INTRODUCTION OF HSUEHSHAN TUNNEL TRAFFIC CONTROL SYSTEM

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ABSTRACT

The alignment of the Taipei-Ilan Expressway at the western side starts from the metropolitan Taipei then goes southern-eastern direction to reach the towns of Shihting and Pinglin. From Pinglin, the longest road tunnel in Asia (5th ranking in the world long tunnel) is designed to penetrate throughout the Hsueh Mountain.

In the aim to facilitate the traffic management and monitoring after completion of the road work, Ministry of Transportation and Communications National Expressway Engineering Bureau is to associate with the civil work of Taipei-Ilan Expressway and at the same time establish the traffic control system and electrical mechanic system. The regional control center (RCC) located at Pinglin about 700m north portal of Hsuehshan Tunnel to cover traffic control system facilities of Taipei-Ilan Expressway. The section control center 3(SCC3) located beside north portal of Hsuehshan Tunnel to cover traffic control system facilities of Hsuehshan Tunnel with redundancy functions of RCC traffic control system.

1. INTRODUCTION

The No. 5 Taipei-Ilan Expressway of total 31 Km in length connects the Nankang interchange (12K+268) of No.3 Northern Second Freeway to the west and links Toucheng interchange (42K+858) of No.5 Expressway to the east Toucheng-Suao section. It can connect the Southern Cross Island Expressway to the south in the future. It will also be an important link in the Taiwan Area Expressway Network. This expressway will greatly improve the transportation linkage of Ilan with other cities, as well as meet the demands arising from regional development. Other benefits are described as following:

* The Taipei-Ilan Expressway will be the first east-west expressway in linking the eastern Taiwan to the western. It will promote the economic development of the east- coast of Taiwan and enable full utilization of the vast available lands on the eastern coast. It is indispensable for Taiwan Area Expressway Network.
* When extended to the Harbor of Suao, it will allow full usage of the harbor, by providing unsurpassed land transportation. Therefore, the Harbor Suao will be able to realize its function in being the major supplementary harbor to Keelung Harbor in northern Taiwan.
* The expressway will be the manifestation of the nation's policy of transferring industries to the east, and enhance a healthy growth in the development of the eastern coast of Taiwan
* Completion of the expressway will achieve balanced regional development for northern Taiwan. With this expressway, the living circle of Ilan will be integrated into the greater Taipei metropolis.
* Upgrade and the develop tourism, land, and produce resources of the Lanyang plain. This will enable the Lanyang Plain to keep up with Taipei metropolis and other major cities on the western-coast.
* The expressway will provide the people of the Lanyang Plain a higher living standard as will as provide the people with a convenient and fast transportation.

Figure 1 presents Taiwan expressway network. The No1 and No3. expressway between Taipei and Kaohsiung has been open for transportation.

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Figure 2 presents TAIPEI- ILAN EXPRESSWAY ROUTE MAP

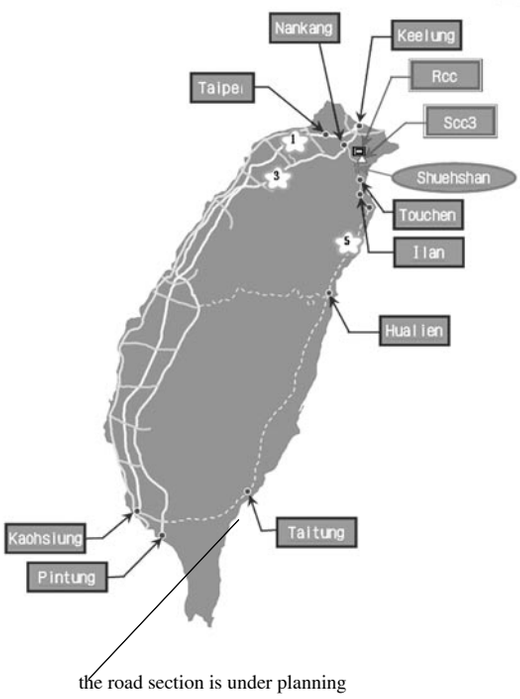


Figure 1 Highway network in Taiwan area

2. TUNNEL CHARACTERISTIC

* Lane: separated two tunnels, and each with two lanes in single direction.
* Milestone: SB27K+320 ~ 40K+245, NB27K+297 ~ 40K+251.
* Ventilation Building: three places including one for fresh air and one for waste exhaustion in distance of 50 meters.
* Ventilation Machinery Room: one underground machinery room for each ventilation place.
* Ventilation through stop: three stops to complete the ventilation cycling networks between two tunnel areas, for ventilation efficiency.
* Communication tunnel: emergency communication walks per 350 meters with total of 18 are built to connect east and west tunnels for escape and to link with pilot tunnels.
* Vehicle Communication Roads are set per 1400 meters with total of 14 to connect east and west tunnels for escape and hazard control, and to link to pilot tunnels for staff use.
* Security facility: Hydrants are installed per 50 meters, emergency phones per 175 meters, and emergency parking curve on outside of emergency

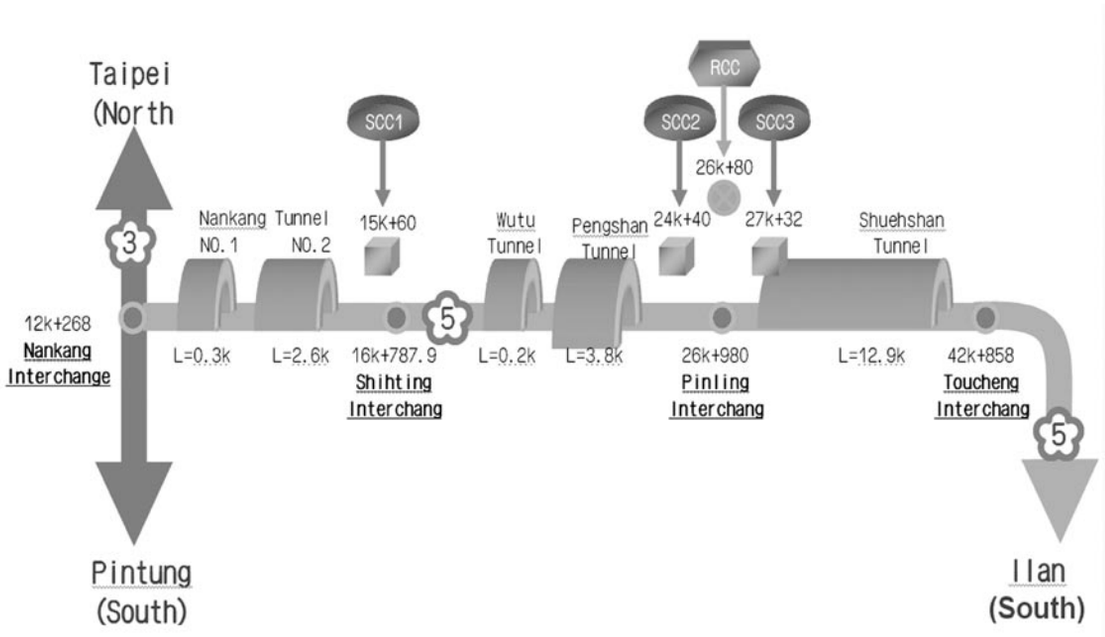


Figure 2 TAIPEI — ILAN EXPRESSWAT ROUTE MAP

vehicle communication roads per 1400 meters.

* Pilot tunnel: Hsuehshan Tunnel is huge construction and in complicated geology. The detecting pilot tunnel of 4.8 meter in diameter is built between two separated tunnels for overall understanding along geological characters as design and construction references and for control risks on ground water and weak geology problems. The Tunnel is used for assistant path during main tunnel construction, for maintenance and emergency after dedication.

3. ITS APPLICATION

Intelligent transportation systems (ITS) encompass a broad range of wireless and wireline communications-based information, control and electronics technologies. When integrated into the transportation system infrastructure, and in vehicles themselves, these technologies help monitor and manage traffic flow, reduce congestion, provide alternate routes to travelers, enhance productivity, and save lives, time and money. The service contents of Taipei-Ilan control system in ITS application are shown in Table 1.

Table 1 SERVICE CONTENS OF TAIPEI-ILAN TRAFFIC CONTROL SYSTEM

ITS Development Term	ITS Contents	Service Contents of Taipei-Ilan Traffic Control System
1.ATMS (Advanced Traffic Management System)	1.Traffic control	. Speed control . Congestion control . Lane control in Tunnel . Total Volume control in Tunnel
	2.Traffic Monitoring	. On-line simulation and congestion prediction . Traffic information detection
	3.Incident Management	. Automatic incident detection . Incident response plan . Emergency rescue support in Tunnel
	4.Incident Management	. Wind detection . Fog detection . Rain detection
2.ATIS (Advanced traveler information system)	1.Route guidance	. Establish interface with information provider
	2.Traveler Service Information	. Provide service information . Establish on-line multi-media traffic information for information provider access
	3.On-Trip Traffic Information	. Changeable Message sign (provide incident routing ,control information) . Tunnel FM broadcasting and public addressing system
	4.Pre-Trip Traffic Information	. Establish interface with information provider . Establish on-line multi-media traffic information database including CCTV image
	5.Parking Information	
3.APTS (Advanced Public Transportation system)	1.On-Trip public Transportation Information	. Provide traffic information for operators
	2.Public Transportation Operation management	----------
	3.Public Transportation Vehicle Safety	----------
4.CVO (Commercial Vehicle Operations)	1.Heavy Vehicle Management	. Provide weighing station information
	2.Automatic Road Side Safety Inspection	. Provide weighing station information
	3.Commercial Vehicle Team Operation	. Transfer commercial vehicle operation information to traffic information provider . Provide vehicle dispatching system traffic information
	4.Safety Monitoring in Commercial Vehicle	----------
	5.Commercial Vehicle Electronic Information	----------
5.ETC(Electronic Toll Collection)	ETC Service	. Provide ETTM date exchange interface

6.EMS(Emergency Management System)	1.Emergency incident Notice	----------
	2.Emergency Rescue Vehicle Management	----------
	3.Notural Disaster Traffic Management	----------
7.AVCSS (Advanced Vehicle Control and Safety System)		----------
8.Handicap Protection System		----------

4. TRAFFIC CONTROL RESPONSE PLAN

4.1 Description

The main objective of establishment of traffic control system is aimed at monitoring the road conditions and implementation of traffic control strategy. The traffic control strategy shall be studied and stipulated in accordance with the characteristics of control road conditions and sort of different incident. The traffic control strategy shall be implemented and achieved by use of appropriate traffic control facilities.

4.2 Scope of Road Lines

Control road section shall cover road section of Taipei-Ilan Expressway under area of traffic control in central region, i.e. Nankang interchange originated from Taipei-Ilan Expressway in west and Toucheng interchange of Taipei-Ilan Expressway in East.

4.3 Incident Detection Road section

Incident Detection Road section in Hsuehshan Tunnel where incident happens frequently in the controlled road sections as:

SB: 27K+320~40K+245

NB:27K+297~40K+251

4.4 Bad Weather Road Section

Bad weather road section in the area of control road section as:

* The road section from south portal of Hsuehshan Tunnel to Toucheng Interchange covering mileage 40K+250-42K+858 is considered as fog area.
* The road section from Pengshan Tunnel to north portal of Hsuehshan Tunnel covering mileage 25K+450-27K+250 is considered as fog/rain/wind area.

4.5 Traffic Control Strategy and Facilities

The traffic control system shall adopt the traffic control strategy as follows to minimize the congestion of recurrence and non-recurrence that happens in the congested road sections frequently and in the bed weather road sections.

* Road user's information display
* Main line speed limit control
* Tunnel traffic control
* Ramp metering signal

The traffic control facilities shall be installed in accordance with the traffic control strategy specified to achieve the objective of the strategy expected. The traffic control facilities of Taipei-Ilan Expressway include following items:

* Vehicle detector(VD)
* Changeable message sign(CMS)
* Closed circuit television camera(CCTV)
* Changeable speed limit sign(CSLS)
* Ramp Metering Signal (RMS)
* Emergency telephone (ET)
* FM and Public Addressing (PA)
* Weather detector(WD)
* Fog sign(FS)
* Rain detector(RD)
* Ramp Metering Signal(RMS)
* Yellow Lamp

4.5.1 Road User's Information Display

The major function of road user's information system is to provide traffic information required to the road users on the freeway and those who are not on the freeway yet but prepare to entering to in order to facilitate them to take proper response. The objective shall:

* Display the message about the congestion and bad weather (fog, heavy raining) road conditions in downstream road sections to warn the drivers to reduce the speed and drive slow and careful to prevent the incident from occurring.
* Display the message about construction, lane closed in downstream road sections, direct and remind the road users to drive cautiously following the lane designated to prevent the incident from occurring.
* Display the message about the ramp metering control in downstream road sections as complement of ramp metering control strategy.
* Display the message about the road conditions of the superseded road as complement of diversion control strategy to assist the road users to choose the optimum driving path.
* Display the message of incident occurred on the freeway (name of road, direction, mileage, number of lanes closed) and the probability of road superseded etc. to remind the drivers to drive carefully to avoid the 2nd time occurrence of the incident.
* The way the message to be displayed

(1) Management of General Incident

The general incident management is conducted based on the message display function to achieve implementation of diversion strategy. Due to the different requirements, so the different message display shall be displayed as well.

A. Warning Message

The warning message is only to tell road users the message about the incident rather than to make any suggestion. The message contents shall be different based on the distance, far or near, between the place of incident and CMS, and that shall divide farthest, farther and nearest from the CMS. The farthest CMS shall display the name of the place where the incident occurred, type of incident and number of lanes blocked; the farther CMS shall display the mileage of the place where the incident occurred, type of incident and number of lanes blocked; the nearest CMS shall display there is incident ahead, type of incident and u\number of lanes blocked.

B. Message of Non-Coercive Detour

The message of non-coercive detour shall display the message in suggestive tone. The message contents shall be different based on the distance, far or near, between the place of incident and CMS. The farthest CMS shall display the name of the place where the incident occurred, type of incident, number of lanes blocked and action suggested; the farther CMS shall display the mileage of the place where the incident occurred, type of incident, number of lanes blocked and action suggested; the nearest CMS shall display "there is incident ahead", type of incident, number of lanes blocked and action suggested.

C. Message of Coercive Detour

The message of coercive detour shall display the message in suggestive tone. The message shall be different based on the distance, far or near, between the place of incident and CMS. The farthest CMS shall display the mileage of the place where the incident occurred, type of incident, number of lanes are closed and the message of suggestion. The nearest CMS shall display "there is incident ahead", type of incident of lanes are closed and the message of suggestion.

(2) Congestion Management

The congestion management is mainly divided into two type such as congestion diversion and strategy and control of congestion queue. The message to display shall be different too.

A. Congestion Queue

The length of congestion queue shall change

when vehicle moves forward. CMS shall be installed at different location in congestion queue, the message to display shall be decided based on the length of congestion ahead. The CMS in the upstream of queue shall be divided as farthest, farther and nearest based on the distance, far or near, from the end of congestion queue. The farthest CMS shall display the name of the place where the congestion begins and ends and the length of congestion. The farther CMS shall display the place where the congestion shall end and the length of congestion. The nearest CMS shall display "there is congestion ahead" and the length of congest. The CMS in the congestion queue shall display the length of congestion based on the distance from the place where the congestion begins to the place where CMS is located.

B. Weather and Other Conditions

The weather incident mainly shall cover heavy fog and storm but special condition shall include landslide, flood, etc.. The message shall display the type of incident and warning or message of speed limit.

C. Ramp Metering Control

The CMS installed on the general roads shall display the message of ramp metering control when the ramp metering strategy is to be implemented.

D. Information Display Priority

The message of different incident that happens at the same time shall be displayed in priority based on the importance of the incident.

4.5.2 Main Line Speed Limit Control

The main line speed limit control is to use the changeable message sign to control the driving speed of special road sections designated. The speed limit control shall be implemented mainly for the road sections where the accident happens frequently and at the bad weather road sections. Proper driving speed shall be studied and stipulated to prevent the accident from occurring when heavy fog, rain, should happen on the freeway and driver' s visibility should be affected. The speed limit control shall be implemented necessarily in the upstream road sections to stabilize the traffic flow and relieve the degree of congestion when the freeway is getting to be congested gradually. The implementation of main line speed limit control may comply with the changeable message sign to display proper information to inform the road users. The fog/rain strategy is shown as table2. The congestion strategy is shown as table3.

Table 2 THE FOG/RAIN STRATEGY

Strategy	State of incident
Heavy fog-closure	The visibility index surpassed the closure Threshold
Heavy fog-warning	The visibility index is lower than the closure Threshold
Heavy rain-closure	Rainfall surpassed the closure threshold
Heavy rain-warning	Rainfall is lower than the closure threshold

Table 3 THE CONGESTION STRATEGY

Speed Limit Condition	Speed Limit		
	Without speed limit control	80 Km/Hour	60 Km/Hour
Traffic	Q<2300	2300<q< 2500 or	2500<q
Speed Limit	70<V	50<V<70	V<50

4.5.3 Tunnel Traffic Control

The tunnel is close section. If the incident, fire or congestion occurs in tunnel, it will be more dangerous than open area. When the incident occurs in tunnel, the traffic control system shall implement proper traffic control strategy to protect road user safely and keep traffic flow smoothly. Figure 2 presents the tunnel traffic control strategy.

* When the incident occurs or lanes closed under construction, the upstream LCS shall display land condition to road users to change lane.

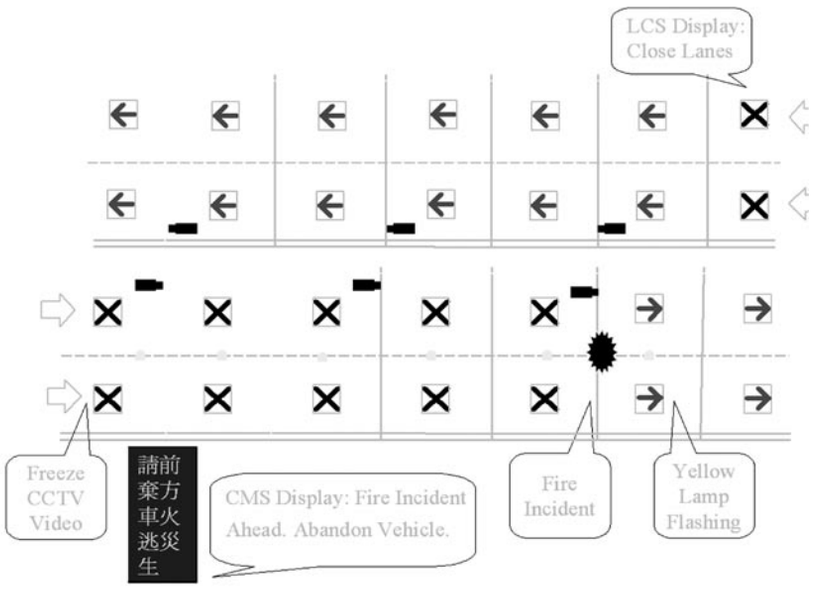


Figure 2 Tunnel Traffic Control Strategy

* When incident or fire occurs in tunnel, the upstream LCS shall display all land closed to road users to reduce speed.
* When incident or fire occurs in tunnel, the upstream yellow lamp shall be flashing to warn road users carefully.
* When downstream traffic congestion occurs, the upstream LCS shall display all land closed to closed all lanes temporarily.

4.5.4 Ramp Metering Signal

The ramp control uses ramp metering signal to implement RMS strategy and close the ramp to control traffic flow into main line. Figure presents the RMS architecture. The Main functions of RMS are shown as following:

* When incident or fire occurs in tunnel, the upstream RMS shall control traffic flow into main line to reduce incident impact.

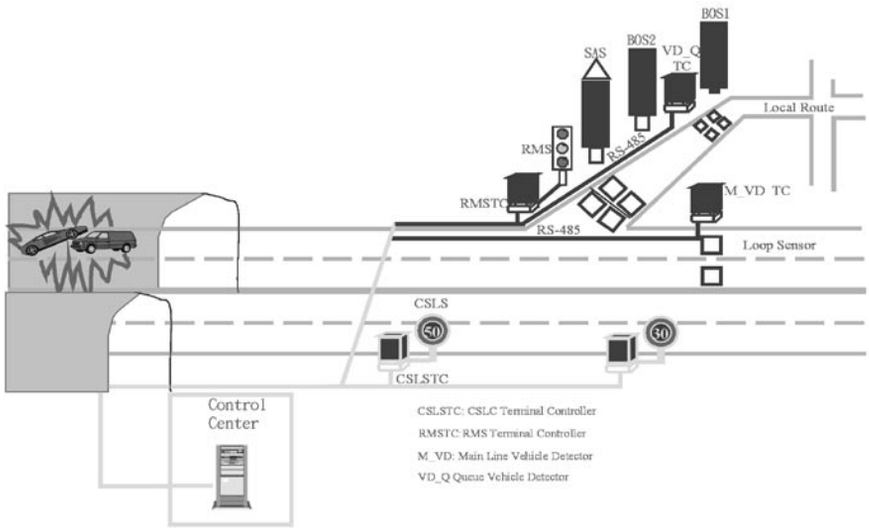


Figure 3 Ramp Metering Signal Architecture

* When incident or fire occurs in tunnel seriously, the upstream RMS shall close all lanes.

4.6 Incident Classification

Incident may be classified in 6 large categories as following:

* General incident:

  General incident includes accident, construction, fire, scattered articles, road surface damage, block, vehicle with trouble, special service, etc.

* Congestion incident : congestion

* Weather incident : Heavy fog , heavy rain , strong wind

* Tunnel incident : Fire, air quality ,lighting ,power distribution

* Electrical Mechanics system incident : tunnel air quality, tunnel lighting , tunnel power system

* Control incident : Congestion speed limit control, Ramp metering control, Tunnel traffic control

The resources of above incidents may be from ET, VD, RD, VI, WD, patrol car, police, road user. Those information will be collect to traffic control system to implement proper traffic strategy and traffic facilities. The traffic control strategy of incident classification is shown as table 4. The traffic control facilities of traffic control strategy are shown as table 5.

Table 4 THE TRAFFIC CONTROL STRATAGY OF INCIDENT CLASSIFICATION

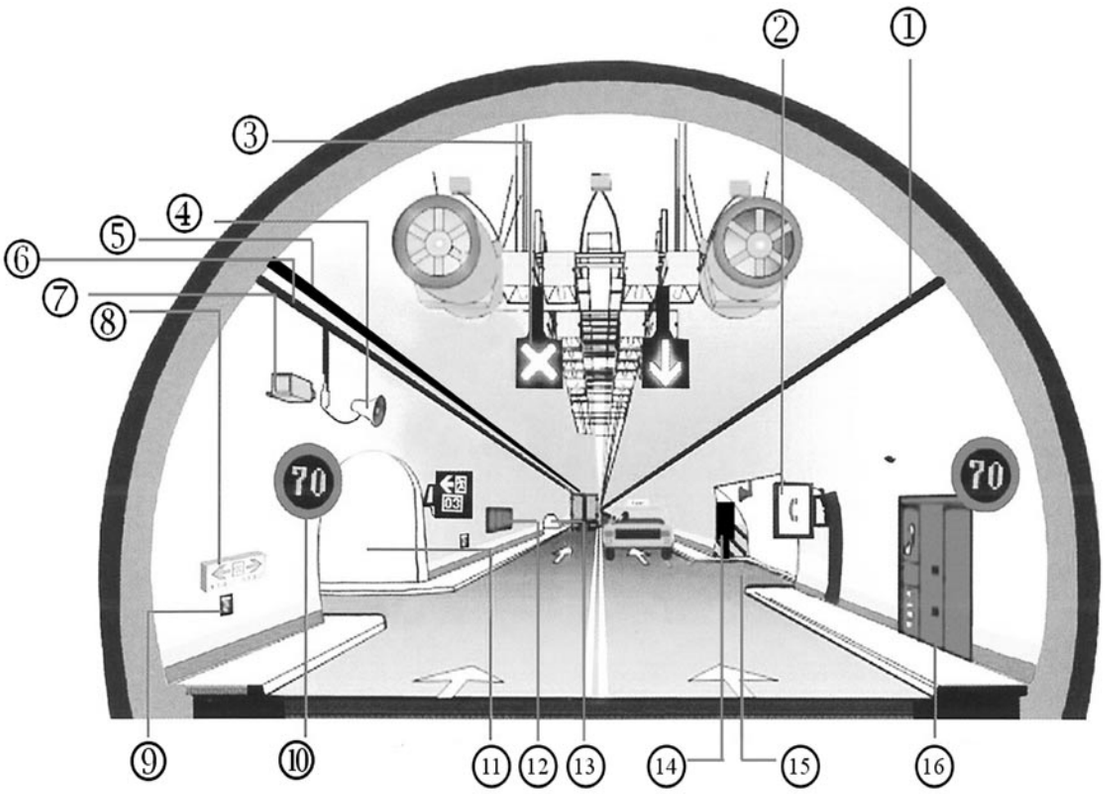
Strategy / Classification	Road User's Information Display	Main Line Speed Limit Control	Tunnel Traffic Control	Ramp Metering Signal	Road Surveillance
Congestion Incident	×	×	×	×	
General Incident	×	×	×	×	
Tunnel Incident	×	×	×	×	×
Weather Incident	×	×		×	×
Control Incident	×	×	×	×	×
Electrical Mechanics System Incident	×	×	×		×

Table 5 THE TRAFFIC CONTROL FACILITIES OF TRAFFIC CONTROL STRATEGY

Facilities	CMS	CSLS	LCS	RMS	CCTV	YELLOW LAMP	FOG ALAM SIGN
Classification							
Congestion Incident	×	×		×	×	×	×
General Incident	×	×	×	×	×	×	×
Tunnel Incident	×	×	×	×	×	×	×
Weather Incident	×	×		×	×	×	×
Control Incident	×	×	×	×	×	×	×
Electrical Mechanics system Incident	×	×			×	×	×

5. SYSTEM EQUIPMENT

According to traffic control strategy, the traffic control facilities layout is shown as Figure 4.



1.FM Leakage Coaxial Cable

2.Emergency Telephone

3.Lane Control Signal(LCS)

4.Loud Speaker

5.UHF Leakage Coaxial Cable

6.VHF Leakage Coaxial Cable

7.CCTV Camera

8.Escape Guide Sign

9.Escape Lamp

10. Changeable speed limit sign(CSLS)

11.Vehicular Cross Connection (Each 1400M)

12.Hydrant and Fire Extinguisher

13.Pdrestrian Cross Connection(350M)

14.Changeable message sign (CMS)

15.Emergency Parking Bay(Each 1400M)

16. Hydrant and Fire Extinguisher

Figure 4 Traffic Control Facilities Layout of Hsuehshan Tunnel Cross Section

6. SYSTEM INTERFACE

The interfaces between traffic control system and electrical mechanics system include hardware interface software interface.

6.1 Hardware Interface

(1) Hardware Interface

The tunnel electrical-mechanic monitoring system provides a router with IEEE 802.3interface in Mutsa control center (RCC), the traffic control system provides a router with IEEE 802.3 interface, accordingly. The purpose of this interface is to communicate and interlock high lever system events and related vehicle detection, fire alarm and tunnel ventilation data. The definition of "high level system events" is "A traffic event that has to be synchronously proceeded and concurrently controlled by both tunnel electrical mechanics and traffic control systems". The system interfaces of traffic and electrical mechanics architecture are shown as Figure 5.

(2) Software interface

Basically, the electrical mechanics system and traffic control system shall exchange through TCP/IP communication protocol. Both systems

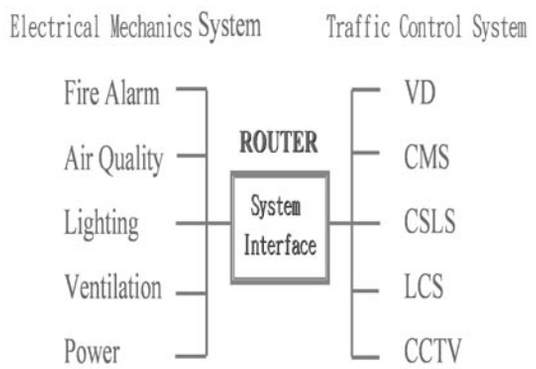


Figure 5 The system interfaces Architecture

have to obey the TCP/IP communication protocol and further application driver of each system can developed by individual system. The data exchange flow of fire incident architecture is shown as Figure 6.

A. Data provided by traffic control system to electrical mechanic system.

(A) Traffic data

a. Be transmitted within an unit time interval (adjustable) and at the time of staring and ending reversible lane control.

b. Average vehicle flow large car, small car and truck-tractor (vehicle/min).

c. Average speed of large car, small car truck-tractor.

d. The above b. and c. datum of whole vehicle detection spot alone the route.

e. Be transmitted when reversible lane control event started and ended (include preparing for event starting ending time).

(B) For data of the road adjacent to tunnel.

a. Be transmitted when fog event occurred and ended.

b. Data provided by electric mechanic system to traffic control system:

(C) Fire event

a. Time to transmit: Be transmitted at the time that event occurs and recovers.

b. Required date: Name of tunnel, zone , location (North/south bound, cable and conduit corridor, code number of architecture on the top of ventilation shoot or mechanic room), status (event occur or recover).

c. Traffic control system adopt CCTV to automatic event interlocking.

d. Both events have to be transmitted in case of adjacent zones occur fire.

(D) Air quality

a. Time to transmit: Two thresholds (advance warning and utmost values) shall be set. If the density exceeds the threshold of advance warning, the value have to be transmitted for every

unit time (adjustable).When the density exceed the threshold of utmost valves, alarm signal and density value has to be sent immediately and keep on transmitting until the density below than the threshold of advance warning.

b. Required data:

(a) CO: location, mileage, density.

(b) NOx: location, mileage, density.

(c) VI: location, mileage, visibility.

(d) Temperature: location, mileage, degree.

c. Any fault data occur, the datum of above said fore(4) items shall be transmitted again.

(E) Lighting event

a. Time to transmit: Be transmitted at the time that lighting loops breakdowns and recovers.

b. Required data: Name of tunnel, zone, location, lamination outside the tunnel, number of lighting loops required and number of breakdown loops.

(F) Power distribution event:

a. Time to transmit: Be transmitted at the time that power distribution breakdowns and recovers.

b. Required data: Name of tunnel, zone, status(tai-power and emergency power supply status).

(G) Machine room entrance security event:

a. Time to transmit: Be transmitted at the time that event occurs (intrusion) and event eliminates.

b. Required data: Name of tunnel, location, code of card reader, status.

C. Double confirm data structure shall be applied, i.e., the receiving end has to feedback the received data to the transmission end to ensure the data transmitted are exact. If the transmission end does not receive confirmation from receiving end within 20 second (preset, adjustable), it shall transmit the data again, at least three (3) times.

D. The data formats are shown in Appendix 1. Any data format, even may not be included in the required exchange data between two systems, shall be retained as its original format.

E. System shall automatic restore the data transmission function, after communication interruption is recovered.

7. CONCLUSIONS

The Taipei-Ilan Expressway plans to open for transportation by end of December, 2005. Before road section opening, the traffic control system

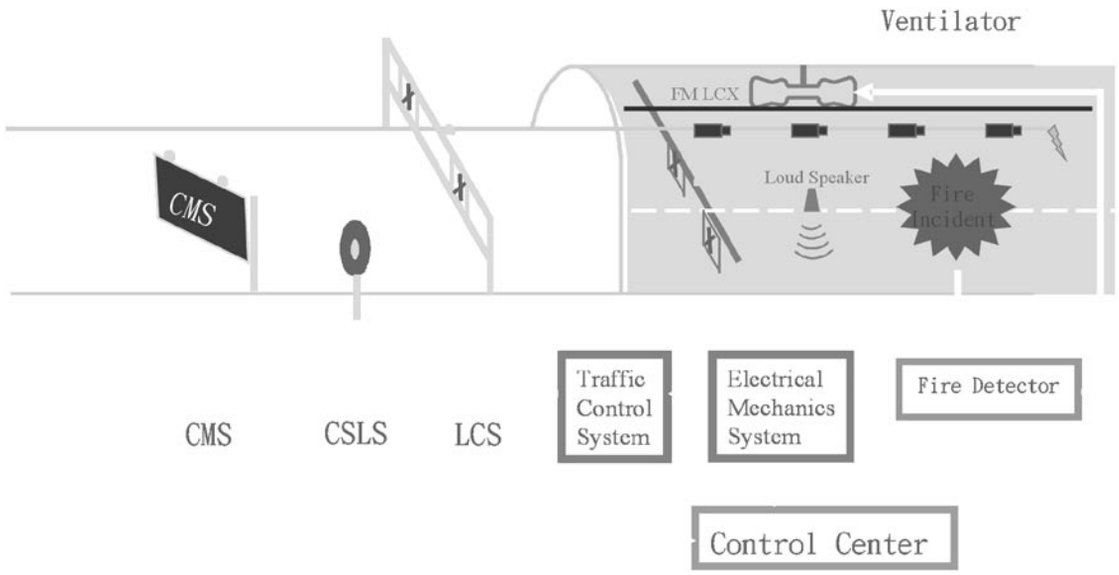


Figure 6 Fire Incident in tunnel Architecture

and electrical mechanic system shall be passed the extremely system integration test and integral system integration test for tunnel safety issues.

The concepts of traffic control strategy design are based on the experience of other road section traffic control system design, road section characteristics, traffic volume analysis and weather analysis. Therefore, the traffic control system is significantly influenced to the long tunnel safety issues.

Following issues are still subjects after original traffic control system design for tunnel safety.

* Establish on-line traffic control software simulation to assess result of traffic control strategy implement and road section traffic characteristics.
* Establish violation enforcement to punish change lane and speeding violations.
* Establish all channels FM system in tunnel .

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