b) Anemometer

Several kinds of anemometer are available but propeller type anemometer is commonly used for the expressway and highway applications. To measure the influence of the wind on moving vehicles at the spot along the expressway and highway and provide wind information to drivers, anemometer is positioned at the height two to three meters above the ground.

4) Installation Location

For the Malaysian expressway and highway, 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.

a) Alor Setar Interchange
b) Gurun Interchange
c) Butterworth Interchange
d) Taiping Interchange
e) Ipoh Utara Interchange
f) Gopeng Interchange
g) Bidor Interchange
h) Tanjung Malim Interchange
i) Kajang Interchange
j) Ayer Keroh
k) Ayer Hitam Interchange
l) Kulai Interchange
m) Karak Highway

5.4 Closed Circuit Television System

1) Introduction

Although visual data provided by the closed circuit television (CCTV) system do not produce any quantitative data, they contain numerous qualitative 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:

a) Traffic flow monitoring
b) Disaster prevention in tunnel
c) Weather observation
d) Others

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 tape recorder with a time signal generator will be included in the central equipment for recording and re-playing the image data.

3) Installation Location

Table 9 presents the installation location of CCTV camera on the study routes.

5.5 Changeable Message Sign System

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 by a computer automatically or by operators manually.

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.

3) Type of Signboard

Out of the various types of changeable message sign such as lamp matrix type, scroll type. etc, 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.

Table 9: Installation Location of CCTV Camera

Class	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 Stages 2 and 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

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 and clear of its meaning. Besides, messages will be displayed in Malay only for the same reason although other languages are commonly used in this country.

Review of the interchange names and other words and phrases in Malay to describe causes and consequences is made and the maximum length of message a signboard can display is set to 50 letters including blanks between the words, which will be arranged in two rows.

The size of a letter is set as 35 cm high by 25 cm wide expressed by dot matrix of five horizontal dots by seven vertical dots at 50 mm interval in both directions.

5) Installation Standard

Table 7 mentioned earlier summarizes the installation standards of changeable message sign at each management level.

5.6 Changeable Speed Limit Sign

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.

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.

3) Type of Signboard

Of various types of the sign available, rotating disk type is recommended from the viewpoint of cost and similarity in appearance with the fixed speed limit sign.

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. 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.

5.7 Radio Broadcasting

1) Introduction

Radio broadcasting is one of the most common means of information dissemination.

Radio broadcasting booth is constructed in the control center. 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. Drivers receive traffic information through the ordinary car radio which acts as a driver information tool.

2) System Configuration

Radio broadcasting system of traffic information utilizes the existing broadcasting system. An microphone and a transmitter to the broadcasting station are provided.

5.8 Highway Radio

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 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.

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.

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. Proposed system adopts the slit coaxial cable.

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. Assuming the maximum vehicle speed of 110 Km/h and maximum length of message as 40 seconds, the length of service section is calculated as 3.7 Km.

5) 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.

5.9 Transmission System

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 as described below.

a) Trunk line transmission system
b) Local line transmission system
c) Access line transmission system

Figure 21 illustrates the hierarchical composition of transmission system.

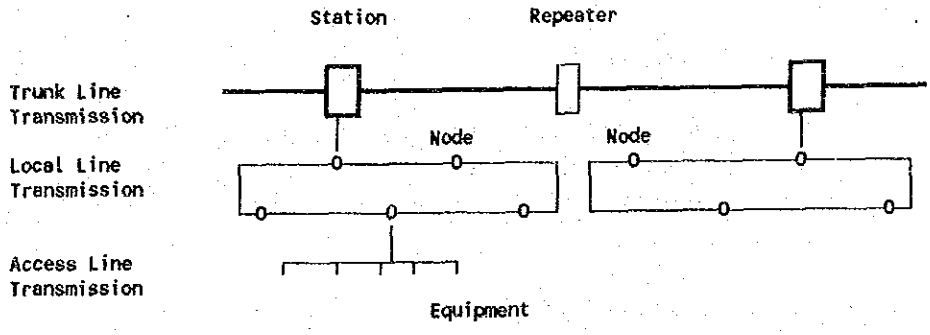

Figure 21: Transmission System Hierarchy

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

2) Trunk Line Transmission

Three alternatives for the trunk line transmission system, namely metallic cable system, optical fiber cable system and micro wave system, are compared to select the most suitable system. The comparison shows that optical fiber transmission system has become the standard for the long haul transmission and is recommended for the Malaysian expressways and highways too. If no transmission traffic other than for expressway control and management is added, 100M (or 90M or 120 M) system is deemed appropriate for the section with video signal transmission, while 32M system for the section without video signal transmission.

3) Local line transmission system

Local line transmission system covers the section of about 70 to 90 km in length. Three methods are candidates for local line transmission.

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

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.

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.

5) Video Signal Transmission System

Among the video signal transmission methods being used PFM-IM system using optical fiber system 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.

6) Cable

a) Trunk and Local Line Cable

The single mode optical fiber cable is recommended for trunk line cable.

b) Access Line Cable

Color coded polythene insulated subscriber's cable (CCP cable) is commonly used for access line and 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.

Composite cable which combines the optical fiber cores and metallic conductors into one cable is recommended so as to save installation cost for the Malaysian expressways and highways.

5.10 Radio System

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.

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.

3) Base Station

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:

a) Maintenance office
b) Control center
c) Interchange, toll plaza and tunnel
d) Service area and parking area
e) Other necessary location

4) Radio Equipment

a) Frequency

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

b) Communication method

Press talk method is recommended for the following reasons:

i) Less number of frequencies are required.
ii) Equipment is simpler than other types.
iii)Capable of monitoring the conversation of other mobile unit.

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.

5.11 Telephone System

1) Introduction

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

a) Private branch exchange telephone system
b) Command telephone system
c) Emergency telephone system

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. For this purpose, in-house telephone system or private branch telephone system covering all the offices are required.

The system consists of digital exchange of various capacity placed at headquarters, regional office, maintenance office, toll gate, etc. and telephone sets.

3) Command Telephone System

It happens quite often in an expressway and highway management that 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.

5.12 Central Computer System

1) Introduction

Many of the processing executed in the control center is performed by a central computer system.

2) Functions

Central computer system has the following functions:

a) Information Collection
b) Terminal Equipment Control
c) Man-machine Interface
d) Countermeasures Formation
e) Reports
f) Recording
g) Operation Monitoring
h) Data Communication

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.

4) Software Configuration

The size and speed of the computer requires a high degree of sophistication in making the computer operable. The software fails into several categories, operating system, utility programs and application programs. The last two are controlled by the operating system.

a) Operating System

The operating system must have a real-time multi-tasking function for multiple processing of main memory resident programs and non-resident programs in an efficient manner.

b) Utility Programs

Utility programs are designed to facilitate the efficient use of computer system resources.

c) Application Programs

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

i) Detector data processing routine
ii) Weather data processing routine
iii)Changeable message sign control routine
iv)Changeable speed limit sign control routine
v) Man-machine interface routine
vi)Statistical processing routine
vii)Report producing routine

5.13 Uninterruptible Power Supply

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

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

6.0 COST ESTIMATE

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.

6.1 Construction Cost

1) Cost Item

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

a) Information Collection System

i) Emergency Telephone
ii) Vehicle Detector
iii)Weather Observatory Equipment
iv)Closed Circuit Television (CCTV)

b) Information Dissemination System

i) Changeable Message Sign
ii) Changeable Speed Limit Sign
iii)Highway Radio

c) Information Processing System

i) Central Processor
ii) Peripherals
iii)Graphic Display Panel
iv)Software

d) Communication System

i) Trenching, Conduit and Cable
ii) Trunk Line System
iii)Local Line System
iv)Exchange
v) Radio System

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

2) Equipment Cost

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

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

3) Installation Work Cost

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

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, however, local cost is adopted for materials such as handhole, concrete and gravel. PVC conduit is an exception, which is found more costly here than in Japan so that foreign cost is used.

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

System construction cost is presented in Table 10 for each route and maintenance office by sub-system, and in Table 11 by stage.

Table 10: 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 11: 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.

6.2 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

Salary of staff engaged directly in the operation of control center and sub-center. An operation on a 24-hour basis by three 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 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

The 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 12 and breakdown of the operation and maintenance cost at stage 3 is presented in Table 13.

Table 12: 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	1,496	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 13: Annual Operation Cost at Stage 3

Unit: M$'000

Route/Section	Length (km)	Operation Staff	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.

7.0 EVALUATION OF TRAFFIC CONTROL AND MANAGEMENT SYSTEM

7.1 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 the objectives are:

a) High speed
b) Safety
c) Economy
d) Punctuality
e) Comfort
f) Convenience
g) Wide coverage area

These features are often disrupted by the traffic obstacle, which is caused by motorist such as excessive demand, accident and breakdown, by road administrator such as work on the expressway, and by natural phenomenon such as inclement weather.

Functions of the traffic control and management system is to monitor the traffic and road conditions and to collect information on the incident that affects the operation of the expressway as soon as possible. Then, the system provides assistance to those who are already involved in the incident, and at the same time provides the information to those motorists who are heading for the site or section of the incident. For a more serious incident, traffic control such as lane closure and ramp closure will be enforced.

These functions of the system will bring about various kinds of benefits to the motorist. 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 the traffic and road information of the expressway so that they are more aware of the situation and able to take an action, if necessary. Traffic control function regulates the traffic flow and reduce accident, congestion, and delay. In short, the following benefits accrue to the motorists:

a) Any kind of assistance to the motorist in a timely manner,
b) Reduction in accident rate, congestion, delay, time cost and pollution,
c) Prevention of secondary accident,
d) Information to take detour or change schedule,
e) Alleviation of irritation.

Among the benefits listed above, those benefits related to the 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

Surveillance or information collection function of the system makes it possible for the road administrator to grasp traffic and road condition on a real time basis. Occurrence of an incident will be quickly recognized by the road administrator, thus necessary countermeasures will be taken without delay and basic features of the expressway listed above will be restored.

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

7.2 Cost Comparison

Benefits by the traffic control and management system are discussed above and most of them cannot be expressed accurately in monetary terms. It would be worth while, however, to compare the cost of the system with the figures relevant to the toll road construction and operation to understand its magnitude.

1) Comparison with road construction cost

Comparison between construction costs of the roads under study and the system construction cost is summarized in Table 14 together with the ratio of the latter to the former. Road construction cost shown in the table is an

approximate direct cost obtained from the actual cost data for the existing routes and estimates for the planned route. They are re-arranged into the section covered by each maintenance office using unit construction cost per kilo-meter.

Table 14: Road Construction Cost - System Construction Cost

Section/Route	Distance (Km)	Road Cost Total (M M$)	Road Cost Per Km (M M$)	System Cost Total (M M$)	System Cost Per Km (M M$)	Ratio
Alor Setar	96.7	550.3	5.7	31.1	0.32	5.7%
Butterworth	76.4	520.0	6.8	28.4	0.37	5.5%
Taiping	91.4	666.9	7.3	33.8	0.37	5.1%
Ipoh	87.6	485.7	5.5	47.9	0.55	9.9%
Tanjung Malim	90.3	469.5	5.2	31.3	0.35	6.7%
Kajang	75.9	206.3	2.7	38.9	0.51	18.9%
Ayer Keroh	97.3	420.3	4.3	45.7	0.47	10.9%
Air Hitam	83.5	437.0	5.2	28.8	0.34	6.6%
Skudai	59.1	224.5	3.8	22.4	0.38	10.0%
Sub-total	758.1	3,980.5	5.3	308.3	0.41	7.7%
New Klang Valley Exp.	53.6	316.0	5.9	31.0	0.58	9.8%
Penang Bridge	14.0	729.8	52.1	13.1	0.94	1.8%
Federal Highway	15.0	78.3	5.2	1.8	0.12	2.3%
Senai Highway	28.0			1.5	0.05	
KL - Karak Highway	46.8			21.0	0.45	
Total	915.5	5,104.6	5.6	376.8	0.41	7.4%

Notes: 1) New Klang Valley Exp. system includes Rawang - Bukit Lanjan section of N-S Expressway.
2) Construction cost of Senai Highway and Karak Highway is not known.
3) Karak Highway is only considered for the stretch between toll plaza.

From the table above, it is noted that for the North-South expressway, the ratio of the system construction cost to the road construction cost is 7.7 percent in average. Relatively higher figure for Kajang section seems to be due to the early construction of the section. The cost of the planned road widening for KL-Seremban section is not included.

On the other hand, the ratios of the system cost for other routes vary greatly due to the large difference in the road construction cost per kilo-meter. Exact construction cost of Senai Highway and Karak Highway is not known, but 46.8 million M$ has been spent on upgrading Karak Highway.

Although the number of information sources about the similar comparison is limited, the ratio of the system cost to the road construction cost shown in the table is jibes with the cases in other countries and deems reasonable.

2) Comparison with toll revenue

Based on the traffic volume forecast, the annual toll revenue in the future for all the routes under study is estimated. The estimates take the scheduled toll rate increases into consideration for the sections operated by the concession company and assume the toll increase of the same percentage for other routes. The figures are compared with the construction and operation costs of the traffic control and management system estimated in the preceding chapter. The results are presented in Table 15.

Table 15: Comparison of Toll Revenue and System Cost

Route	Annual Toll Revenue (M$ million) 1988	1995	2005	Construction Cost (M$ million)	Annual Operation Cost (M$ million)
Toll roads operated by concession company (North-South Expressway, Senai Highway, New Klang Valley Expressway, Federal Highway)	73	434	969	342.6	18.4
Penang Bridge	32	66	145	13.1	1.2
Karak Highway	9	19	40	21.0	1.4
Total	114	519	1,154	376.8	21.0

Should the system construction and operation costs be born by the motorists, toll must be increased to cover the cost. Necessary toll increase is calculated assuming that the system will be completed 1992 through 1995 and operated for 15 years after the completion, which is a conservative assumption for facilities such as cable. Table 16 shows the toll increase in percentage to the current toll rate in case toll is increased to cover the system construction and operation costs.

Table 16: Calculated Toll Increase

Route	Construction Cost (M$ million)	Annual Operation Cost (M$ million)	Toll Increase (%)
Toll roads operated by concession company (North-South expressway, Senai Highway, New Klang Valley Expressway Federal Highway)	342.6	18.4	8.4
Penang Bridge	13.1	1.2	3.2
Karak Highway	21.0	1.4	16.1
Total	376.8	21.0	7.9

Necessary toll increase is about 8% for the entire toll roads. For the routes operated by the concession company, the increase is 8.4% which is close to the average figure. Low percentage of Penang Bridge is due to the fact that the bridge is already equipped with some equipment and amount of additional facilities is relatively low, and its relatively higher toll rate. On the contrary, Karak Highway requires large increase in toll rate to cover the necessary cost. This is attributed to the low toll rate per kilo-meter presently adopted.

3) Comparison with vehicle running cost

Running cost of various types of vehicle on the toll roads is calculated. Running costs estimated by Klang Valley Transportation Study are used here with modification to fit the vehicle classification adopted by toll roads. The running costs used are presented below (Table 17).

Table 17: Running Cost of Vehicles

Class	Type	Running Cost (cents/Km)
0	Vehicle with 2 axles & 2 wheels	4.7
1	Vehicle with 2 axles & 3 or 4 wheels but excluding taxi	16.7
2	Vehicle with 3 axles & 6 wheels but excluding bus	51.0
3	Vehicle with 3 or more axles	70.1
4	Taxi	12.8
5	Bus	41.3

Traffic composition is assumed for each section of the routes based on the survey data. Using composition data, weighted running cost of PCU is calculated. Then, unit running cost is multiplied by the forecasted traffic volume in PCU and section length to obtain the total running cost of the vehicles on the motorway, expressway and toll highways. The results are presented in Table 18.

Table 18: Total Running Cost of Vehicle on Toll Roads

Route	Total Vehicle Running Cost (M$million) 1988	1995	2005
Toll roads operated by concession company (North-South Expressway, Senai Highway, New Klang Valley Expressway, Federal Highway)	529	1,676	2,875
Penang Bridge	21	28	45
Karak Highway	76	106	169
Total	626	1,810	3,089

Comparing the system construction, operation and maintenance costs with other costs related to the toll roads, and considering the benefits realized by the system as described in this chapter, the costs incurred by the introduction of the system is well within the reasonable range and motorists may be able to afford it, should the cost is born by them.

8.0 IMPLEMENTATION PROGRAMME

Standard implementation program of the traffic control and management system is first presented in this chapter for a representative section and then actual implementation schedule is proposed.

Implementation schedule is divided into three steps; detailed design, procurement of contractor, and construction work. However, procurement of contractor is not discussed here as the procedure and schedule vary depending on the method taken.

8.1 Detailed Design

Preliminary engineering design is conducted by this Study.

Detailed design is, however, necessary at the next step before the construction of the system begins. Detailed design has two aspects, equipment and system design and installation work design. Different design process will be taken for each sub-system and its installation work. Major activities undertaken during the detailed design stage are:

a) Design planning
b) Site survey
c) Functional design
d) Design calculation
e) Specification writing
f) Preparation of drawings
g) Preparation of bill of quantity
h) Cost estimation
i) Final checking

Duration of the detailed design depends on the kind and number of equipment and length of the section. It is estimated as a typical case that a section under one maintenance office, which is 70 Km to 90 Km in length, requires about eight months for the detailed design assuming that the as-built drawing of the road is available.

8.2 Construction Work

After a contractor is selected, actual construction work of the system begins. This stage is grouped into four works; communication civil work, communication cable work, roadside facility work, and control center facility work.

1) Communication civil work

The work is to construct underground conduit line for communication cable and carried out in the following steps:

a) Work planning
b) Procurement of materials
c) Transportation of materials
d) Construction work
e) Inspection and commissioning

Materials for the work will be procured from either domestic supplier or foreign supplier. In the latter case, sufficient time must be allowed for transportation of the materials to the work site including custom clearance.

Trenching work including, digging, conduit laying, handhole placing and backfilling is estimated to progress 1 Km a day by one party for earth section if machine is used. Therefore, the work will take about three months for the section under one maintenance office. Completed conduit line must be inspected for the freedom from debris inside.

2) Communication cable work

Communication cable is laid through the conduit by this work. As composite cable is used, only one line of cable is laid. The work consists of the following steps:

a) Planning
b) Procurement of cable and materials
c) Transportation
d) Laying and splicing of cable
e) Testing
f) Commissioning

The cable will be made to order by a foreign supplier so that enough time must be allowed for transportation. Precaution is required during cable laying as the allowable maximum tension of optical fiber cable is smaller than the conventional copper cable.

Cable is spliced after laying and various tests are conducted to ensure the correct connection and the required cable characteristics.

3) Roadside facility work

The procedure of the roadside facility work is as follows.

a) Design approval
b) Equipment manufacturing
c) Factory test
d) Transportation
e) Installation work
f) Testing and adjustment
g) Commissioning

The equipment proposed by the supplier is reviewed and approved at the design approval stage. Then the equipment is manufactured, which takes six to eight months depending on the equipment. Test of the equipment is conducted at the factory at the presence of the client before shipping.

Once the equipment is delivered to the site, they are erected according to the schedule. Footing and support structure for the roadside facilities must be, therefore, constructed timely to avoid delay.

Each equipment will be undergone stand alone test after installation to ensure their operation in isolated mode.

4) Control center facility work

Almost same procedure is taken for the center facilities including software for computer. However, the testing and adjustment is more extensive and time consuming as the normal operation of not only respective equipment but also that of the whole system must be confirmed.

Facilities not included in the supply contract such as the control center building, power supply, air-conditioning, etc. must be completed well in advance of the equipment installation.

Figure 22 shows the implementation schedule of a typical section covered by one maintenance office. As shown on the figure, detailed design takes eight months, while construction work needs 22 months resulting in the total duration of 30 months. It must be noted, however, that no time is allotted for the procurement of the contractor.

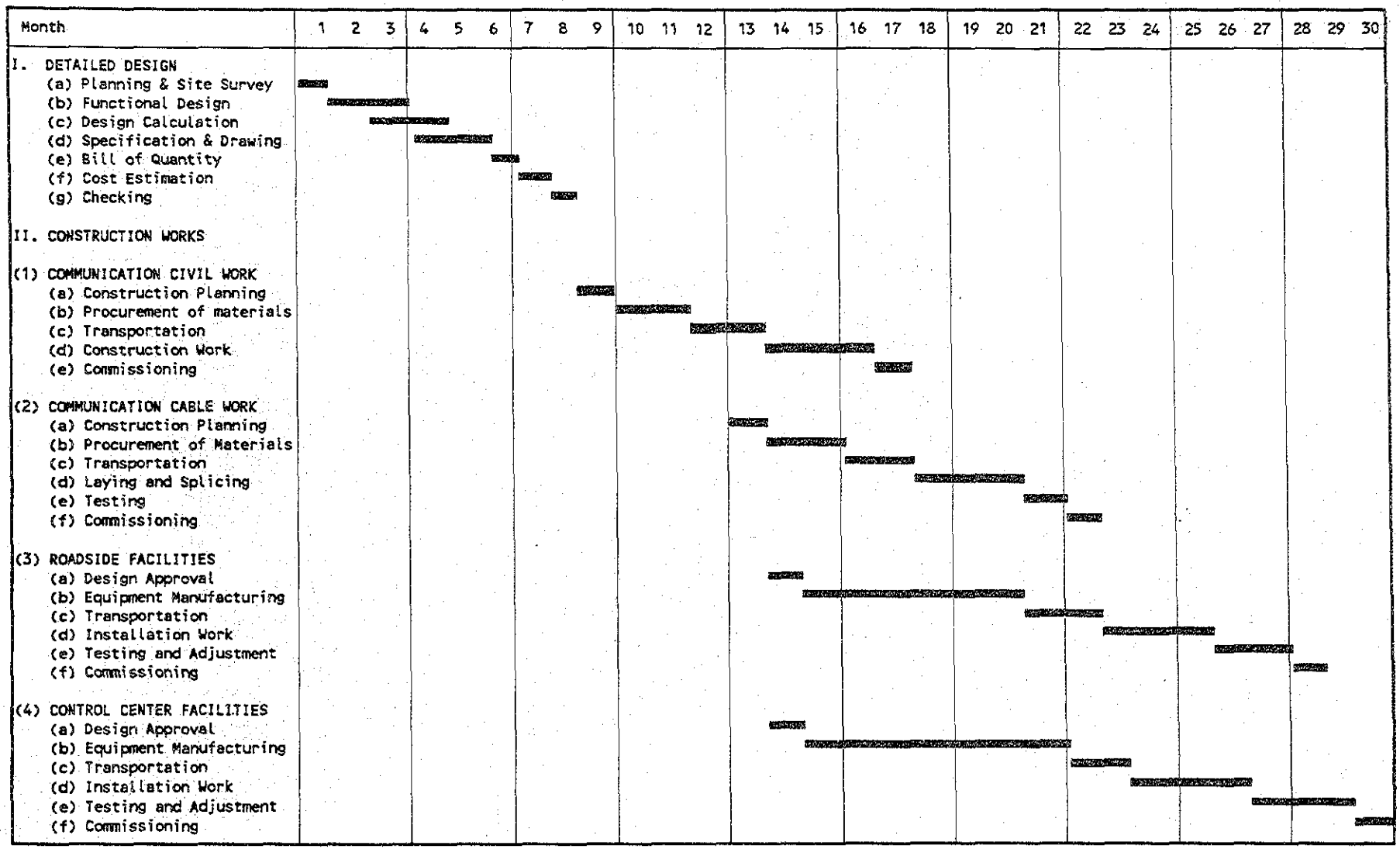

Figure 22: Typical Implementation Schedule

8.3 Implementation Program

The staging plan of construction program mentioned earlier is elaborated here taking into consideration the implementation process and the difference in the size of the system for each section. However, implementation of only stages 1 and 2, which are completed by 1995, are programmed here as the implementation of stage 3 system is beyond 1995 and depends largely on the future traffic development. The implementation program is presented in Figure 23, which is prepared based on the following assumptions:

1) If the section is already in use, the implementation starts as soon as possible.

2) If a portion of the road section is yet to be constructed, schedule is set in such a way that the system will be completed at the end of the target year of road construction.

3) Contractor procurement period of six months is assumed.

4) For the road section to be constructed, communication civil work may be done simultaneously with the road construction work but such arrangement is not considered in the schedule.

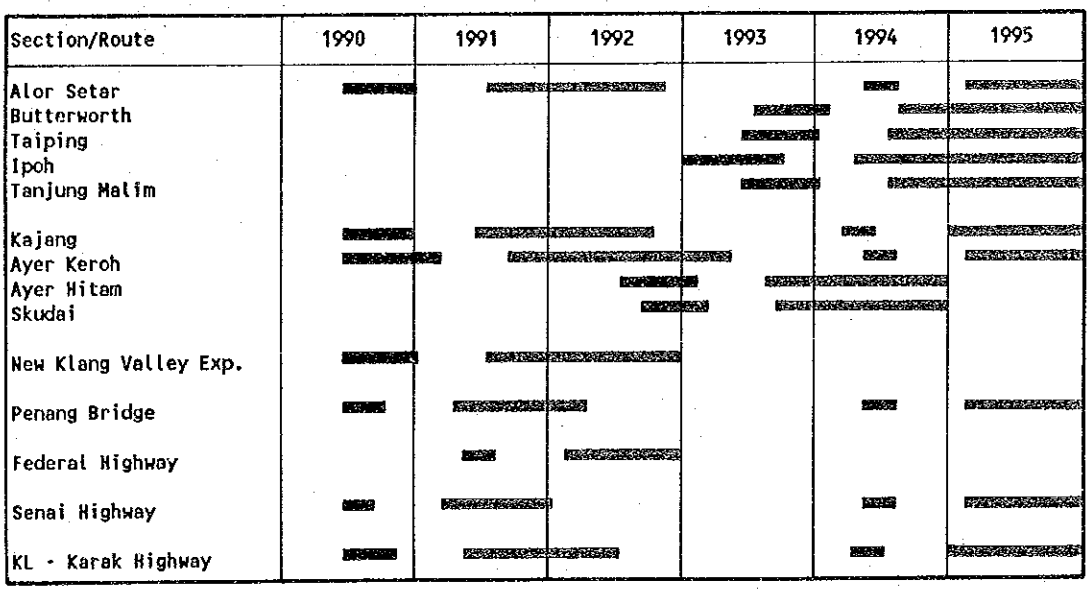

Figure 23: Implementation Programme

In accordance with the implementation program, annual financial requirement is calculated assuming that the cost is incurred uniformly during the construction period. Detailed design cost, system operation cost and other project management costs are not included. The results are presented in Table 18. The column under "1996-" indicates the cost for Stage 3 system, which will be incurred during the years 1996 through 2005.

Table 18: Annual Financial Requirement

Unit: Million M$

Route	Annual Financial Requirements						Total
	1991	1992	1993	1994	1995	1996-	
Toll roads operated by concession company (North-South Expressway, Senai Highway, New Klang Valley Expressway, Federal Highway)	34.4	84.6	22.5	82.3	99.9	19.2	342.7
Penang Bridge	6.5	3.3	-	-	2.4	1.0	13.1
Karak Highway	9.5	9.5	-	-	1.9	-	21.0
Total	50.4	97.4	22.5	82.3	104.2	20.2	376.8

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