901	196	2,723	31.1
Tanjung Malim	90.3	26	228	1,115	196	1,565	17.3
Kajang	75.9	26	379	1,302	196	1,903	25.1
Ayer Keroh	97.3	157	380	1,802	196	2,535	26.1
Air Hitam	83.5	26	225	1,041	196	1,488	17.8
Skudai	59.1	26	208	767	196	1,197	20.3
SENAI HIGHWAY	28.0	0	55	154	0	209	7.5
NEW KLANG VALLEY EXP.	53.6	131	376	1,143	196	1,846	34.9
FEDERAL HIGHWAY	15.0	0	100	49	0	149	9.9
Sub-total	854.8	627	3,258	12,589	1,960	18,434	21.6
PENANG BRIDGE	14.0	131	213	661	196	1,201	85.8
KARAK HIGHWAY	46.8	131	184	855	196	1,366	29.2
Sub-total	60.8	262	397	1,516	392	2,567	42.2
Total	915.6	889	3,655	14,105	2,352	21,001	22.9

Notes: 1) New Klang Valley Expressway includes 16.6 km of N-S Expressway (Rawang-Bukit Lanjan section).
2) Length of Karak Highway is the stretch between toll plaza.

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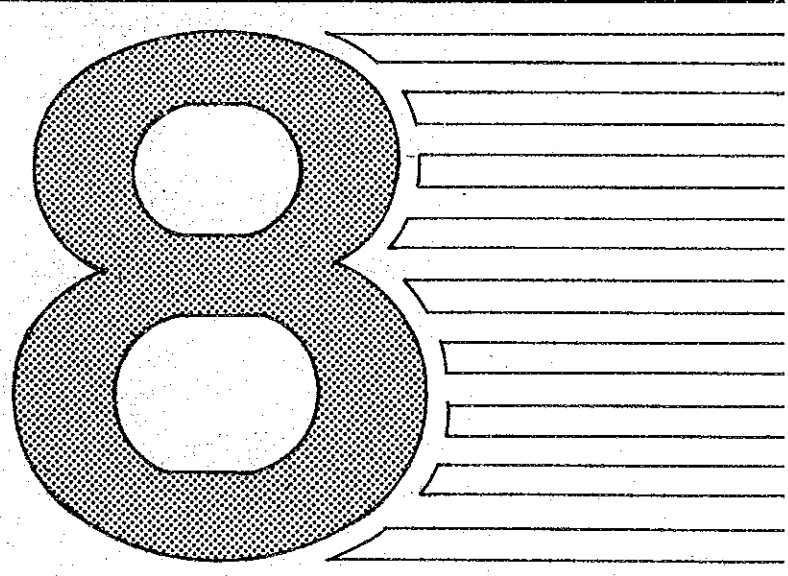

8.0 EVALUATION OF TRAFFIC CONTROL AND MANAGEMENT SYSTEM

8.1 *Introduction*

In this chapter, the traffic control and management system proposed in the preceding chapters is evaluated. At first, benefits that will be derived from the system are identified. Some of the benefits such as reduction in delay can be expressed in monetary terms, while others such as alleviation of irritation cannot be quantified. Because of this feature of the system, benefits are not calculated and ordinary cost-benefit analysis is not applied. Subsequently, economic evaluation is made by comparing the system construction and operation costs with the road construction cost, toll revenue and operating cost of vehicles on the toll roads.

8.2 Benefit Analysis

1) Benefits to motorists

Expressway is constructed with higher design standards than ordinary roads such as better alignment, wider lane, access control, separation by median, etc. In addition, traffic regulation or control and other management measures contribute to achieve the three key objectives of the expressway, namely, safety, smooth flow and comfort. The features of the expressway that directly connected with these objectives are:

* High speed
* Safety
* Economy
* Punctuality
* Comfort
* Convenience
* Wide coverage area

These features are often disrupted by traffic obstacles caused by motorists themselves such as excessive demand, accident and breakdown; or by road administrator such as executing maintenance work on the expressway; or by natural phenomena such as inclement weather conditions.

The functions of the traffic control and management system are to monitor the traffic and road conditions and to collect up-to-date information on the incident that affects the operation of the expressway. Armed with such information, the system then provides assistance to those who are already involved in the incident, and at the same time giving advice to those motorists who are heading for the site or section of the incident. For a more serious

incident, motorists may be warned of traffic control measures such as lane closure or ramp closure.

These functions of the system will bring about various kinds of benefits to the motorists. Information collection function makes it possible for motorists who have met any trouble or accident to report the incident to the road administrator through the emergency telephone and ask for assistance. Information dissemination function provides motorists on the expressway and on the surface roads alike with traffic and road information of the expressway so that they are more aware of the situation on the expressway and able to take any appropriate travel action, if necessary. Traffic surveillance and control function regulates the traffic flow and reduce accident, congestion, and delay. In short, the following benefits accrue to the motorists:

* Any kind of assistance to the motorists in a timely manner,
* Reduction in accident rate, congestion, delay, time cost and pollution,
* Prevention of secondary accident,
* Information to take detour or change schedule,
* Alleviation of irritation.

Among the benefits listed above, those benefits related to time or accident can be expressed in cost saving. For example, time saving or mitigation of severity of injury realized by the use of the emergency telephone can be estimated from the time cost and injury cost. Similarly, total time cost saving by reduction of delay can be calculated using unit time cost and traffic volume. However, such calculation is not done here as there are too many uncertain factors that must be assumed to calculate and the result would be inaccurate.

2) Benefits to road administrator

The traffic surveillance and information collection function of the system make it possible for the road administrator to grasp traffic and road conditions on a real time basis. Occurrence of an incident will be quickly recognized by the road administrator so that necessary countermeasures will be taken without delay and good operational conditions of the expressway can be restored.

In addition to these benefits gained by daily management of the expressways, traffic and operation data of the expressway accumulated for some period will provide the road administrator with the necessary data base for formulating future traffic management policy. Safety countermeasures, traffic regulation and road improvement plan can be developed by analyzing the traffic volume, congestion and accident records. Performance of the system can be reviewed and improvement plan of the system, operation and maintenance prepared.