

# Safety Management and Emergency Response for Hsuehshan Tunnel

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## I、Preface

With mountainous terrain, tunnels become an essential design in highway engineering in Taiwan. But the closed characteristic makes tunnel different to open space in management. If a disaster occurs, it will be hard to communicate, give rescue and handle the situation. So we have to consider and prepare more and more than ordinary highway.

Because of several tunnel disasters that made serious injuries and fatal, property lost and long term transportation interrupted were happened in Europe, so that we pay more attention in safety management, disaster prevent and rescue for long tunnel. Especially to the 12.9 Kilo-meters Hsuehshan Tunnel on freeway NO.5, except higher safety standards in design and construction than ordinary sections, we had planed an emergency response and disaster rescue plan in advance. If a disaster happened, we will have best reaction.

When We, The National Freeway Bureau (called Freeway Bureau below), take over the Hsuehshan Tunnel, we had planed and executed a lot of measures for safety management and emergency response. We proposed a “Integrated Emergency Response Plan for Disaster Prevention and Rescue for Hsuehshan Tunnel” (called Emergency Response Plan below). The Emergency Response Plan was according to conduct a lots works of disaster prevention and rescue.

We will make an abstract below about the works of safety management and emergency response for Hsuehshan Tunnel.

## II、Safety Management Measures

For keeping Hsuehshan Tunnel users being safe, the facilities for maintaining safety were considered when the tunnel in planning, designing and building stage. Then before the tunnel was opened to traffic, we drew up and executed management measures to cooperate with those facilities for achieving the goal of safe traffic in tunnel.

### A. Facilities for Maintaining Safety

The facilities for maintaining safety in Hsuehshan Tunnel were constituted by civil and traffic engineering, tunnel mechanical-electrical system and traffic control system. And tunnel mechanical-electrical system and traffic control system can be integrated into operating to reaching the effectiveness of preventing disaster, reducing damage and supporting rescue.

#### 1. Civil and Traffic engineering

- (1) Pilot tunnel: the pilot tunnel locates below and middle of two main tunnels. There are stairs to connect with connecting tunnels. In building stage, it was for advanced geological investigation. When the tunnel was opened for traffic, it can be used for maintain works and rescue and escape routes.
- (2) Connecting tunnels: to connect two main tunnels, the connecting tunnels were 350 meters interval. There were 28 connecting tunnels only for persons. But in 1,400 meters interval, there are 8 connecting tunnels for vehicles too with. The connecting tunnels have fire-resistance doors and positive-pressure ventilation. And they can connect to pilot tunnel by stairs. They were safe shelters, escape-evacuation routes, and can be used for rescue routes too.
- (3) Emergency parking bay: with 1,400 meters interval, there were 8 bays per-direction across the exit of vehicle connecting tunnels. They provide suspending for help spaces for breakdown or accident cars.
- (4) Control station: the stations provide spaces for intercept and check works to prevent violating and dangerous vehicles entering tunnel. There are two stations at northern and southern ends of Hsuehshan Tunnel. The northern end station locates by northern exit of Wutu tunnel; the southern end station uses Toucheng Toll station space. And they both have driving ways.
- (5) Height limit facilities: to avoid the vehicles higher than limitation entering. There are

height limit gates set up at southern entering ramps of Nangang System, Shirdin and Pinglin interchanges.

- (6) Signs and Markings:
  - a. Signs and markings of “Forbid Changing Lane”.
  - b. Signs and markings of “Safe Distance Identification”: providing reference for users to keep a least 50 meters safe distance.
  - c. Signs of “Turn on Head Lamp in Tunnel”.
  - d. Signs of “Forbid the Vehicle Loading Hazardous Goods Entering” and “Forbid Trucks Entering”.
  - e. Signs for marking the location of facilities, such as emergence telephone, connecting tunnels, etc.

## 2. Tunnel Mechanical-Electrical System

The system is assembled by 6 subsystems, electrical power supply and distribution, tunnel lighting, ventilation, fire alarm, fire fighting, monitoring and control system.

- (1) Electrical power supply and distribution system
  - a. The main power comes from 2 sets of independent high-voltage power supplied by Taipower Company. There are 2 high-voltage substations at both ends of Hsuehshan Tunnel. At the northern end, Pinglin, there is a 161KV substation with 2 power circuits, one for regular and one for backup. At southern end, Toucheng, there is a 69KV substation with 1 power circuit. Each feed line capacity can supply load of all facilities in tunnel. In normal, each substation supply power demand of half tunnel. If necessary, one substation can switch to the other. To make sure of enough and reliable power supply.
  - b. There are UPS and diesel power generators for backup power supply if out-source power break off.
  - c. UPS can provide power for important facilities such as emergency lighting, fire alarm, traffic control system between out-source power break off and generators start up. The UPS capacity is setup for 60 minutes.
  - d. There are 2 sets of generators in both substations. It is designed to start up automatically in 20 seconds if out-source power break off. And its capacity is enough to supply all the emergency load of lighting, ventilation, fire alarm, fire fighting, traffic control and communication equipments.
- (2) Tunnel lighting system
  - a. Tunnel lighting is designed for traffic, moving at design speed, to approach, enter, travel through and exit a road tunnel at a safety level equal to that on adjacent stretches of open road. Fluorescent lamps are used for the main lighting in Hsuehshan Tunnel. And high-pressured sodium vapor lights are used for enhanced lighting on entering and exiting tunnel sections. Actually, this design is for all tunnels on Freeway No.5.
  - b. The lighting control mode: except 0 to 3 o'clock is fixed 1/10 lighting, for provide the illumination for safely driving, the other period automatically control a appropriate lighting according to the result of comparing detected value from 'brightness detector' and preset value. The system has manual control function for backup too. The operator in Pinglin Control Center (called PLCC below) can monitor and control the lighting situation.
  - c. In tunnel, 1/10 lights connect to UPS to provide basic lighting if out-source power break off. Then the generator will start up to supply power that all lights need.
  - d. On the left sidewall, 50 centimeters above the walking trail, there are escape guiding lights per 50 meters. The lights will auto-light up at fire alarm. On the left sidewall, there are escape direction guiding signs per 100 meters to mark the distance to

connecting tunnels. And at exits of every connecting tunnel have 'Exit Guiding Light' for guiding users to escape.

(3) Ventilation system

- a. Hsuehshan Tunnel uses 'Enhanced Longitudinal ventilation System' to provide ventilation and exhaust smoke. Jet fans on tunnel top, 3 sets of ventilation station and air interchange station with axial fans compose the system. There are one intake shaft and one exhaust shaft in every ventilation station. Fresh air introduced from intake shaft dilutes with the vehicle emissions. Then the dirty air is exhausted from exhaust shaft and tunnel exit.
- b. The connecting tunnels and pilot tunnel is introduced fresh air from axial fans in machine rooms located at tunnel exits. It's independent from main tunnel ventilation system. The users stay in connecting tunnels or pilot tunnel will get fresh air. The connecting tunnels also keep positive air pressure to keep smoke out.
- c. According to tunnel status, the ventilation system can be sorted into 6 operation modes, normal, traffic jam, emergency (escape and exhaust smoke), power off and maintenance mode. The system can get data from traffic, fire and air quality detectors, and then auto-switch on appropriate mode if the data is over the preset thresholds. The operation status is monitored by Pinglin Control Center. And Control Center can control the operation remotely by manual.
- d. There are CO, NO<sub>x</sub>, and VI detectors in tunnel. In normal, according to detection, the system auto-control the fans operating to keep good air quality and clear vision in tunnel. If in fire, according to fire alarm, the system auto-start up a preset mode or operator manually operates an appropriate mode to exhaust smoke in order to let users escape and rescuers execute a rescue.

(4) Fire alarm system

- a. There are fire detectors in main tunnels, connecting tunnels, and machine rooms. Detecting fire alarm signal can auto-transfer to control center, and then gearing with fire fighting, ventilation, lighting and traffic control system.
- b. Additionally, it allows to manually notifying fire alarm by pressing the fire alarm button on hydrant box that located along the tunnel per 50 meters, or using the emergency telephone to communicate with control center.

(5) Fire fighting system

- a. There is a hydrant box per 50 meters along main tunnel right-side wall and in every connecting tunnel. There are 2 20 ponds ABC type powder fire extinguishers, 1 or 2 water valves (depend on hydrant box type), 30 meters fire hose in the box, and emergency power supply socket, telephone sockets, and fire alarm button on the box. The box door is setup open detection function. If the button is pressed on the door is opened, the alarm will send to control center. Control center will get the alarm and locate its position.
- b. There is a 214 tons hydrant water tank at Hsuehshan Tunnel northern end to supply hydrant water. There are 2 main hydrant pipes along the southbound and northbound cable corridors that are under main tunnel. The pipes have BYPASS function to make sure enough water supply if break. Additionally, there is a 1,000 tons water tank under the basement in PLCC connecting to hydrant water tank to supply water in time.
- c. The CO<sub>2</sub> fire-fighting system is setup in machine room. It can auto detect fire alarm and work. Manually starting up is allowed too.

(6) Monitoring and control system

- a. The system can monitor and control the operating status of power supply, ventilation, lighting, fire alarm, fire fighting, air conditioner in machine rooms and other

mechanical-electrical equipments.

- b. Whole tunnel is monitored and controlled by PLCC. The operators can watch the operating status of all equipments from workstation. They can handle present situation in the tunnel and take appropriate measures.
- c. Except auto control function, manual or remote operation is allowed if equipment malfunction or in emergency.

### 3. Traffic control system

- (1) Traffic control system collects event data via detectors auto-detection and manual report, and then judges and start up the appropriate reaction plan. Then executing traffic control measures, displaying and announcing message to achieve the goal of traffic management for Freeway No.5.
- (2) The way of system operation:
  - a. Getting integrated traffic and event data from roadside data collection system, mechanical-electrical system, toll system, and manual report.
  - b. Operators confirm and input event data. Event reaction plan program will produce a management strategy. After confirming, operators execute traffic control and information display, and announce related event conduct and rescue units.
  - c. Central computer handles traffic data and event reaction process. And there is transmission system to connect each system.
  - d. When an emergency event occurring, PLCC can coordinate and command rescue units in cooperation by wave-radio system.
- (3) Like to other traffic control system, this system is composed of traffic and event data collection, information display, traffic control, central processing and control units. Additionally, enhancing information display and communication function in accordance to demand of Hsuehshan Tunnel safety maintain and emergency rescue.
- (4) Traffic and event data collection equipments include vehicle detector (VD), CCTV, emergency telephone (ET), etc. Additionally, a new Tunnel Image Incident Detection (IID) system is in building to enhance event data collection function and increase event response speed.
- (5) Information display equipments include CMS (Changeable Message Sign), tunnel loudspeaker and FM broadcast system. Especially, compare with only 2 FM channels for other tunnels, the FM system for Hsuehshan Tunnel is a multi-channels system (23 for southbound and 18 for northbound). Those channels cover most main broadcasting stations to enhance the information providing effect.
- (6) Traffic control equipments include LCS (Lane Control Sign), CSLS (Changeable Speed Limit Sign), emergency fences and entering ramp metering.
- (7) Central process and control equipments are installed in PLCC. It includes Central Computer, Full Integrated Workstations (FIWS), Data Projector and Screens, CCTV monitors and transmission equipment, etc. the FIWS provides window-based graphic interface. And it has full integrated function let operator can execute various operation to control the local equipments. The operators in PLCC monitor, control and manage the traffic control and mechanical-electrical system working status all day.
- (8) Communication system includes:
  - a. Telephone: it's further divided into Emergency Telephone (ET) and exclusive use telephone for freeway agencies. The ET is setup along the freeway. On open section, there is an ET per kilometer. In tunnel, there is an ET per 175 meters and per connecting tunnels. It can let user talk to operator in PLCC directly. Exclusive use telephone is provided for inner communication between the freeway management agencies including Freeway Bureau and Highway Police Bureau.
  - b. Wave-radio: there is exclusive UHF wave-radio system for freeway NO.5. Additional,

police VHF and fire department VHF wave-radio systems have been setup in Hsuehshan Tunnel too. For transmitting radio signal into the tunnel, there are wave-radio leakage cable and relay stations installed. And there is a radio dispatch station in PLCC to integrate those different wave-radio systems to enhance the connection between every agency in emergency.

c. Cellphone: private telecommunication companies establish the 2G/3G cellphone base stations jointly. And a leakage cable for cellphone is setup along tunnel to transmit signal. Let people can use cellphone in tunnel.

4. Police Enforcement: except above safety maintain facilities build by freeway agency, for enhancing enforcement, highway police agency had setup enforcing speedy violation equipments. And a violation enforcement system focus on speedy, distance not enough and changing lane is in building.

#### B. Safety management measures

Except above established facilities, we thought management measures are indispensable for keeping Hsuehshan Tunnel in safety. On the one side, the measures can regular users in good habits on using tunnel; on the other side, those can let safety facilities bring the anticipated and most effectiveness in order to reduce dangerous factor.

##### 1. Driving regulation for Hsuehshan Tunnel

###### (1) Drew up and announced a notification for safety

We especially drew up a 'Notification for safe driving in Hsuehshan Tunnel of Freeway NO.5'. The Notification was officially announced by MOTC (Ministration of Transportation and Communication). The Notification must be paid special attention and follow if users are going to and driving in Hsuehshan Tunnel. It includes items of before entering the tunnel, driving in the tunnel and action if meeting emergency event.

Except general regulations that are also suitable in common tunnels like forbid carried hazardous goods vehicle, forbid changing lane, turn on headlight. In the Notification, there are more strict regulations about vehicle type limit and safe distance. Now in Hsuehshan Tunnel (including adjacent sections), only allow small car (passage car and light truck) and bus to pass. The vehicle in tunnel has to keep a least 50 meters distance under normal traffic and 20 meters distance if traffic speed is lower than 20 KPH.

Additionally, the Notification also illustrate if meet accident or event, the users how to treat, response and escape.

###### (2) Cooperative control works

For co-operating the regulations of above Notification, the related control works are below.

a. Installed related signs: installed signs of 'Forbid Truck Pass', 'Forbid Carried Hazardous Goods Vehicle Pass', 'Turn on Head Light in Tunnel', 'Keep Safe Distance' to warn drivers following regulations.

b. Control stations: there are 2 control stations located at 2 sides of tunnel to strengthen violation vehicle control. The northern side station, for southbound traffic, is located at northern end of Wutu Tunnel, about 8 Kilometers away from Hsuehshan Tunnel. The southern side station, for northbound traffic, uses Toucheng Toll Station area to be the control point.

c. Enhancing bus inspection: coordinate motor vehicle agency and police agency taking Hsuehshan Tunnel into a key point to conduct periodical and Non-periodical bus inspection. The inspection focuses on driver's qualification and safe facilities on bus are qualified or not.

d. Strengthen violation enforcement in tunnel: highway police increase patrol density and enforce more mobile to raise enforcement effect.

(3) Propaganda to users

No matter setting up safety maintenance facilities or executing management measures, the final purpose is users can use the tunnel in safety. So we must have propaganda to educate users recognizing the facilities and knowing how to use it, understanding and following the regulations. And these safety measures can bring the most effectiveness.

Before Hsuehshan Tunnel opening for traffic, the MOTC guided an intensive propaganda. The works including:

- a. Massively produce variety propaganda materials, short film DVD, posters, folding pages, flags, and hand fans.
- b. Use multi promotion channels. Except official resource like CMS, electrical board, scrolling text marquee, etc, the printed media like newspapers, magazines, and electrical media like TV, broadcast and Internet.
- c. Cross-filed activities combination, like set a promotion booth in a garden party or local festival.

After Hsuehshan Tunnel opening for traffic, safety promotions is still a key works for Freeway Bureau, and continue in working. And PLCC is opened for visiting not only profession group but also common people. Especially In common people visiting, enhance illustrating how to use Hsuehshan Tunnel in safety.

2. Establish management agency and rescue organization

For maintaining facilities function in normal condition, conducting management measures, and executing rescue works in emergency, engineering, police and firefighting departments all established specialized agencies.

- (1) Engineering department: the Northern Region Engineering Office of Freeway Bureau founded Toucheng Branch engineering office (Toucheng Branch below) and Pinglin Control Center to conduct facility maintains and safety management works in cooperation. Their works in divided as blow:

- a. Toucheng Branch engineering office
  - (a) Civil and traffic engineering facilities maintains and management.
  - (b) Accident conducting work of Hsuehshan Tunnel southern end to Su-ao section.
  - (c) Command rescue work at accident and disaster scene of Hsuehshan Tunnel.
- b. Pinglin Control Center
  - (a) Tunnel mechanical-electrical system and traffic control system maintains and management.
  - (b) Accident conducting work of Nanggang system interchange to Hsuehshan Tunnel southern end section.
  - (c) Tunnel mechanical-electrical system and traffic control system monitor and operation full day.
  - (d) Command and communication center for accident and disaster rescue of Hsuehshan Tunnel.
  - (e) Firefighting task-force command and management.
  - (f) Towing service work.

Firefighting task-force was specially setup for Hsuehshan Tunnel rescue works. Now is conducting by contracting out with private company. There are 49 members. One is group leader doing administration works like arranging shift table, training, etc. The other 48 members divide into 4 squads with 12 members. Every squad divides into 3 teams stationing at northern end, southern end and middle point of Hsuehshan Tunnel. Every point installs motorcycles with fire extinguisher and medical box. When a serious accident or disaster happens in Hsuehshan Tunnel, the force-task will reach the scene in 7 minutes and execute

primary fire fighting, primary medical treatment and escape guidance. Then assist the official fire fighting squad to execute rescue works.

The towing service on Freeway No.5 is contracting with single contractor. The contractor has to locate towing vehicles at assigned places 24 hours, and prepare enough backup towing vehicles. It is different from other freeways using agreement rule. It allows multi companies to provide towing service after applying and passing qualification examination.

- (2) Police department: the 9<sup>th</sup> Police Brigade of National Highway Police Bureau (NHPB) takes in charge of the enforcement and traffic control works on Freeway No.5. And there are Toucheng and Shidin Branch on southern and northern side of Hsuehshan Tunnel.
- (3) Firefighting department: New Taipei City Fire Bureau founded Hsuehshan fire squad on northern end of Hsuehshan Tunnel, and I-lan City Fire Bureau founded Special fire squad on southern end of Hsuehshan Tunnel. These 2 squads specially take in charge of firefight and rescue works of Hsuehshan Tunnel.

Except above specialized agencies, it must need support from other cooperative rescue works, including traffic control, firefighting assistance, emergency medical treatment, etc. Therefore, a complete rescue organization is based on above specialized agencies, and joint with existing central and local government police, firefighting, medical departments, even environmental protection and military departments.

### 3. Organize and execute training and exercises

It's necessary to provide proper training to relative members, no matter for conducting safety management and facilities maintenance, or executing emergency rescue. Hsuehshan Tunnel is the first time to face a tunnel so long in Taiwan. Therefore, every department pays much attention to training.

Before the Hsuehshan Tunnel was opened to traffic, the engineering, police and firefighting departments had arranged relative professional training courses depending on their mission requirement. And the training is continued to conduct after the Hsuehshan Tunnel was opened to traffic. Their major trainings are below:

- (1) Engineering department: facility maintenance, mechanical-electrical system and traffic system operation, rescue skill for firefighting task-force, disaster rescue standard operation process.
- (2) Police department: enforcement and anti-accident measures for long tunnel, disaster rescue standard operation process.
- (3) Firefighting department: rescue skill for long tunnel, disaster rescue standard operation process.

Moreover, considering of long tunnel management and rescue works experienced overseas. Therefore, assigned relative staffs to Europe and Japan to learn knowledge and earn experience, in order to use for reference for domestic trainings.

To let the agencies and members participated disaster rescue works be familiar to rescue operation process. There were totally 14 rescue exercises had been hold before the Hsuehshan Tunnel opened to traffic. Then, we hold exercise once each quarter continually after the Hsuehshan Tunnel opened to traffic.

## III 、 Emergency response operation

A disaster can't be guaranteed wouldn't happen forever even the safety management works are planed and executed very well. Therefore, the proper emergency response operation has to be planed in advance. Occasionally a disaster happens, the rescue works can be executed immediately and finished in shortest time to let the damage reduce to minimums. The key points about emergency response operation are below.

### A. Establish command system

It's very important that how to integrate and use existing facilities, manpower (engineering, police, firefighting, medicals, etc.) and relative supporting agencies and staffs, and apply rescue strategy when a disaster happens in Hsuehshan Tunnel. Moreover, definite command system and mission assignment, proper time of setting up organization, and establishing deputy rule are the keys of executing a successful rescue.

It has to consider the resources for rescue and necessity of mobilization when established command system. At first, it needs to classify the grade of incidents. The incidents under some grades, like small accident or scattering things, only need to be treated by management agencies. If the incident situation goes to worse, it needs to combine more agencies to take a cooperative rescue.

#### 1. Modes of incident classification

The incidents in tunnel are classified to 4 grades: slight, general, serious and dangerous. The classification contents and planning of announcing treatment units are below.

##### (1) Grade 1: slight incident

a. Contents: it only leads to light traffic interfere in tunnel. This grade incident, like scattering things or vehicle malfunction, can be treated by user self and resident management agencies in general. The tunnel can keep traffic by least one lane with simply traffic control.

b. Treatment units: branch engineering office, PLCC (including firefighting task-force, incident conducting crew), highway police, towing vehicle, Police Broadcast Station.

##### (2) Grade 2: general incident

a. Contents: it only needs to close partial lane to treat. The treatment for this grade incident, like minor rear-end accident or maintaining works, generally can be finished in regular operation rule by resident management agencies and authorized contractors.

b. Treatment units: branch engineering office, PLCC (including firefighting task-force, incident conducting crew), highway police, towing vehicle, official fire squads, Police Broadcast Station.

##### (3) Grade 3: serious incident

a. Contents: it causes one direction tunnel full closure and traffic interruption and has to detour or other way for keeping traffic. This grade incident, like series car crash, needs to ask relative agencies from local government to assist rescue works.

b. Treatment units: branch engineering office, PLCC (including firefighting task-force, incident conducting crew and backup crew), highway police, towing vehicle, official fire squads, local medical agencies and hospitals, Police Broadcast Station.

##### (4) Grade 4: dangerous incident

a. Contents: it has to close two direction tunnels for emergency rescue. The incident happens because of fire from car accident, accident from violation vehicle that carrying chemical or toxic hazardous goods, terrorist attack, etc. Depending on situation development, it even needs to ask Central Disaster Response Center to lead rescue works.

b. Treatment units: branch engineering office, PLCC (including firefighting task-force, incident conducting crew and backup crew), highway police, local police, towing vehicle, official fire agencies, local and central medical agencies and hospitals, local environmental protection units, Police Broadcast Station. Moreover, if necessary, announcing National Fire Agency, Ministry of National Defense, Environmental Protection Ministration, National Police Agency, and National Airborne Service Corps, etc. to assist or lead rescue works.

#### 2. Command system



According to the difference of rescue operation is opening up and participated units enter point in time, the Hsuehshan Tunnel rescue standard operation procedure has been divided to 7 steps, from finding and announcing to recovery. Moreover, the procedure can be divided to 2 stages according to incident scale and developing status.

- (1) Initial response stage: it is about from incident found and announced to first level rescue agencies are out on rescue duty. In this stage, the rescue resources come from residential rescue units, including Toucheng Branch, PLCC, highway police squads, firefighting squads at both tunnel ends and other police or medical support units that can arrive at this stage.
- (2) Expending rescues stage: if above initial rescue operation still can't prevent disaster developing, the rescue works has to be expended. The relative rescue units will be announced and go to join the rescue works until rescue works are finished then enter recovery step. In this stage, except agencies of initial stage, the rescue resources include engineering, police, firefighting, medicals, towing units, etc. from adjacent region, and response to special events, like chemical or terrorist attack disaster, treatment units if necessary. Those supporting units have been planned and coordinated in advance.

Table 1 is the working divisions and members of initial response stage. Figure 1 is the command system of initial response stage. Table 2 is the working divisions and members of expending rescue stage. Figure 2 is the command system of expending rescue stage. Table 3 is the commander or chief and their deputies of each working division.

Table 1 Work Organization of Initial Response Stage

Organization members		Assigned agency	
EOC	Commander(spokesman)	PLCC Chief <sup>1</sup>	
	Assistant subdivision	PLCC, Firefighting squad, 9 <sup>th</sup> Police Brigade, Neighbor medical agencies	
Assistant division	Chief	PLCC deputy chief	
	Traffic control team	PLCC staffs	
	Mechanical-electrical team		
	Communication team		
Broadcast team			
Scene operation division	Chief		Toucheng Branch deputy chief
	Rescue subdivision	Leader	Hsuehshan Tunnel Fire Squads
		Rescue team	Hsuehshan Tunnel fire squad staffs/ PLCC firefighting task-force staffs
		Water serving team	Hsuehshan Tunnel fire squad staffs/ Freeway accident conducting staffs
		Search team	Hsuehshan Tunnel fire squad staffs/ PLCC firefighting task-force staffs
		Safety control team	Hsuehshan Tunnel fire squad staffs/ PLCC firefighting task-force staffs and Freeway accident conducting staffs
	Traffic control subdivision	Leader	9 <sup>th</sup> Police Brigade
		Freeway team	Touching squad/ Shidin squad of 9 <sup>th</sup> Police Brigade
		Local highway team	Xindian Precinct of New Taipei City Police Bureau/ Jiaoxi Precinct of Yilan County Police Bureau
		Scene control team	9 <sup>th</sup> Police Brigade squad staffs/ PLCC firefighting task-force staffs and Freeway accident conducting staffs
	Medical subdivision	Leader	Hsuehshan Tunnel fire squad/EMT leader
		Injury inspect team	Medical agency dispatch staffs
		Medical treat team	Hsuehshan Tunnel fire squad/EMT leader
		Injuries deliver team	Hsuehshan Tunnel fire squad/EMT leader
		Pacify team	Hsuehshan Tunnel fire squad staffs/ PLCC firefighting task force staffs

1: EOC commander and division chief can be the highest rank staff or assigned staff.

2: Hsuehshan Tunnel firefighting squads are Hsuehshan fire squad at northern end and Special fire squad at southern end. According their duty region or rescue time effectiveness, the fire squad first announced will be the chief and the other one is the assistants.

3: Neighbor medical agencies follow the rule of fire squad to turn out for work.

Table 2 Work Organization of Expanding Rescue Stage

Divisions		Assigned agency		Members		
EOC	Commander	Northern Region Engineering Office* (or dispatched by Freeway Bureau or MOTC if disaster expanding or special demand)		The Director of N.R.E.O. (Director general of Freeway Bureau, Minister of MOTC or assigned staff)		
	News officer	N.R.E.O.(dispatched by Freeway Bureau if disaster expanding or special demand)		Assigned staff of N.R.E.O. or PLCC chief serving concurrently (or assigned staff by Freeway Bureau)		
	Safety officer	Freeway Bureau		Touchang Branch engineer or staff		
	Coordinator	N.R.E.O.(or dispatched by Freeway Bureau if disaster expanding or special demand)		PLCC deputy chief serving concurrently (assigned staff by Freeway Bureau)		
	Staffs from rescue agency	N.R.E.O./Highway police/Local fire & medical department		Staffs assigned by those agencies		
Assistant division in EOC	Plan subdivision	Chief		N.R.E.O.	Chief of Construction section	
		Leader		N.R.E.O.	Chief or assigned staff of Equipment & Supplies section	
		Resource team		N.R.E.O.	Assigned engineer or staff	
		Status team		N.R.E.O.	Assigned engineer or staff	
		Data team		N.R.E.O.	Assigned engineer or staff	
		Technical team		Rescue advisors	Fire, medical, civil departments of university relative to rescue works	Experts/professors
				Hazardous good treatment	Local government environment protect bureau/toxic disaster center	Assigned staff
				Structure disaster treatment	N.R.E.O. (assigned by Freeway Bureau on demand)	Engineer of Construction section or Toucheng Branch (Engineers from Technical or Construction Division of Freeway Bureau)
				Explosives treatment	Criminal Investigation Bureau	Assigned officer

\* Northern Region Engineering Office is shortened to N.R.E.O. in the table below.

Table 2 Work Organization of Expanding Rescue Stage (continues)

Divisions		Assigned agency		Members	
Assistant division in EOC	Logistic subdivision	leader		N.R.E.O.	Chief or assigned staff of General Affairs section
		Service team	Supply	N.R.E.O.	PLCC engineer/firefighting task-force staffs
			Equipment	N.R.E.O.	PLCC engineer/firefighting task-force staffs
		Support team	General Affairs	N.R.E.O.	General Affairs staff from N.R.E.O. and Toucheng Branch
			Transportation	N.R.E.O.	PLCC and Toucheng Branch engineers/drivers
	Control center subdivision	Leader		N.R.E.O.(or dispatched by Freeway Bureau if disaster expanding or special demand)	PLCC chief (or assigned staff from Traffic Management Division of Freeway Bureau)
		Traffic control team		N.R.E.O.	PLCC traffic engineers/ system operators
		Mechanical-electrical team		N.R.E.O.	PLCC mechanical-electrical engineers/ system operators
		Communication team		N.R.E.O.	PLCC traffic engineers/ system operators
		Broadcast team		N.R.E.O.	PLCC traffic engineers/ system operators
Scene operation division	Chief		N.R.E.O.	Chief of Toucheng Branch	
	Traffic control subdivision	Leader		9 <sup>th</sup> Police Brigade of NHPB	Captain of Toucheng police squad
		Freeway team		NHPB	Polices of 1 <sup>st</sup> ,6 <sup>th</sup> ,9 <sup>th</sup> Police Brigade
				N.R.E.O.	Staffs of Toucheng, Mucha, Neihu Branch
		Local highway team		New Taipei City Police Bureau	Polices of Xindian Precinct
				Yilan County Police Bureau	Polices of Jiaoxi Precinct
	Scene control team		9 <sup>th</sup> Police Brigade / N.R.E.O.	Police of Toucheng and Shidin squads/ PLCC firefighting task-force staffs	
	Rescue subdivision	Leader		Fire department of jurisdiction	The highest rank staff of fire department
		Search team		Fire department and other rescue agency	Assigned by leader
		Rescue team		Fire department and other rescue agency	Assigned by leader
Water serving team		Fire department and other rescue agency	Assigned by leader		
Safety control team		Fire department and other rescue agency	Assigned by leader		

Table 2 Work Organization of Expanding Rescue Stage (continues)

Divisions		Assigned agency	Members	
Scene operation division	Medical subdivision	Leader	Initial stage: fire squads at ends of tunnel or city(county) fire department	
			Disaster expanding and a medical station established: city(county) medical department/hospital of emergency medical net	
		Injury inspect team	Initial stage: fire squads at ends of tunnel or city(county) fire department	EMT of fire squads
			Disaster expanding and a medical station established: city(county) medical department/hospital of emergency medical net	Medical staffs of hospital
		Injuries deliver team	fire squads at ends of tunnel or city(county) fire department	EMT of fire squads
		Pacify team	N.R.E.O.	PLCC firefighting task-force staffs
	Medical treat team	city(county) medical department/hospital of emergency medical net	Assigned medical staffs	
	Special support subdivision	Explosives treatment team	Ministry of Interior	Assigned staffs
		Air support team	National Airborne Service Coprs.	Assigned staffs
		Nuclear-Biochemistry treatment team	Environmental Protection Administration	Assigned staffs
Other disasters		Depend on disaster type	Assigned staffs	

- 1: there are professional subdivisions under scene operation division. The chief of division and leader of subdivision is the highest rank officer or assigned deputy staff. Before the assigned chief or leader arrive incident scene, the highest rank staff at scene is in charge of command work and connecting with EOC. Then transfer the position to chief or leader.
- 2: for emergency rescue organization operating smoothly, commander, chiefs, leaders and crews all need to build a deputy rule in usual.
- 3: if the disaster expanding continuously, the command level upgrades to Director General of Freeway Bureau, and the division chiefs and subdivision leaders have to follow the level to upgrade.
- 4: relative agencies in this command system should accept command and dispatch from commander.

Table 3 Commanders and their deputy of Hsuehshan Tunnel incident rescue command system

stage	Command system	Title	1st deputy	2nd deputy	
Initial response stage	Commander	PLCC chief	PLCC deputy chief	PLCC staff on duty	
	Chief of Assistant division	PLCC deputy chief	PLCC staff on duty	PLCC assigned engineer	
	Chief of Scene operation division	Touching Branch deputy chief	Touching Branch staff on duty	Touching Branch assigned staff	
Rescue expanding stage	Commander	Director of N.R.E.O.	Deputy Director of N.R.E.O.	Chief of Construction section, N.R.E.O.	
	Chief of Assistant division in EOC	Chief of Construction section, N.R.E.O.	Chief of Equipment & Supply section, N.R.E.O.	N.R.E.O. assigned staff	
	Assistant division	Plan team	Chief of Equipment & Supply section, N.R.E.O.	Assigned by Director	
		Logistic team	Chief of General Affairs section, N.R.E.O.	Assigned by Director	
		Control center team	PLCC chief	PLCC deputy chief	PLCC staff on duty
	Chief of Scene operation division	Touching Branch chief	Touching Branch deputy chief	Touching Branch staff on duty	

\*This table applies to Northern Region Engineering Office of Freeway Bureau. If the disaster expanding so that Freeway Bureau needs to join, the command system and deputy rule will accord to significant disaster conducting regulation of Freeway Bureau.

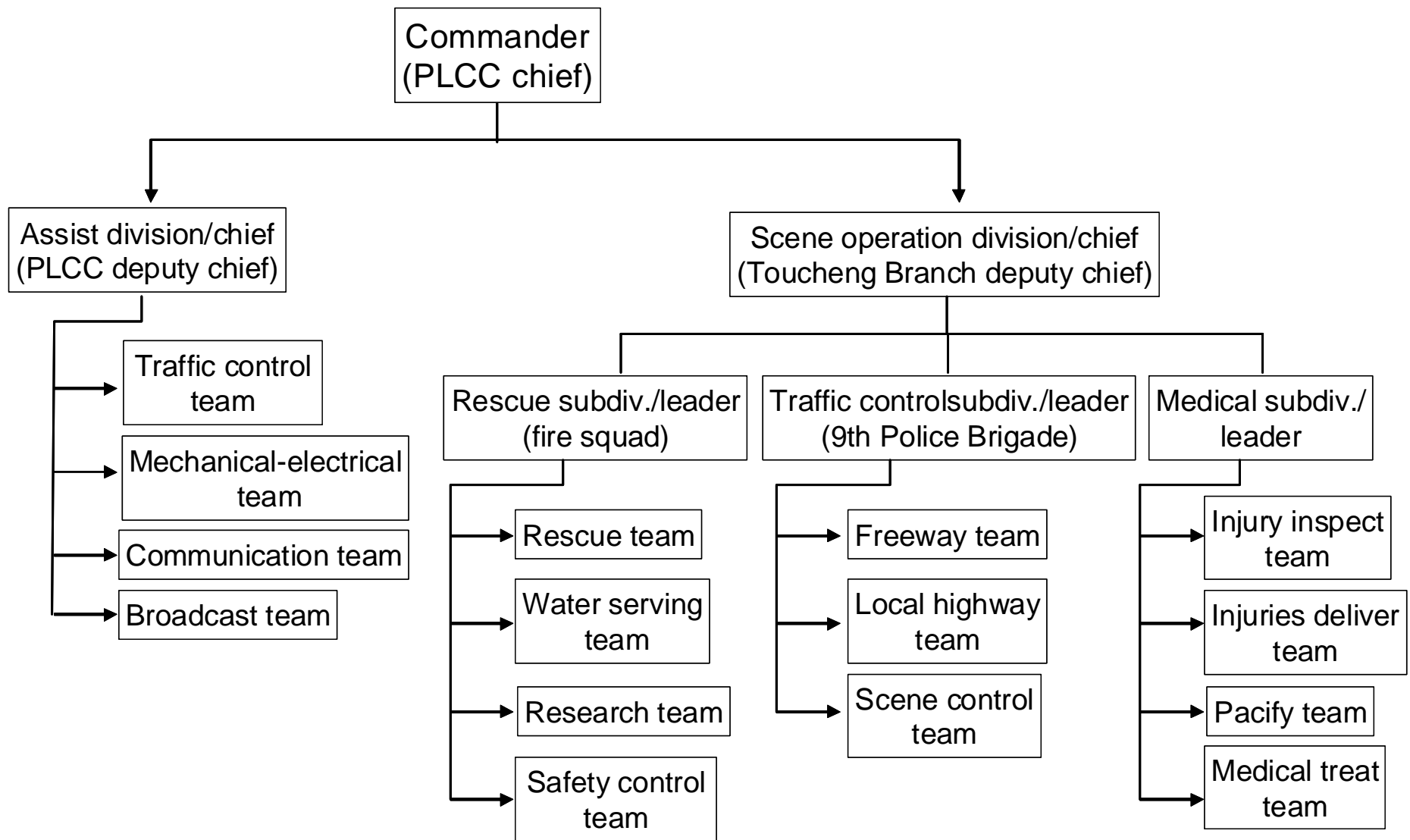


Figure 1 the Command System of Initial Response Stage for Hsuehshan Tunnel Disaster Rescue Work

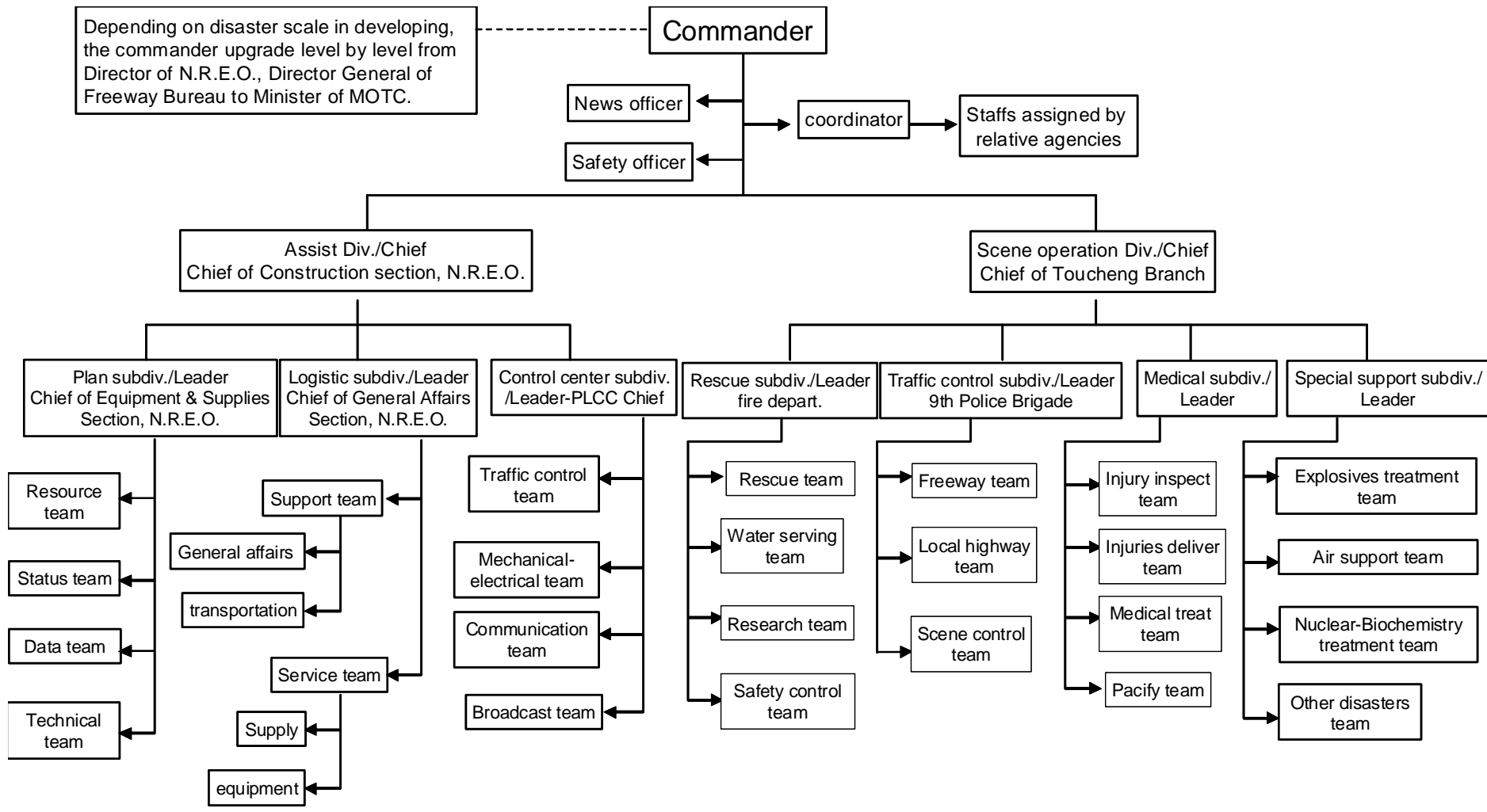


Figure 2 the Command System of Rescue Expanding Stage for Hsuehshan Tunnel Disaster Rescue Work



## B. Rescue standard operation procedure (SOP)

A united rescue work combined each units is necessary if a serious or dangerous incident, like fire or hazardous goods leaking, happens in Husuehshan Tunnel. Therefore, we plan a rescue SOP to let rescue units follow in order to bring the most effect for emergency response and rescue.

According to the sequence of disaster treatment, the treatment procedure divides to 7 steps like figure 3. The contents of every step are below.

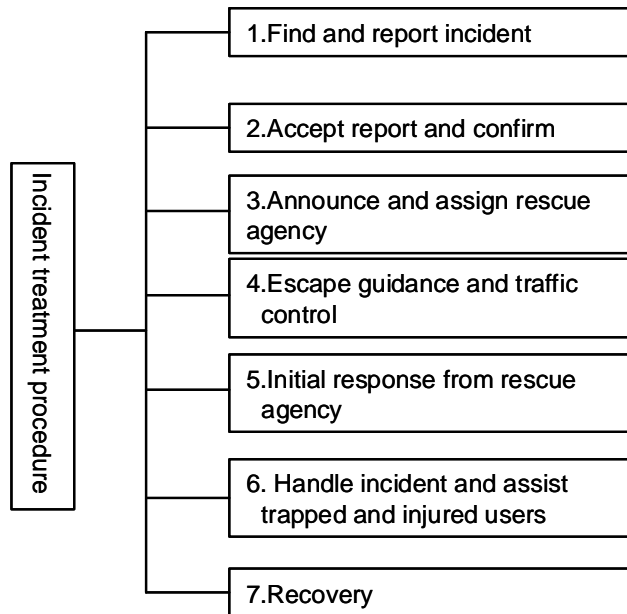


Figure 3 Incident treatment steps

### 1. Find and report incident

#### (1) System auto-detection:

- a. Traffic control system detects an event by vehicle detections.
- b. Mechanical-electrical system detects fire alarm, smoke or worsened air quality event.

#### (2) Artificial report:

- a. Users report to fire department, police or PLCC by cell-phone or ET.
- b. Highway police, engineering office patrols and CCTV are aware of a incident.

### 2. Accept report and confirm incident

Operators in PLCC gather incident data from system auto-detection and artificial report then make confirm by CCTV.

### 3. Announce and assign rescue agency

- (1) PLCC immediately announce firefighting task force to go for duty, and notify incident conducting crew, firefighting squads at both tunnel ends and highway police to go to the scene of incident at the same time.
- (2) PLCC monitor disaster-developing status. If the disaster expanding, the emergency response center will be established immediately and add to notify Northern Region Engineering Office, adjacent branch engineering offices, local police department, fire department and Police Broadcast Station.
- (3) PLCC and Toucheng Branch start up reaction plan of traffic control system, traffic control project and logistic support work. PLCC will provide traffic situation and proper rescue routes.
- (4) After receiving notification, each rescue agencies has to confirm incident status and rescue route, dispatch proper rescue staffs, vehicles and equipments,

and rush to the scene of incident.

- (5) The dispatch center of fire department applies proper medical recourses of emergency medical net according to data of injury numbers, condition and fire scale, and etc. Moreover, the coordinative medical supporting project from adjacent county (city) will be start up if necessary.

#### 4. Escape guidance and traffic control

- (1) The firefighting task force staffs evacuate and guide people to escape.
- (2) Highway and branch engineering office staffs handle users' escaping situation and surrounding traffic conditions.
- (3) PLCC and highway police start up proper traffic control and detour project after deciding scope of traffic control area. Then notify and guide the local fire department and relative support agencies to scene of the disaster at the same time.
- (4) PLCC assist communication and operate safety facilities in tunnel.
- (5) Local fire department staffs reach scene to meet highway police and branch engineering office staffs, confirm the relative position and disaster status.

#### 5. Initial response from rescue agency

- (1) In initial stage, the first arrived staff of branch engineering office will be the leader of incident scene. The highway police direct traffic control works.
- (2) If a fire incident, the command of rescue division will transfer to firefighting squad leader when the squad arrives, then assign experimental firefighting crew executing rescue works.
- (3) If the disaster can't be control, the scene leader has to report PLCC to establish emergency command center (EOC). The EOC will request for manpower and equipment support to relative agencies by rescue demand. Those rescue agencies have to assign a representative to report EOC when they arrive the scene.

#### 6. Handle incident and assist stalemates and injuries

##### (1) Handle incident

##### A. EOC:

- a. Keep smooth communication with scene operation division to have incident developing and rescue operating situation in hand.
- b. Evaluate present status by integrating information from every agency, then coordinate and command scene rescue and logistic support works.
- c. According to incident type and scale to define an outpost area by asking professional opinion from supporting rescue agencies. Notify scene operation division to execute control work. The outpost area should be adjusted all the time depending on incident developing and handling status.
- d. Report to higher-ups periodically.
- e. Assign a spokesman to connect and speak to news media.

##### B. Scene operation division:

- a. According to the command from EOC, the chief of scene operation division coordinates the scene rescue works.
- b. Execute rescue works by every subdivision:
  - (a) Rescue subdivision: fire agencies execute firefighting and search works.
  - (b) Medical subdivision: medical staffs or EMT of fire squad assist injury inspection and classification, medical treatment and sending to hospital.

- (c) Traffic control subdivision: plan and execute scene, surround freeway and local highway traffic control works. Control the outpost area that EOC assigned.
- C. Assistant division:
  - a. Planning subdivision: according to the Emergency Response Plan written in advance to drive every subdivision executing their works. Collect and record rescue resources (manpower, equipment) dispatching, incident status (facility damage, injury, fatal, etc.) and rescue operation information and report to commander. Provide the inquiry for Emergency Response Plan contents to commander.
  - b. Logistic subdivision: evaluate the logistic demand of rescue works and provide every logistic support and service. Plan and prepare the outside working space and concentrated point for rescue resource. Report the status of logistic works to commander.
  - c. Control center subdivision: keep wave-radio in working. Operate the mechanical-electrical, traffic control, broadcast system. Connect to rescue agencies and report proper rescue route to them in time.
- (2) Assist trapped and injured users
  - A. PLCC continuously broadcast to guide users to escape via connecting tunnel.
  - B. The operator in PLCC should pay attention to people are escaped or not when they are operating system.
  - C. The leader of scene rescue subdivision confirms the position and status of trapped people, fire status, etc. Then provides the relative information to EOC. In order to EOC ask for proper rescue equipment, vehicle and medical manpower entering incident scene to assist injured people.
  - D. Medical agency commands hospitals to active emergency medical project in order to provide medical resources and aid information.

## 7.Recovery

- (1) EOC commander confirms the incident and rescue works have finished, then notify the chief of scene operation division to prepare for evacuation.
- (2) The chief of scene operation division commands engineering office staffs to remove traffic control equipment, inspect traffic facility damage status, clear scattering things or obstacles on road.
- (3) All rescue agencies in scene have to check and count manpower and equipment if the incident is over. After reporting to chief of operation division, according to the command to evacuate staffs and remove control.
- (4) After all rescue agencies leaving, notify recovery agencies to enter the scene:
  - A. Incident cause investigation: notify relative investigators (police, fire, etc.) entering scene to investigate.
  - B. Towing work: notify the towing vehicles to tow the accident car to PLCC or Touchang Branch after the investigation is finished.
  - C. Tunnel structure inspection: Touchang Branch staffs clear the scene and company the structure experts to inspect the damage status.
  - D. Mechanical-electrical and traffic control facilities damage inspection: PLCC staffs inspect tunnel mechanical-electrical, fire, traffic control facilities status. Moreover, making an integrated evaluation with tunnel structure to make sure the tunnel is safe before re-open for traffic.
- (5) Evaluate the status of re-open for traffic and report to EOC. The EOC commander decides to re-open for traffic and report to higher-ups. And notify

the news media to announce the re-open news.

(6) EOC gather all the incident data in order to execute review works.

#### IV 、 Conclusion

No matter before or after opening for traffic, the issue of maintaining Hsuehshan Tunnel in safety always attracts attention from all people and groups. Therefore, all the participated agencies and staffs are devoted to the safety maintain works. Under their effort, the tunnel still keeps a good record of ‘zero death accident’ and the lowest accident rate section of freeway.

But we do not take this as satisfy. We continue to research how to improve or enhance the safety maintenance facilities. For example, the mechanical-electrical system examination research and the successive improving engineering, building an incident image detection system, plan of upgrading traffic control system to meet ITS require are all in schedule. On the other hand, the safety management measures are also continuous to execute and review. For example, referring to several rescue exercises and a few operating experience of fire incidents in tunnel, the rescue SOP had been modified to meet the real demand. We believe a safe Hsuehshan Tunnel will be continuously provided to users via our efforts.