

# Fire and Life Safety for Underground Facilities: Present Status of Fire and Life Safety Principles Related to Underground Facilities

ITA Working Group 4, "Subsurface Planning"  
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**Abstract** — This study on the present status of fire and life safety principles for underground facilities is based on contributions by eight member nations of the International Tunnelling Association: Australia, Canada, China, Germany, Italy, Japan, Sweden and the U.S.A. This document may serve as a tentative guideline for future development in this field. Findings are divided into three major category areas of underground works: road tunnels, railway tunnels, and underground parking facilities. Tables and explanatory information for each category are provided. © 1998 Elsevier Science Ltd. All rights reserved.

## 1. Foreword

**W**e all know that the advantages of locating a number of activities underground are many, not least from an environmental point of view: land can be saved for alternative usage, noise and pollution from traffic can be limited, disturbance to the surface during construction can be reduced, to mention a few.

From several investigations, we also know that many people may feel uncomfortable driving and dwelling underground. One reason, of course, is that lack of natural light decreases the ability of orientation in time and place. Another major reason for negative reactions toward traffic tunnels and underground space is the fear of accidents and fire in an enclosed area.

The concept of Fire and Life Safety in Underground Facilities has been on the agenda of ITA's Working Group No. 4, "Subsurface Planning," for many years. Several valuable contributions on the subject have been delivered and some have been published in the ITA journal *Tunnelling and Underground Space Technology* (see, e.g., Fermaud et al. 1997, Chow 1996, Carmody et al. 1994, and Meland and Lintorp 1994). The initiative to focus on aspects related to fire and life safety in underground facilities was taken by my predecessor, the American architect Michael Barker, who was the Animateur of this working group for several years.

It has been the ambition of WG4 to compile a report more specifically on existing regulations in member countries related to fire and safety in underground facilities — a task

that has not proved easy. It seems that we build a lot underground, but few countries have general rules for fire and life safety principles. However, we are herewith pleased to present to readers of *T&UST* a summary of a study based on the contributions of ITA member countries that are well-experienced in the utilization of the underground.

Eight countries — Australia, Canada, China, Germany, Italy, Japan, Sweden, and the U.S.A. — contributed to this study. The Working Group has accepted the contributions as a representation of major subsurface facilities worldwide, and welcomes further contributions on this topic from other countries that have technical information regarding fire and life safety for subsurface facilities.

It is our hope that this document will help guide countries that have no or limited safety regulations and that the report will contribute to the rational development of safety measures in underground facilities in the future.

At an early stage, the Japan Tunnelling Association offered to take on the responsibility to implement this important project, and it is therefore with great pleasure that the undersigned and our Tutor, Professor Sebastiano Pelizza, wish to thank not only those who completed the technical tables but also the administration and staff of the Japan Tunnelling Association on behalf of our Working Group.

— ANNICA NORDMARK, ANIMATEUR  
Working Group 4, Subsurface Planning

## 2. Background

At its meeting in April 1993, the ITA Working Group on Subsurface Planning accepted the offer of the Japan Tunnelling Association to collect technical data for the fire and life safety study. The JTA then organized a technical committee composed of experts in various areas of subsurface planning. The questionnaire was sent to ITA member

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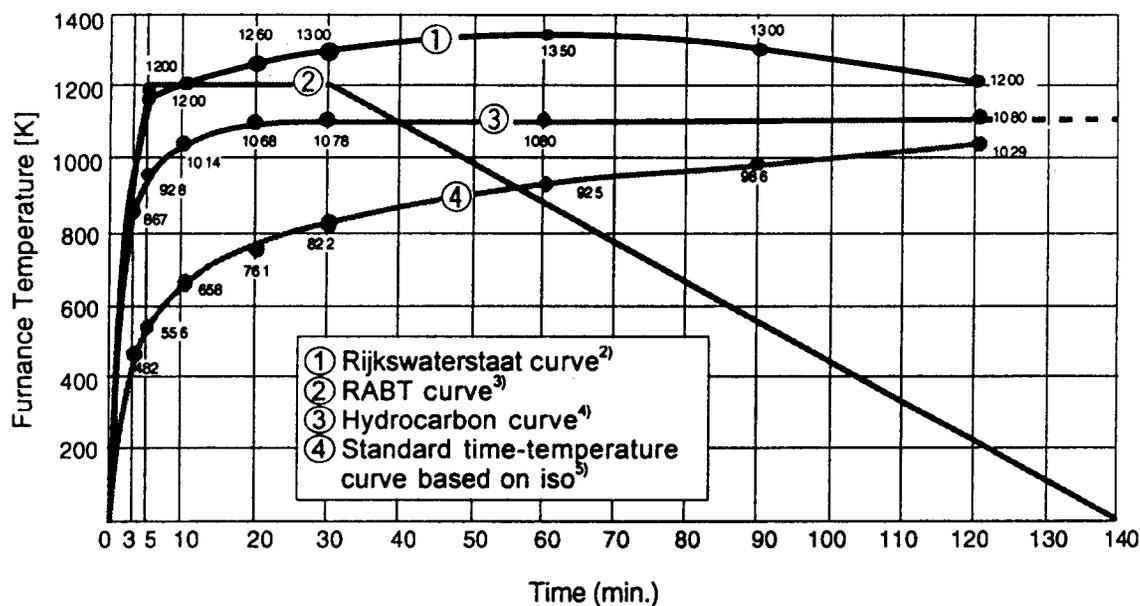


Figure 1. Time-temperature curve of several conditions.

countries, soliciting information that could be compiled and presented in the form of technical tables.

After the responses were received, the information was divided into three categories — Road Tunnels, Railway Tunnels, and Underground Parking Spaces — in terms of fire and life safety aspects. These tables are presented at the end of the written text of this report.

The committee also drew conclusions about the current status internationally of fire and life safety for these types of underground facilities, and some comments were expanded for the final report. Significant findings are presented separately for the three categories of subsurface facilities.

This abbreviated report is based on the final ITA Working Group report, "Fire and Life Safety for Underground Facilities: Present Status of Fire and Life Safety Principles Related to Underground Facilities" (ITA 1998), which was adopted by the ITA General Assembly at its meeting in São Paulo, Brazil, in April 1998. The summaries herein of road, rail, and subway tunnels and other underground facilities are extracted from the full report.

### 3. Road Tunnels

Seven countries — Australia, Canada, Germany, Italy, Japan, Sweden and the U.S.A. — submitted information for technical tables for road tunnels. The categories addressed in the technical tables deal with seven important aspects of fire and life safety:

- fire- and collapse-resistant structures incorporated in road tunnels;
- elimination of combustible materials in road tunnels;
- detection and alarms;
- compartmentalization;
- emergency systems (rescue, escape and refuge)
- fire and smoke control; and
- maintenance of safety systems.

Conclusions drawn from the responses from the various countries to each of these items are discussed below.

#### 3.1. Fire- and Collapse-Resistant Structures

The arrangement of the magnitude of fire (time-temperature curve) seems to be the most important criterion

for design and construction of fire- and collapse-resistant structures.

Figure 1 shows the time-temperature curve of several conditions for road tunnels. The appropriate heat generation ratio for each type of vehicle is:

- private cars ( 3–5 MW),
- vans (10 MW),
- goods vehicles or coaches / buses (20 MW),
- petrol tankers (50 MW) and
- large petrol tankers (100 MW).

Thus, if a tanker with 50 m<sup>3</sup> of petrol is completely burned, 300 MW of energy is released. Therefore, at the planning and design stage for tunnel safety, the appropriate heat generation ratio in case of fire will be 100–300 MW. This value is also related to the restriction condition for dangerous goods passage.

#### 3.2. Elimination of Combustibles

Noncombustible materials should be adopted for the structures of road tunnels. Major immersed tunnels in Europe and the U.S. are provided with fire-protection materials at ceilings and the upper part of the side walls. In some cases, cable ducts are also protected by fire-protection materials.

The installation of water sprinkler systems is still an outstanding problem. However, foam sprinkler systems are being installed in some road tunnels, e.g., in the U.S. and Japan.

#### 3.3. Detection and Alarms

Three countries provided standards for detection and alarm systems, but further information about standards is necessary. The responses indicated that safety systems that include an action plan for fire-fighting and rescue methods are essential.

Detection systems appear to have the highest priority in road tunnels. Fire (flame) detection systems entail some significant problems with regard to smoke detection and time delay of detection, etc.

Traffic sensors are useful in detecting unusual traffic conditions. Therefore, a traffic monitoring system could be utilized as a sensor for all kinds of other unusual occasions

(motorcades, parades, etc.), as well as for fire detection.

Temperature detection systems in the traffic space seem to be useful for fire detection, and video monitoring systems were reported as being very useful in recognizing accidents.

### 3.4. Compartmentalization

No outstanding problems with compartmentalization were reported by the respondents. [It should be noted that compartmentalization also concerns the layout of safety facilities such as emergency exits and routes.] Responses indicated that drainage systems are considered a very important means of preventing the spread of fire.

### 3.5. Emergency Systems — Rescue, Escape and Refuge

Some nations have guidelines for the arrangement of escape routes, and several nations have specified design standards for rescue and escape provisions.

Respondents noted that special considerations are necessary for disabled passengers in case of emergency. Others noted that designers may need to reach a compromise between cost and safety. Both of these issues should be examined in greater detail in future.

Specific aspects of emergency systems contributed by respondents include the following:

- Cross-passages connecting parallel road tunnels can be used for refuge.
- Recommended spacing between cross-passages ranges from 100 m to 700 m, depending on the traffic volume, the shape of tunnel structure and the tunnel length.
- Specialized evacuation spaces, such as cross-passages and service tunnels, are significant facilities for tunnel safety.
- The air pressure of the safety spaces for refuge and evacuation is controlled to be pressurized in relation to the fire space.

### 3.6. Fire and Smoke Control

The most significant recommendations of respondents concerning fire and smoke control measures are given below.

- Smoke control systems must be installed for long tunnels with high-volume traffic conditions and for tunnels where transport of dangerous goods is permitted.
- Numerical simulation modelling for fire and smoke dispersion must become an established part of the design process.
- At the fire space, the air pressure must be kept lower than the evacuation space.
- The condition for the magnitude of fire must be given.
- The heat release ratio for traffic tunnels must be considered for each type of vehicle (see data for time-temperature curve, in section 3.1, above).
- Figure 2 shows the relation between air velocity in tunnel space and heat release ratio. The air velocity in the vicinity of the fire point in case of fire must be controlled to be more than  $600 \text{ f} \cdot \text{p} \cdot \text{m}$  (3 m/s) for evacuation.

### 3.7. Maintenance of Safety Systems

Maintenance systems vary depending on each country, but it is clear that the maintenance systems and conditions influence the reliability of the safety systems. Research and development of maintenance-free equipments will be essential for advanced tunnel technology in terms of fire and life safety.

## 4. Railway/Subway Tunnels

Seven countries — Australia, Canada, China, Italy Japan, Sweden and the U.S.A. — submitted responses to the questionnaire on fire and life safety for railway/subway tunnels. As for road tunnels, the categories addressed in the technical tables for railway and subway tunnels deal with seven aspects of fire and life safety:

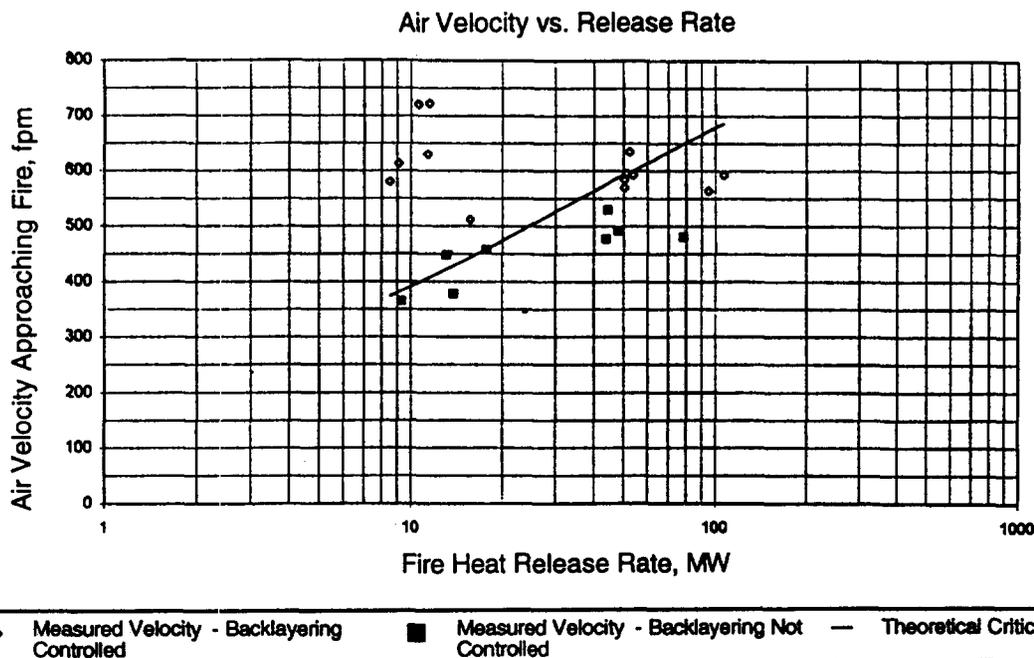


Figure 2. Comparison of measured air velocity with theoretical critical velocity.

- fire- and collapse-resistant structures incorporated in rail tunnels;
- elimination of combustible materials in rail tunnels;
- detection and alarms;
- compartmentalization;
- emergency systems (rescue, escape and refuge)
- fire and smoke control; and
- maintenance of safety systems.

Conclusions drawn from the responses from the various countries to each of these items are discussed below.

#### 4.1. Fire- and Collapse-Resistant Structures

The U.S.A. and European countries specify detailed regulations for fire- and collapse-resistant structures in rail and subway tunnels. In China and Japan there are no such special regulations; these countries follow standard building laws for construction.

#### 4.2. Elimination of Combustibles

In principle, noncombustible materials are used in each country, and countermeasures seem to be well-considered in most countries.

No major problems or outstanding research/development needs in this area were reported by respondents.

#### 4.3. Detection and Alarms

Detection and alarm requirements and methods vary considerably by country. For example, Canada cites very specific regulations for the types of alarm systems required for both basic and supplementary structures, whereas Japan notes no specific regulations applying to either rail or subway tunnels, and Australia follows standard building codes and fire department regulations.

As noted above for road tunnels, traffic control and operation systems can detect unusual traffic conditions; therefore, such systems could be utilized as a sensor for all kinds of unusual traffic situations (see section 3.3).

#### 4.4. Compartmentalization

In the case of fire, compartmentalization (e.g., fire walls and doors) must be considered for egress. Considerations include numbers, locations, and capacities of tunnels, and the required width of pathways for egress. In some countries, design is carried out case by case, based on instructions from the fire department.

#### 4.5. Emergency Systems — Rescue, Escape and Refuge

In Japan, Sweden and the U.S.A., internal regulations and standards stipulate in detail the escape routes and distance to the station exit or emergency exit. In other countries, the regulations follow instructions from the fire department. With regard to refuge, the air pressure of the safety space for evacuation must be controlled to be pressurized in relation to the fire space.

The Seikan Tunnel in Japan (53.9 km long) is provided with a 23.3-km-long service tunnel in its undersea section, connected with cross-passages. The spacing between cross-passages is between 600 m and 800 m.

The Channel Tunnel (51 km long) is also provided with a service tunnel between the running tunnels; the spacing between the cross-passages connecting the running and the service tunnels is 375 m.

#### 4.6. Fire and Smoke Control

No general regulations for basic tunnel structure were reported by respondents.

Some respondents noted that ventilation equipment at stations is designed in such a way that smoke extraction is also possible.

Respondents reported that in recent years, in general, noncombustible materials for rolling stock must be used. Furthermore, if appropriate, loaded goods must be considered fire-combustible materials.

#### 4.7. Maintenance of Safety Systems

Japan, Sweden, Canada, and the U.S.A. have standards for maintenance of safety systems. In general, the tunnel operator carries out inspections independently.

### 5. Underground Parking Spaces for Human Occupancy

Four countries — Italy, Japan, Sweden, and the U.S.A. — submitted information for the technical tables dealing with fire and life safety for underground parking spaces. Main conclusions for each category in the tables are given below.

#### 5.1. Fire and Collapse-Resistant Structures

In principle, fire-resistant structures are used in each country.

#### 5.2. Elimination of Combustibles

In Italy, the use of underground parking space is restricted to certain types of vehicles; and storage of flammable and explosive materials is prohibited in underground parking facilities.

#### 5.3. Detection and Alarms

Standards of fire detection and alarm systems are defined in relation to the floor area, or follow standards for underground building facilities (e.g., regulations pertaining to architectural standards).

#### 5.4. Compartmentalization

Fire-proof walls and doors are considered for preventing spread of fire in some countries in relation to number of cars or floor area.

#### 5.5. Emergency Systems — Rescue, Escape and Refuge

The provision of special staircases for evacuating people and refuge spaces for escape and rescue activities are stipulated by national standards that are similar. The facility grade differs considerably from country to country.

#### 5.6 Fire and Smoke Control

Provisional measures are taken into consideration for smoke control, with special smoke extractors in case of fire and smoke extraction handled by ordinary ventilation equipment.

### 6. Fire and Life Safety in Selected Subsurface Facilities in Japan

The JTA Subsurface Planning Committee also prepared similar technical tables for selected railroad tunnels and for unattended subsurface facilities in Japan. The unattended subsurface facilities include

- an underground power plant;
- sewerage equipment—treatment plant;
- sewerage equipment—connection tunnel to treatment plant;

- underground storage space (LPG);
- oil storage space in rock base; and
- an underground LNG tank.

Technical tables for these types of facilities are provided in the full report, which also includes descriptions of safety devices for different kinds of subsurface facilities.

### Acknowledgments

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<b>China</b>	X. Hou, Underground Space Center, Tong Ji University
<b>Germany</b>	A. Haack, STUVA
<b>Italy</b>	M. Clerico, Politecnico di Torino, Dipartimento di Georisorse e Territorio L. Mazziotti, Corpo Nazionale Vigili Del Fuoco
<b>Japan</b>	Y. Ota, Chiyoda Engineering Consultants Co., Ltd. H. Chikahisa, Tobishima Corp. T. Iida, Japan Railway Construction Public Corp. K. Iwai, Pacific Consultants Co., Ltd. S. Miyake, Teito Rapid Transit Authority Y. Yuasa, Mitsui Construction Co. Ltd.
<b>Sweden</b>	Arne Brodin, Scandiaconsult Safety, Engineering Swedish National Rail Administration Stockholm City Fire Department C. Ytterstene, Stockholm Road Administration
<b>U.S.A.</b>	R. Sterling (now at the Trenchless Technology Center, Louisiana Tech University)

The Animateur of ITA Working Group No. 4 wishes to encourage interested readers to obtain the full report directly from the ITA Secretariat in Bron, or from the national

group representative from their respective countries. (Editor's note: Addresses for the above are given in the ITA Pages of this issue of *T&UST*.)

### Footnotes

- 1) Ventilation of Road Tunnels Recommendation 1991, Ministry of Transport, Public Works and Water Management, Directorate - General for Public Works and Water Management, Civil Engineering Division.
- 2) Report concerning an investigation into the behaviour of a concrete slab protected by a coating of PROMATECT-H Plates of 25 mm in thickness upon heating according to a curve prescribed by the "Rijkswaterstaat" in the Netherlands. TNO Report B-85-191 (E), May 1985.
- 3) ZTV-TUNNEL, Zusätzliche Technische Vertragsbedingungen und Richtlinien für den Bau von Straßentunneln, Teil 1, Geschlossene Bauweise (Spritzbetonbauweise), August 1995.
- 4) Eurocode 1: Basis of Design and Actions on Structures, Part 2.2: Actions on Structures Exposed to Fire. Draft February 1993.
- 5) Testing Method in the Standard of ISO 834, BS 476: part 20 ~ 24: DIN 4102, part 1 to II.
- 6) "Fire Safety Concepts in Various Traffic Tunnels," STUVA, Germany, March 1994.
- 7) "Memorial Tunnel Fire Ventilation Test Program Test Report," Massachusetts Highway Department and Federal Highway Administration, November 1995.
- 8) J. K. Lemley, B. D. Brown, P. Vandebrouck, "The Channel Tunnel Cooperation in a Transfrontier Environment", International Symposium on Technology of Bored Tunnels Under Deep Waterways, Copenhagen, 3-5 November 1993.

### Additional References

- Carmody, J.; Huet, O.; and Sterling, R. 1994. Life safety in large underground buildings: principles and examples. *Tunnelling and Underground Space Technology* 9 (1), 19-30.
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- International Tunnelling Association. 1998. "Fire and Life Safety for Underground Facilities: Present Status of Fire and Life Safety Principles Related to Underground Facilities." Report of ITA Working Group 4, Subsurface Planning. Available from the ITA Secretariat, Bron, France.
- Meland, Ø. and Lintorp, S. 1994. Fire safety and escape strategies for a rock cavern stadium. *Tunnelling and Underground Space Technology* 9 (1), 31-36.

# **Categories and Hazard Prevention Functions in Road Tunnels**

**Responses Compiled from the following ITA Member Nations:**

**Australia**

**Canada**

**Germany**

**Italy**

**Japan**

**Sweden**

**U.S.A**

**Categories and Hazard Prevention Function in ROAD TUNNELS in Each Nation  
Special Items**

Nation	Special Items
Australia	NIL
Canada	Road tunnlling is based on the road structure regulation of the Ministry of Transportation of Ontario and is covered by the National Fire Protection guidelines and Building Standards Act.
Germany	Hazard prevention functions in road tunnels are determined by German "Additional Technical Contract Conditions and Guidelines for Construction of Road Tunnels (ZTV-Tunnel)" Part I, Draft 1994, and "Guidelines for Equipment and Operation of Road Tunnels " (RABT), new edition 1994.
Italy	Requirements are not codified with particular regulations; general safety laws and special technical codes must be fulfilled.
Japan	Road tunnelling is based on the Road Structure Regulations of the Ministry of Construction and is covered by the Fire Services Law and Building Standards Act. Under the provisions of Article 46 of the Road Law, it is possible to prevent or restrict the passage of vehicles carrying hazardous objects in tunnels longer than 5,000 meters, or in tunnels built along the water's edge and on the sea bottom.
Sweden	Road tunneling is based on Tunnel Regulations of Swedish Road Administration "Tunnel 95 (Publ. 1995:32) and Regulations for the planned Stockholm Rind Road.
USA	Requirements are not codified at a national level. Guidelines recommendations and design methodologies are given in FHWA Prevention and Control of Highway Tunnel Fires, 1984 Report No. FHWA/RD-83/032. 1991 ASHRAE Handbook HVAC Applications, Chapter 13 Enclosed Vehicular Facilities. NFPA 502 Fire Protection for Limited Access Highways, Tunnels, Bridges, Elevated Roadways and Air-Right Structures.

**Categories and Hazard Prevention Function in ROAD TUNNELS in Each Nation  
Fire and Collapse Resisting Structures**

Function Nation	Basic Structure	Supplementary Structure I	Supplementary Facilities II
	Summary	Basic Structure Related Summary	Mechanical and Electrical Equipment Related Summary
Australia	Codes of Practice and building regulations govern fire resistance of structural members.	Building and Fire Regulations.	
Canada	There are no particular regulations. Following building code standards.	There are no particular regulations.	Flammable materials are not utilized in modern construction practices.
Germany	Requirements according to ZTV-Tunnel.	Requirements according to ZTV-Tunnel.	Requirements according to RABT, in dependence on tunnel length.
Italy	No special regulations.	No special regulations.	All equipments and facilities must fulfill the corresponding dedicated special codes when existing.
Japan	There are no particular regulations.	There are no particular regulations.	
Sweden	2 h resistance according to the HC curve without cooling phase.	1 h resistance according to the ISO-curve.	
USA		Drainage requirements for fire fighting water.	
Remarks	The arrangement of magnitude of fire (time-temperature curve) seems to be the most important criteria for designs and constructions of fire and collapse structures.		

**Categories and Hazard Prevention Function in ROAD TUNNELS in Each Nation  
Fire and Collapse Resisting Structures - cont'd**

Function Nation	Problems and Outstanding Items		Miscellaneous
	Basic Structure and Supplementary Equipment I	Supplementary Equipment II	
Australia	None in particular.		
Canada	None in particular.	None in particular.	Environment factors have considerable influence upon design criteria for the construction and final use of the tunnel system. A majority of the criteria must be established in advance of final design so that they may be integrated into the overall system. These factors appear to have a relatively minor influence upon the direct construction cost and is considered secondary to such problems as route location and ground type. Standards set and used by various governmental bodies. (MNR, EUO, FPA, etc.).
Germany			
Italy			
Japan	In the case of reinforced concrete structures built using the submerged tunneling or cut and cover tunnelling methods in particular, a reorganization of concepts related to the protection of structures during a fire.		Problems concerning the extremely long road tunnels found in Japan, under the provision so Article 46 of the Road Law, it is possible to prevent or restrict the passage of vehicles carrying hazardous objects in tunnels longer than 5,000 meters, or in tunnels built along the water's edge and on the sea bottom. Present tunnel disaster prevention equipment, however, is almost all intended to deal only with tunnel fires. Furthermore, the hypothetical fires that are expected to occur are small scale fires, and measures to deal with accidents involving vehicles carrying hazardous materials covered by these traffic restrictions are insufficient.
Sweden			Basic safety stands for transports without hazardous materials. A road traffic control center will be established and supervised traffic and technical installations.
USA	Tunnel fire testing underway in Memorial Tunnel, West Virginia.		
Remarks			

**Categories and Hazard Prevention Function in ROAD TUNNELS in Each Nation  
Elimination of Combustibles**

Function Nation	Basic Structure	Supplementary Structure I	Supplementary Facilities II
	Summary	Basic Structure Related Summary	Mechanical and Electrical Equipment Related Summary
Australia	No regulations.	No regulations	No regulations.
Canada	There are not particular regulations. Non-combustible materials approved by Contract Administration and the Approved Equipment Standards List.	There are no particular regulations. Manuals must be approved.	There are no particular regulations.
Germany	Requirements according to ZTV-Tunnel.	Requirements according to ZTV-Tunnel.	Requirements according to RABT.
Italy	No special regulations, but in principle, non-combustible materials approved.	No special regulations, but in principle, non-combustible materials approved.	
Japan	There are no particular regulations. In principle, non-combustible materials approved by the Ministry of Construction are used.	There are no particular regulations. In principle, non-combustible materials approved by the Ministry of Construction are used.	There are no particular regulations.
Sweden	In principle non-combustible materials in traffic areas.	1 h fire resistance vital safety functions.	Explosive, Compressed gas and Gasoline must be escorted.
USA		May be controls on passage of flammable liquid and gases and, in some cases combustibles.	
Remarks	<p>Non-combustible materials should be adopted to the structures.</p> <p>Major immersed tunnels in Europe and the United States are provided with fire protection materials at ceilings and upper part of side walls. In some cases, cable ducts are also protected by fire protection materials.</p> <p>The installation of water sprinkler systems is still an outstanding problem. However, foam sprinkler systems are installed in some road tunnels in the United States and Japan.</p>		

**Categories and Hazard Prevention Function in ROAD TUNNELS in Each Nation  
Elimination of Combustibles - cont'd**

Function Nation	Problems and Outstanding Items		Miscellaneous
	Basic Structure and Supplementary Equipment I	Supplementary Equipment II	
Australia	None in particular.	None in particular.	
Canada	None in particular.	None in particular.	
Germany			
Italy			
Japan	None in particular.	Improvement of the heat resistance properties of machinery installed inside tunnels. There are no particular regulations governing heat resistance at this time.	
Sweden	Sprinklers can be an alternative to escort.		
USA			
Remarks			

**Categories and Hazard Prevention Function in ROAD TUNNELS in Each Nation  
Detection and Alarms**

Function Nation	Basic Structure Summary	Supplementary Structure I Basic Structure Related Summary	Supplementary Facilities II Mechanical and Electrical Equipment Related Summary
Australia	Building Regulations and Fire Department will govern.	Building Regulations and Fire Department will govern.	Australian Standard Specifications and Codes.
Canada	There are no particular regulations.	There are no particular regulations. This is handled individually for each tunnel.	Battery power supplied as a power source for emergency lighting and alarms as backup. Or a diesel generation and turbine generation set.
Germany			Automatic fire detection and alarm as well as manual alarm in road tunnels longer than 350m.
Italy	No special regulations.	No special regulations.	
Japan	There are no particular regulations.	There are no particular regulations. This is handled individually for each tunnel.	Facilities required in tunnels are prescribed for each grade of tunnel. With this system, the provision of information about the approach zones as well as the tunnel zone is included.
Sweden	3 MW-fire must be detected within 1 min.		
USA		Manual alarms recommended at intervals of not more than 90m.	
Remarks	<p>Three countries provide standards. Further information is necessary.            Safety systems with action plan of fire fight and rescue seem necessary.            Detection systems have the highest priority in road tunnels.            Fire (Flame) detection systems entail some outstanding problems in regard to smoke detection and time delay of detection, etc.</p>		

**Categories and Hazard Prevention Function in ROAD TUNNELS in Each Nation  
Detection and Alarms - cont'd**

Function Nation	Problems and Outstanding Items		Miscellaneous
	Basic Structure and Supplementary Equipment I	Supplementary Equipment II	
Australia	None in particular.	None in Particular.	
Canada	Care taken in design of entrance, passages, vent shafts and public utilities around the underground structure. Communication system utilization.	Water, light, heat (temperature) detection system.	
Germany			
Italy			
Japan	Establishment of a communication system to link the road management personnel with victims of disaster who are in the evacuation routes and refuge areas.	Development of a practical temperature detection system using optical fiber cables.	
Sweden	Establishment of alarm telephone systems.	Temperature detection will be combined with ITV.	
USA			
Remarks	Traffic sensors could detect unusual traffic conditions. Therefore, traffic monitoring system could be utilized as a sensor for all kinds of unusual occasion. Temperature detection systems in the traffic space seem to be useful for fire detection. Video monitoring systems are also very useful to recognize accidents.		

**Categories and Hazard Prevention Function in ROAD TUNNELS in Each Nation  
Compartmentalization**

Function Nation	Basic Structure Summary	Supplementary Structure I Basic Structure Related Summary	Supplementary Facilities II Mechanical and Electrical Equipment Related Summary
	Australia	No particular regulations.	No particular regulations but Fire Department will govern.
Canada	There are no particular regulations. Emergency stairs should be provided for the public.	Considered that the distance from any point in the tunnel to an exit should not exceed 1500 ft.	There are no particular regulations concerning overall system.
Germany			
Italy	No special regulations.	No special regulations.	
Japan	There are no particular regulations.	These are categorized at five levels from grade AA to grade D based upon the volume of traffic and tunnel length. Tunnels of grade A or higher frequently include emergency exits, evacuation routes, etc.	There are no particular regulations governing overall system. In many cases, water sprinkler equipment is installed with one outlet in every 50 meter section. In other cases, these sections are also established for communication equipment such as emergency radio rebroadcast equipment.
Sweden	Main tunnels, Escape routes and Service areas are each one cell.		UPS 60 min. safety related equipment.
USA			
Remarks	No outstanding problems in countries concerned. It concerns also the lay out of safety facilities such as emergency exits and routes. The drainage systems seem to be a very important facility for the prevention of fire spread.		

**Categories and Hazard Prevention Function in ROAD TUNNELS in Each Nation  
Compartmentalization - cont'd**

Function Nation	Problems and Outstanding Items		Miscellaneous
	Basic Structure and Supplementary Equipment I	Supplementary Equipment II	
Australia	None in particular.	None in particular.	
Canada	Proper drainage system, Low points, pumping stations are required if there is seepage. Sufficient pumping capacity.	None in particular.	
Germany			
Italy			
Japan	The establishment of hazard prevention sections (geometric structure) and water drainage system to restrict the dissemination of flammable liquids spilled on the road surface.	Non in particular.	
Sweden	Drainage systems are designed for max. 250 m <sup>2</sup> spillage and capacity 80 l/s.		
USA	Acceptable configurations/trade-offs among: separate escape tunnels, refuge areas, double tunnels, single tunnels vs. length of tunnel, etc.		
Remarks			

**Categories and Hazard Prevention Function in ROAD TUNNELS in Each Nation  
Emergency System-Rescue, Escape and Refuge**

Function Nation	Basic Structure	Supplementary Structure I	Supplementary Facilities II
	Summary	Basic Structure Related Summary	Mechanical and Electrical Equipment Related Summary
Australia	No particular regulations.	No particular regulations but Fire Department will govern.	No regulations.
Canada	There are no particular regulations.	Consultation with concerned bodies ( Fire Department, Police, etc.) Problem of egress from vehicle, storage of disabled vehicles.	Standards according to building codes and through construction with fire department and police. Adequate access to distressed areas and implementation of safety program run by maintenance personnel.
Germany	Requirements according to RABT.	Requirements according to RABT.	Requirements according to RABT.
Italy	No special regulations.	No special regulations, but a final decision is made through consultations with concerned bodies.	
Japan	There are no particular regulations.	After completion of construction of the basic system within the scope of related regulations, a final decision is made through consultations with concerned bodies (fire department, police, etc.)	After the hazard prevention system has been constructed, final decisions are made concerning the relationship of the ventilation method and the smoke control system and of the ventilation method and the state of the emergency doors, through consultations with concerned bodies. The public fire department and the police separately prepare rescue activity manuals.
Sweden	100 - 150 m between escape routes.	Adaptation to disabled persons.	At gradients over 8 %, special rooms are established for disabled persons.
USA		Fire emergency plans. Traffic control system to clear traffic.	Specialized vehicles for use in tunnel emergencies. Sprinklers not to be automatically activated. Portable extinguishers of at least 9 kg capacity both sides of roadway at least 90 m intervals.
Remarks	Some nations have guidelines for the arrangement of escape route. Several nations have arranged design standards. Special considerations are necessary for disabled passengers in case of emergency. Compromise between cost and safety? Cross passages connecting parallel road tunnels can be used for refuge.		

**Categories and Hazard Prevention Function in ROAD TUNNELS in Each Nation  
Emergency System-Rescue, Escape and Refuge - cont'd**

Function Nation	Problems and Outstanding Items		Miscellaneous
	Basic Structure and Supplementary Equipment I	Supplementary Equipment II	
Australia	None in particular.	None in particular.	
Canada	Establishment of refuge space and rescue systems. This matter is handled on an individual basis.	Walkways, adequate lighting and protection from electrical hazards. Emergency stairs to surface.	
Germany			
Italy			
Japan	Establishment of refuge space and rescue systems in the case of extremely deep tunnels and double decked subsurface structures. This matter is now handled differently for each tunnel.	Establishment of basic plans for the integrated operation of all kinds of supplementary equipment installed in subsurface refuge spaces.	
Sweden			
USA	Cost/benefit/drawbacks of shoulder areas in tunnels. Questionable benefits from sprinklers in tunnel fires.		
Remarks	<p>The spacing between cross passages is between 100m and 700m, depending on the traffic volume, the shape of tunnel structure and the tunnel length <sup>1</sup></p> <p>Specialized evacuation spaces, such as cross passages and service tunnels are significant facilities for tunnel safety.</p> <p>The air pressure of the safety space for refuge and evacuation is controlled to be pressurized in comparison to the fire space.</p>		

<sup>1</sup> Fire Safety Concepts in Various Traffic Tunnels, STUVA, Germany, March 1994.

**Categories and Hazard Prevention Function in ROAD TUNNELS in Each Nation  
Fire and Smoke Control**

Function Nation	Basic Structure	Supplementary Structure I	Supplementary Facilities II
	Summary	Basic Structure Related Summary	Mechanical and Electrical Equipment Related Summary
Australia	No particular regulations.	No particular regulations but Fire Department will govern.	No regulations.
Canada	There are no regulations. Ventilation, the control of temperature, humidity, noise, vibration and light.	Provision for adequate water supply as per NFP guidelines. Protection of exhaust fans. Ventilation systems and heat control.	All tunnels must be proved with a means of emergency ventilation to be an effective smoke control system.
Germany	Requirements according to RABT.	Requirements according to RABT.	Mechanical ventilation with special fire and smoke control in road tunnels longer than 400m (two-way-traffic) respectively 700m (one-way-traffic).
Italy	No special regulations.	No special regulations, but ventilation equipment is used.	
Japan	There are no particular regulations.	There are no particular regulations, but ventilation equipment is used to keep smoke and fire out of the refuge areas.	In tunnels with mechanical ventilation equipment, a smoke control pattern is established such that within the range of the ventilation capacity at normal times, it functions as an effective smoke control systems.
Sweden	Longitudinal ventilation 3m/s. Designed for 100MW fire.	Fire and smoke shall be kept downstream.	Entrance ramps will partly be sprinkled to support the smoke control system.
USA			Fire apparatus should be equipped to deliver foam at 757 L/min for 30 minutes. Minimum water supply 1900L/min at 420kPa at any point in tunnel minimum availability for one hour.
Remarks	<p>The smoke control system must be installed for long tunnels with high volume traffic conditions and permissible tunnels for dangerous good transport.</p> <p>At the fire space, the air pressure must be kept lower than the evacuation space.</p> <p>Condition for the of magnitude of fire must be given.</p> <p>Numerical simulation modeling for fire and smoke dispersion must be established.</p>		

**Categories and Hazard Prevention Function in ROAD TUNNELS in Each Nation  
Fire and Smoke Control - cont'd**

Function Nation	Problems and Outstanding Items		Miscellaneous
	Basic Structure and Supplementary Equipment I	Supplementary Equipment II	
Australia	None in particular.	None in particular.	
Canada	Interacting surveillance and communication systems such as telephones, radio, and closed circuit television.	Consultation with private sector. Transfer of knowledge for improvements in technology.	
Germany			
Italy			
Japan		Improvement of technology to simulate the smoke dispersion during fire, and improvement for heat resistance of ventilators.	
Sweden	3-D CFD calculations for dimensioning.	Fire alarm will automatically start traffic, safety and smoke control systems.	
USA	Tunnel fire simulation.		
Remarks	The heat release ration for traffic tunnels is considered for each vehicles are private cars (3-3.5 MW), vans (10MW), goods vehicles or coaches/buses (20MW), petrol tankers (50MW) and large petrol tankers (100MW). If a tanker with 50m <sup>3</sup> of petrol is completely burnt. 300MW of energy is released. Therefore, at the planning and design stage for tunnel safety, the appropriate heat generation ratio in case of fire will be 100 - 300MW.		

**Categories and Hazard Prevention Function in ROAD TUNNELS in Each Nation  
Maintenance of Safety System**

Function Nation	Basic Structure	Supplementary Structure I	Supplementary Facilities II
	Summary	Basic Structure Related Summary	Mechanical and Electrical Equipment Related Summary
Australia	No particular regulations.	No particular regulations but Fire Department will govern.	No regulations.
Canada	Tunnels are handled the same way as other structures. No particular regulations.	Staff must have access to the tunnel for maintenance purposes. Provision made for their movement under safe conditions.	Maintenance inspection manuals for each piece of equipment provided through manufacturer and by maintenance personnel.
Germany			Regulations according to RABT.
Italy	No special regulations.	No special regulations.	
Japan	There are no particular regulations. Tunnels are handled the same way as other structures.	There are no particular regulations. Tunnels are handled the same way as other structures.	The road management personnel prepare maintenance inspection manuals for each piece of equipment.
Sweden	Manuals for each piece of equipment.		
USA		Regular maintenance and testing.	
Remarks	Maintenance systems vary depending on each country. The maintenance systems and conditions are of influence to the reliability of the safety systems. Research and development of maintenance free equipments are required as for an advanced tunnel technology.		

**Categories and Hazard Prevention Function in ROAD TUNNELS in Each Nation  
Maintenance of Safety Systems - cont'd**

Function Nation	Problems and Outstanding Items		Miscellaneous
	Basic Structure and Supplementary Equipment I	Supplementary Equipment II	
Australia	None in particular	None in particular.	
Canada	It may not practical to allow access for maintenance under operating conditions.	Development of maintenance free equipment.	
Germany			
Italy			
Japan	None in particular.	Development of maintenance free equipment.	
Sweden			
USA			
Remarks			

# **Categories and Hazard Prevention Functions in Railway Tunnels**

**Responses Compiled from the following ITA Member Nations:**

**Australia**

**Canada**

**China**

**Italy**

**Japan**

**Sweden**

**U.S.A**

**Categories and Hazard Prevention Functions in RAILWAY TUNNELS in Each Nation  
Special Items**

Nation	Special Items		
Australia	NIL		
China Subway	Subway station is based on the Design Standards of Subway by Ministry of Construction		
Canada	<p>A number of relevant codes, regulations and municipal by-laws govern the design for underground stations. <u>These regulations do not cover tunnels in general tunnels are designed with the same standards where they apply.</u> TTC design manual also sets out design standards. Also driving the functional requirement for fire and life safety in underground facilities in TTC's emergency procedures.</p> <table border="0" data-bbox="349 585 1378 830"> <tr> <td data-bbox="349 585 827 739"> <b>TTC DESIGN STANDARDS:</b>  DM - 0102 (Fire Life Safety)  DM - 0601 (Ventilation)  DM - 0701 (Auxiliary Electrical Systems)  DM - 0803 (Communications) </td> <td data-bbox="827 585 1378 830"> <b>TTC EMERGENCY PROCEDURE DOCUMENTS:</b>  Emergency Plan Guidelines  Subway / SRT Rule Book  TTC Corporate Policy Manual  Subway Ventilation / Emergency Evacuation/Standard Operating Procedures  TTC System Safety Programme Plan </td> </tr> </table>	<b>TTC DESIGN STANDARDS:</b> DM - 0102 (Fire Life Safety) DM - 0601 (Ventilation) DM - 0701 (Auxiliary Electrical Systems) DM - 0803 (Communications)	<b>TTC EMERGENCY PROCEDURE DOCUMENTS:</b> Emergency Plan Guidelines Subway / SRT Rule Book TTC Corporate Policy Manual Subway Ventilation / Emergency Evacuation/Standard Operating Procedures TTC System Safety Programme Plan
<b>TTC DESIGN STANDARDS:</b> DM - 0102 (Fire Life Safety) DM - 0601 (Ventilation) DM - 0701 (Auxiliary Electrical Systems) DM - 0803 (Communications)	<b>TTC EMERGENCY PROCEDURE DOCUMENTS:</b> Emergency Plan Guidelines Subway / SRT Rule Book TTC Corporate Policy Manual Subway Ventilation / Emergency Evacuation/Standard Operating Procedures TTC System Safety Programme Plan		
Italy	Railways are not object of the national regulations (D.P.R. 11-7-80, n. 753, art. 95), but special technical codes must be always fulfilled in particular, subway requirements are codified with special law D.M. 11-1-88 (see table about subways)		
Italy subway	<ul style="list-style-type: none"> <li>• The Italian regulation available for the new subways, is the Decree of Italian MINISTERO DEI TRANSPORT of 11/1/88 (D.M. 11/1/88).</li> <li>• This Decree was elaborated what with the opinions and the advice of C. C. T. S. for Fire Prevention of the Ministero Interno (Fire Italian Technical Committee depending of the Ministero Interno and called COMITATO CENTRALE TECNICO-SCIENTIFICO).</li> <li>• We have also to clarify that for the workshops, warehouses and all type of buildings annexed to the principal activity (subway), if these specific activities are comprised in the list contained in the decree of the Italian Ministry of the Interior 16. 02. 82 (published in the Italian Official Journal n. 98 of 9. 4. 82.), other specific fire prevention regulations are also available in Italy.</li> <li>• For example specific activities can be thermal stations with power more than 30,000 Kcal/h, generating sets installed and so on.</li> <li>• If the I. T. A. is interested to these specific regulations we are disposed to enclosed them in a second time.</li> <li>• We also believe that is not possible to put into the "annex table of functional categories and hazard prevention functions" about subways, all the fire prevention measures foreseen by the D. M. 11. 1. 88.</li> <li>• For that suggest to read the whole text of this regulation that we now enclose.</li> </ul>		
Japan	Rail tunnels are regulated by the Ministry of Transport (construction regulations for standard rail road, Shinkansen rail road and special rail road). The transportation of hazardous goods are restricted by the order of the Ministry of Transport (Explosions Transportation Act).		
Japan Subway	The Building Standard Law states "Facilities which are provided within the site of a railway or tramway for the operation and maintenance are exempt from the provisions of this Law". Article 2 of this Law also states that subway facilities fall under this category. The categorization of fire prevention object in a station under the Fire Service Law is handled as stipulated under 'Station'.		
Sweden			
USA	Safety regulations generally follow NFPA - 130 (1990) a model code for the design of life safety systems for fixed guideway transit systems.		

**Categories and Hazard Prevention Functions in RAILWAY TUNNELS in Each Nation  
Fire and Collapse Resisting Structures**

Function Nation	Basic Structure Summary	Supplementary Structure I Basic Structure Related Summary	Supplementary Facilities II Mechanical and Electrical Equipment Related Summary
	Australia	Codes of Practice and building regulations govern fire resistance of structural members.	Building and Fire Regulations.
Canada	Ontario Building Code (OBC) section 3.12 Rapid Transit Stations. Ontario Fire Code (OFC). Occupational Health And Safety Act (Reg. 692). Municipal by-laws.	Refer to Basic Structure. Fire separations for roof and floor assemblies and various service rooms and ancillary spaces.	Canadian Standards Association (CSA) CAN 4-S101-M "Standard Methods of Fire Endurance Tests of Building Construction and Materials". Ontario Electrical Code (Reg. 0/91). Facility Wiring - DM-0701. Auxiliary Electrical Systems Traction Power - DM-0804.
China Subway	There are no particular regulations.	The resisting capacity of wall and floor cannot be lower than 3 h and 2 h.	
Italy	No special regulations.	No special regulations.	All equipments must fulfill the corresponding dedicated special codes when existing.
Italy Subway	Fire Resistance at structures REI 120, both stations and tunnels (p. 4.4 and 5.2).	Fire resistance of structures must be at least REI 120 (p.4.4).	Fire resistance of structures that contain technical installations REI 90 with doors REI 60 (p. 4.4.5).
Japan	No special regulations.	No special regulations.	
Japan Subway	There are no particular regulations.	There are no particular regulations.	
Sweden	Special design for each new object.	Special design for each new object.	Special design for each new object.
USA	Non-combustible Type I or II construction as defined in NFPA 220.		
Remarks	Detailed regulations in Europe and USA. No special regulations in China and Japan, but follow Architectural Standard Law.		

**Categories and Hazard Prevention Functions in RAILWAY TUNNELS in Each Nation  
Fire and Collapse Resisting Structures - cont'd**

Function Nation	Problems and Outstanding		Miscellaneous
	Basic Structure and Supplementary Equipment I	Supplementary Equipment II	
Australia	None in particular.		
Canada	No particular regulation or code for tunnels. Design on a case by case basis and in accordance to design manual and best engineering practice for underground structures.	Same for I.	Fire and life safety criteria for designs and constructions, other than those specified by Acts, Codes, Regulations and Standards, are generally formulated by consultations with concerned bodies such as Fire Department, Police, Ministry of Labor, environment etc., together with a team of experts. Many capital projects relating to fire and life safety are in place to keep facility in state of good repair and to comply with legislation.
China Subway	Improvement of technology to recover basic structure after fire disaster.		In China, the construction of subway just begin, so this table only includes some existing related laws and regulations, some studies on hazard prevention, and safety are just doing.
Italy			
Italy Subway	Which is the real curve time-temperature for the calculation of fire resistance of structures? (ISO 834, RABT Hydrocarbon curve?) In Italy we use an Italian curve.		Supplementary structures contained in D.M. 11/1/88 are (for the stations): a) Routes of evacuations; b) Protected areas; c) Stairs in the stations.
Japan			In Japan, measurements for long rail tunnels are basically for the train itself, and not for ground structures. As for the Seikan Tunnel, since it is an underwater tunnel several special facilities are provided (detector, fire extinguishers, escape routes, communication). Difficulties: To make the trains fire proof and fire resistant and to lay down fire prevention regulations.
Japan Subway	There are no particular regulations.	There are no particular regulations.	
Sweden			Specified rules are in demand in all the described areas, and involved authorities are discussing problems and possible solutions, but progress is slow.
USA	Impact of fire on tunnel/rock cavern stability.		
Remarks			

**Categories and Hazard Prevention Functions in RAILWAY TUNNELS in Each Nation  
Elimination of Combustibles**

Function Nation	Basic Structure	Supplementary Structure I	Supplementary Facilities II
	Summary	Basic Structure Related Summary	Mechanical and Electrical Equipment Related Summary
Australia	No regulations.	No regulations	No regulations.
Canada	Ontario Building Code (OBC) section 3.12 Rapid Transit Stations. Ontario Fire Code (OFC). Occupational Health And Safety Act (Reg. 692). Municipal by-laws. Non-combustible construction. Material specified with fire resistance rating. Also National Fire Prevention Association (NFPA) and Underwriter's Laboratories of Canada Standards (ULCS).	Refer to Basic Structure. Fire resistance of specified fire ratings. NFPA 80: "Fire Doors and Windows"	Fire protection methods (See Table 1 of DM-0102-02 of Appendix 1.)
China Subway	The material such as plastic cannot be used.	Combustible materials cannot be used.	There are no particular regulations.
Italy	No special regulations.	No special regulations.	
Italy Subway	Reaction to fire of materials (classes of reaction to fire determined according to the D.M.I. 26.06.84) in all the underground spaces.	Requirement of reaction to fire of building materials as before for the basic structure.	Electrical cable installed in prefabricated race ways of fire-proofing material (p. 6.3) or in a structural underground passage resisting to fire (p. 6.3)/-Reaction to fire of the holder of lighting installation (p.6.3.1)
Japan	No special regulations.	No special regulations.	No special regulations. ----- Smoke exhaust devices must be able to operate under 200°C heat conditions for at least are one hour (Seikan Tunnel).
Japan Subway	There are no particular regulations.	In principle, underground structure are to be made non-combustible.	Interior finish, including the underlying wall, are to be made from non combustible material.
Sweden	Special design for each new object.	Special design for each new object.	Special design for each new object.
USA	Structures - Non-combustible Type I or II	Vehicles - Requirements for analysis/testing of materials/assemblies (assess smoke emissions, ease of ignition, rate of heat and smoke release).	
Remarks	In principle, non combustible materials used in each country. Counterplan seems to be well considered in most countries. No problems or outstanding items.		

**Categories and Hazard Prevention Functions in RAILWAY TUNNELS in Each Nation  
Elimination of Combustibles - cont'd**

Function Nation	Problems and Outstanding Items		Miscellaneous
	Basic Structure and Supplementary Equipment I	Supplementary Equipment II	
Australia	None in particular.	None in particular.	
Canada	No particular regulation or code for tunnels. Design on a case by case basis and in accordance to design manual and best engineering practice for underground structures.	Same for 1	Fire and life safety criteria for designs and constructions, other than those specified by Acts, Codes, Regulations and Standards, are generally formulated by consultations with concerned bodies such as Fire Department, Police, Ministry of Labor, environment etc., together with a team of experts. Many capital projects relating to fire and life safety are in place to keep facility in state of good repair and to comply with legislation.
China Subway	None in particular.		
Italy			
Italy Subway			Supplementary structures contained in D. M. 11/1/88 are (for the stations): a) Routes of evacuations; b) Protected areas; c) Stairs in the stations.
Japan		It is necessary to do investigation to improve the cable least resistance.	
Japan Subway	There are no particular regulations.	There are no particular regulations.	
Sweden			
USA	Needs for low combustibility can conflict with desire for comfortable, attractive spaces.		
Remarks			

**Categories and Hazard Prevention Functions in RAILWAY TUNNELS in Each Nation  
Detection and Alarm**

Function Nation	Basic Structure	Supplementary Structure I	Supplementary Facilities II
	Summary	Basic Structure Related Summary	Mechanical and Electrical Equipment Related Summary
Australia	Building Regulations and Fire Department will govern.	Building Regulations and Fire Department will govern.	Australian Standard Specifications and Codes.
Canada	Central alarm and control facility at each transit station consisting of station trouble alarm, station supervisory alarm, and station fire alarm. Fire detectors installed in service rooms and ancillary spaces. Public phone system connected to '911' emergency number.	Emergency alarm stations (EAS) indicated by blue light with TTC telephone and Emergency trip switch (ETS) located at FFA, cross passages, station platform ends, and about every 152m and emergency egress points.	Annunciators - NFPA 20. Fire protection system consists of station standpipe systems, sprinkler systems, fire department connections, fire extinguishers, fire alarm systems and fire protection.
China Subway	No particular regulations but there must have detection and alarms.	No particular regulations but there must have detection and alarms.	Equipment should be controlled by two ways: automatic and manual.
Italy	No special regulations.	No special regulations.	
Italy Subway	Automatic fire detector systems (p. 6.2.2)	Alarm systems must be disposed in a space of the station manned by the personnel of services (p.6.2.2) Alarms by speaker phones in all the rooms with people (p. 6.2.3)	Automatic fire detectors in the local containing technical installation and along the moving stairs of the stations (p.6.2.2)
Japan	No special regulations.	No special regulations.	No special regulations. Tunnels longer than 5 km are provided with lights, telephones, fire fight hydrants and equipment and signs showing the distance to the exit. In several long tunnels there are detectors for trains standing still with fire trouble. ----- Inside and outside the Seikan Tunnel there are train fire detectors and there is a connection to the ATC train operation system.
Japan Subway	There are no particular regulations.	There are no particular regulations.	Facilities in station areas • Warning equipment: Automatic Fire Detectors. • Information equipment : communications and broadcasting equipment, wireless supplementary antenna equipment. Equipment installed between stations (tunnels) communication equipment (trains and tunnels <--> operation command center).
Sweden	Special design for each new object.	Special design for each new object.	Special design for each new object.
USA	Detection and alarms required in all ancillary space.		Heat and smoke detectors required at traction power substations.
Remarks	No special regulations for basic structures. For supplementary facilities, their provision is conformed to corresponding regulations.		

**Categories and Hazard Prevention Functions in RAILWAY TUNNELS in Each Nation  
Detection and Alarm - cont'd**

Function Nation	Problems and Outstanding Items		Miscellaneous
	Basic Structure and Supplementary Equipment I	Supplementary Equipment II	
Australia	None in particular.	None in Particular.	
Canada	Fire alarm monitoring being upgraded.	Same for I	Fire and life safety criteria for designs and constructions, other than those specified by Acts, Codes, Regulations and Standards, are generally formulated by consultations with concerned bodies such as Fire Department, Police, Ministry of Labor, environment etc., together with a team of experts.  Many capital projects relating to fire and life safety are in place to keep facility in state of good repair and to comply with legislation.
China Subway		Development of significant signal for leading people to the rescue place.	
Italy			
Italy Subway	Especially the problems of detection is a new problem for the underground spaces. Perhaps we have to study in depth this question, taking into account of the particular environment.		Routes of evacuation and exits in general are dimensioned taking into account of the ebb capacity (p. 4.2).
Japan			
Japan Subway	There are no particular regulations.	infrared detectors are recommended to installed to detect overheated cars.	Automatic fire alarm equipment must be installed outside of platform, concourses, passageways and shops.
Sweden			
USA	Initiation and speed of evacuation relative to information provided to occupants.  Would visual message board clarify evacuation alarms?		
Remarks	Traffic Control and Operation System could detect unusual traffic conditions. Therefore, the system could be utilized as a sensor for all kinds of unusual occasion.		

**Categories and Hazard Prevention Functions in RAILWAY TUNNELS in Each Nation  
Compartmentalization**

Function Nation	Basic Structure	Supplementary Structure I	Supplementary Facilities II
	Summary	Basic Structure Related Summary	Mechanical and Electrical Equipment Related Summary
Australia	No particular regulations.	No particular regulations but Fire Department will govern.	No regulations.
Canada	Means of egress designed for occupant loads. Considerations include number, location, capacity, and width of paths.	Emergency service buildings (ESBs) which are additional ventilation fan sites.	Central alarm and control facility (CACF) at each transit station to function as a command post.
China Subway	The area of each fire control district cannot be more than 1500m <sup>2</sup> .	In each fire-control district there should be more than 2 emergency exit.	The maximum distance between two water spray equipment is 50m.
Italy	No special regulations.	No special regulations.	
Italy Subway	Compartmentalization between different closed spaces in the stations must be fulfilled with structures REI 60 (p. 4.4.6)	Air over-pressure protection systems operated by a system of detectors, appointed to block the smoke between the platform of the stations and the route of evacuation (p. 4.3.2. and 4.3.3.).	All the rooms containing technical installation must be separated by room containing people with structures at least REI 120 (p. 4.4 5.).
Japan	No special regulations.	No special regulations.	No special regulations. ----- The sprinkler equipment has a capacity with a unit length of 40m.
Japan Subway	Because principle structural members are of fireproof construction, the concourse section shall be demarcated into individual fire regions no larger than 1,500 sq. meters. (Building Standard Law)	Sections connecting stations with other stations or underground shopping malls shall be equipped with fire doors. Substations, electric rooms and machine rooms shall be separated from other areas by fireproof separations.	There are no particular regulations.
Sweden	Special design for each new project.	Special design for each new project.	Special design for each new project.
USA	No special requirements except in vehicle design.	All openings to non-transit occupancies to have fire-protective assemblies.	
Remarks	In the case of fire, compartmentalization must be considered for the egress. Considerations include number location capacity and width of path. In other countries, design is carried out case by case, based on instructions from Fire Department.		

**Categories and Hazard Prevention Functions in RAILWAY TUNNELS in Each Nation  
Compartmentalization - cont'd**

Function Nation	Problems and Outstanding Items		Miscellaneous
	Basic Structure and Supplementary Equipment I	Supplementary Equipment II	
Australia	None in particular.	None in particular.	
Canada	Historically, train ways were considered as alternate exits from stations. New stations are constructed with two exits to grade.	Same as I	Fire and life safety criteria for designs and constructions, other than those specified by Acts, Codes, Regulations and Standards, are generally formulated by consultations with concerned bodies such as Fire Department, Police, Ministry of Labor, environment etc., together with a team of experts. Many capital projects relating to fire and life safety are in place to keep facility in state of good repair and to comply with legislation.
China Subway	None in particular.	None in particular.	
Italy			
Italy Subway		When the electrical cables cross two separate compartments, these cables don't have to constitute a vehicle of fire propagation. We have also to study this problem.	Routes of evacuation and exits in general are dimensioned taking into account of the ebb capacity (p. 4.2).
Japan			
Japan Subway	There are no particular regulations.	There are no particular regulations.	
Sweden			
USA			
Remarks			

**Categories and Hazard Prevention Functions in RAILWAY TUNNELS in Each Nation  
Emergency Systems-Rescue, Escape and Refuge**

Function Nation	Basic Structure	Supplementary Structure I	Supplementary Facilities II
	Summary	Basic Structure Related Summary	Mechanical and Electrical Equipment Related Summary
Australia	No particular regulations.	No particular regulations but Fire Department will govern.	No regulations.
Canada	Egress path in tunnel via walkways and along track works. 2 remote independent egress for station platform. Cross passages between adjacent tunnels every 381m between stations.	Emergency exit buildings (EEBs) - maximum spacing between EEBs and EEBs to station to be 762m. Fire fighter's access (FFA) - via public area and one fire fighter's access shaft per station end to track level.	Emergency power supply to fire alarm, supervisory control and data acquisition (SCADA) system, emergency lighting and ventilation. Emergency lighting DM-0701-05. Emergency Communications DM-0803.
China Subway	There are no particular regulations.	Before construction the design of emergency systems must be agreed by public fire department.	Before construction the design must be agreed by Public Fire Department.
Italy	No special regulations.	No special regulations.	
Italy Subway	Emergency exit for the personnel of service (p.3.4. of D. M. ); emergency entrances for fire brigades (p. 3.5 of D. M.); platforms of service in the tunnels for the evacuation of the train eventually stopped (p. 5.1).	The position of the exits for the passengers and the route of evacuation must be indicated in a clear way with signs, according to the D.P.A. 08. 06. 82. n° 524 (Italian Official Journal n° 218 of 10.08.82).	Safety lightning installation (p. 6.2.4 and 7.1.3). More than one energy source for the equipments electrical of emergency (p. 6.2.5) (for ex. installation of generating set put into a room with characteristics of fire resistance)
Japan	No special regulations. The principle is to leave the tunnel.  ----- In the Seikan Tunnel, there are two refuge locations (stations) dividing the tunnel into three shorter section.	No special regulations. Often the slanting portal of depressed structures is used for escape.  ----- In the section under water, there are escape routes every 600 - 800 m to the paralleled service tunnel. In the section under the main land, there are no special facilities outside two slanting escape routes. The underground stations are provided with emergency refuge chambers and escaped routes (Seikan Tunnel).	No special regulations.  ----- in the escaped routes and the emergency refuge chambers fresh air is brought in by a system of blowers. The control room monitors to prevent disasters and several communication networks have been set up. Public Fire Brigade and police are contacted from the control room(Seikan Tunnel).
Japan Subway	Evacuation routes from station platform shall be installed within 50 meters of one end of each platform. Evacuation guidance equipment: at least two different evacuation routes from the platform to the surface shall be provided.	No part of a room shall be more than 100 meters distant from an evacuation exit. In the case of a platform fire, the concourse shall be deemed the evacuation location.	Facilities in station areas • Fire extinguishers, interior fire hydrant systems, interconnected spray equipment or sprinklers. • Interconnected water supply pipes, emergency illumination equipment, evacuation exit, guidance lights, and passageway guidance lights. Equipment installed between stations (tunnels) • Interconnected water supply pipes • Emergency illumination equipment • Evacuation signs
Sweden	Described in internal regulation BVH 541.3 "Design of and equipment for railway tunnels regarding safety".	Described in internal regulation BVH 541.3 "Design of and equipment for railway tunnels regarding safety".	Described in internal regulation BVH 541.3 "Design of and equipment for railway tunnels regarding safety".
USA	Regulation of exit capacities, type of exit, travel time to place of refuge and distance to exit.	Evacuate station occupant load from the platform in 4 minutes or less, to point of safety in 6 min. or less. Max. travel distance to an exit is 91m.	
Remarks	In Japan, Sweden and USA, internal regulations, standards etc. stipulate in detail the escapes route and distance to the station exit or emergency exit. In other countries, the regulations follow instructions from Fire Department. The Seikan Tunnel in Japan (L=53.9km) is provided with a service tunnel at undersea section (L=23.3km) connected with cross passages. The spacing between cross passages is between 600m and 800m.		

**Categories and Hazard Prevention Functions in RAILWAY TUNNELS in Each Nation  
Emergency Systems-Rescue, Escape and Refuge - cont'd**

Function Nation	Problems and Outstanding Items		Miscellaneous
	Basic Structure and Supplementary Equipment I	Supplementary Equipment II	
Australia	None in particular.	None in particular.	
Canada	Rehabilitation of ventilation systems to be undertaken.	Same as I	Fire and life safety criteria for designs and constructions, other than those specified by Acts, Codes, Regulations and Standards, are generally formulated by consultations with concerned bodies such as Fire Department, Police, Ministry of Labor, environment etc., together with a team of experts. Many capital projects relating to fire and life safety are in place to keep facility in state of good repair and to comply with legislation.
China Subway	Establishment an emergency way for people running to the rescue place easily.	None in particular.	
Italy			
Italy Subway			
Japan			
Japan Subway	When single -track tunnels are constructed on a line, connecting shafts for evacuation purposes should be built between the in-bound and out-bound lines.	Elevators for daily use are recommended to used during evacuations. (This is not permitted under existing regulations.)	Air respirators should be on hand in stations at all times. Either storage battery equipment or household generators should be used as emergency power sources.
Sweden			
USA	Is emergency egress across tracks acceptable for LRT stations? Should remote entry points into fire/smoke protected exit enclosures which utilize the same shaft be acceptable as two exits.		
Remarks	The Channel Tunnel (L=51km) is also provided with a service tunnel between the running tunnels. The spacing between the cross passages connecting the running and the service tunnels is 375m <sup>9</sup> . The air pressure of the safety space for evacuation is controlled to be pressurized in comparison to the fire space.		

<sup>9</sup> J.K. Lemley, B.D. Brown, P. Vandebrouck, "The Channel Tunnel Co-operation in a Transfrontier Environment", International Symposium on Technology of Bored Tunnels Under Deep Waterways, Copenhagen, 3-5 November 1993.

**Categories and Hazard Prevention Functions in RAILWAY TUNNELS in Each Nation  
Fire and Smoke Control**

Function Nation	Basic Structure	Supplementary Structure I	Supplementary Facilities II
	Summary	Basic Structure Related Summary	Mechanical and Electrical Equipment Related Summary
Australia	No particular regulations.	No particular regulations but Fire Department will govern.	No regulations.
Canada	Emergency ventilation DM-0601 NFPA 130 "Fixed guide way transit system". Four station emergency ventilation fans on exhaust to control smoke migration along protected egress routes.	Ventilation to station area rooms shut-off independently to prevent smoke migration into area rooms.	Stations provided with wet stand pipe system. Dry type sprinkler system utilized. Fire extinguishers in accordance with OFC and TTC requirements. Tunnels have standpipes and hose systems.
China Subway	In each basic structure, fire and smoke control district must be arranged.	There are no particular regulations but ventilation equipment used to keep smoke and fire out of refuge areas.	In fire disasters, the mechanical ventilation equipment at normal time must be effective using as smoke control system.
Italy	No special regulations.	No special regulations.	
Italy Subway	Extinguishment systems: fire hoses, hydrants, extinguishers (6.2.1.1) sprinklers in the shops commercial rooms bars etc. (p.6.2.1.2)	Extinguishers Sprinklers in the services rooms.	Sprinklers (moving stairs eventually installed in the stations.)(p. 4.2.5)
Japan	No special regulations.	No special regulations.	No special regulations. With the use of blowers and exhaust device the smoke pattern is controlled.
Japan Subway	There are no particular regulations.	Hanging walls shall be installed between platforms and lines, and at stairs and escalators.	Effective smoke exhaust equipment shall be installed at stations as well as between them. (smoke exhaust equipment can also be used for mechanical ventilation purpose.)
Sweden	Described in internal regulation BVH 541.3 "Design of and equipment for railway tunnels regarding safety".	Described in internal regulation BVH 541.3 "Design of and equipment for railway tunnels regarding safety".	Described in internal regulation BVH 541.3 "Design of and equipment for railway tunnels regarding safety".
USA	No particular regulations.	Ventilated systems shall provide stream of non contaminated air to passengers. Exercises/drills required at least twice per year.	Fans must withstand 148.8°C for one hour. Fans must work in supply or exhaust mode. Local override of controls to be available.
Remarks	No general regulations for basic tunnel structure. At stations, ventilation equipment is designed in such a way that smoke extraction is also possible.		

**Categories and Hazard Prevention Functions in RAILWAY TUNNELS in Each Nation  
Fire and Smoke Control - cont'd**

Function Nation	Problems and Outstanding Items		Miscellaneous
	Basic Structure and Supplementary Equipment I	Supplementary Equipment II	
Australia	None in particular.	None in particular.	
Canada	Portal doors for smoke control being added.	Same as I	Fire and life safety criteria for designs and constructions, other than those specified by Acts, Codes, Regulations and Standards, are generally formulated by consultations with concerned bodies such as Fire Department, Police, Ministry of Labor, environment etc., together with a team of experts. Many capital projects relating to fire and life safety are in place to keep facility in state of good repair and to comply with legislation.
China Subway	Establishment an emergency way for police from surface can go to station to put fire out.	Improvement of technology to simulate the smoke dispersion during a fire, and improvement for heat resistance of ventilators.	
Italy			
Italy Subway			Smoke evacuation system in the station (natural or mechanical) and in every tunnel between two stations (only natural evacuation) (p. 6.2.6, 7.2.4)
Japan		It is difficult to specify fire prevention regulations especially for freight trains.	
Japan Subway	It is difficult to presume smoke level for railway car fires.	There are no clear standards for the capacity of tunnel smoke exhaust equipment.	Fire proofing measures for platforms and tunnels are targeted at fires in the train cars, for concourses are targeted at fires in shops. Fire and smoke should be restricted by keeping a downward air flow between the platforms and concourse stairs.
Sweden			
USA	Trade-off between high spaces in stations delaying descent of smoke and hot gases vs. smaller spaces/ compartmentalization to control smoke movement.		
Remarks	The composed materials for rolling stock in recent years must not combustible basically. If necessary, the amount of loaded goods must be considered as combustible materials for fire.		

**Categories and Hazard Prevention Functions in RAILWAY TUNNELS in Each Nation  
Maintenance of Safety Systems**

Function Nation	Basic Structure Summary	Supplementary Structure I Basic Structure Related Summary	Supplementary Facilities II Mechanical and Electrical Equipment Related Summary
Australia	No particular regulations.	No particular regulations but Fire Department will govern.	No regulations.
Canada	Routine inspection and preventive maintenance. In accordance with system safety manual.	Routine inspection and preventive maintenance. No particular regulations.	Maintenance of fire detection/alarm system in NFPA 72.
China Subway	There are no particular regulations.	There are no particular regulations.	Management takes on maintenance of safety.
Italy	No special regulations.	No special regulations.	
Italy Subway			
Japan	No special regulations.	No special regulations.	The maintenance workers are provided with a maintenance check manual.
Japan Subway	There are no particular regulations.	There are no particular regulations.	Manuals are provided to all railway operators. Fire extinguishing equipment must be inspected in accordance with the Law.
Sweden	Described in internal regulation BVF 507.2 "Safety inspection of permanent constructions".	Described in internal regulation BVF 507.2 "Safety inspection of permanent constructions".	Described in internal regulation BVF 507.2 "Safety inspection of permanent constructions".
USA	No particular regulations.	Exercises/drill required at least twice per year.	Standards exist for maintenance of detection/alarm systems (NFPA 72).
Remarks	Japan, Sweden and USA have standards for maintenance. In general, tunnel operator carries out inspections independently.		

**Categories and Hazard Prevention Functions in RAILWAY TUNNELS in Each Nation  
Maintenance of Safety Systems - cont'd**

Function Nation	Problems and Outstanding Items		Miscellaneous
	Basic Structure and Supplementary Equipment I	Supplementary Equipment II	
Australia	None in particular.	None in particular.	
Canada	Repair and replacement work on-going for existing tunnels and stations to comply with OBC, OFC and Ontario Fire Marshall's directive.	Same as I.	Fire and life safety criteria for designs and constructions, other than those specified by Acts, Codes, Regulations and Standards, are generally formulated by consultations with concerned bodies such as Fire Department, Police, Ministry of Labor, environment etc., together with a team of experts. Many capital projects relating to fire and life safety are in place to keep facility in state of good repair and to comply with legislation.
China Subway	None in particular.	None in particular.	
Italy			
Italy Subway			
Japan			
Japan Subway	There are no particular regulations.	There are no particular regulations.	
Sweden			
USA			
Remarks			

# **Categories and Hazard Prevention Functions in Underground Car Parks for Human Occupancy**

**Responses Compiled from the following ITA Member Nations:**

**Italy**

**Japan**

**Sweden**

**U.S.A**

**Categories and Hazard Prevention Functions in UNDERGROUND CAR PARKING SPACES FOR  
HUMAN OCCUPANCY in Each Nation  
Special Items**

Nation	Special Items
Italy	Requirements are codified by dedicated Decree 01-02-86: besides, special technical codes must be always fulfilled.
Japan	<p>An underground parking facilities is defined as an "Automobile garage or parking facilities" under Fire Protection Structures in the Fire Services Law *1, Facilities and the Building Standard Law *2.</p> <p>*1 Law providing standards for fire prevention, warning and control as well as protection of people from death and injury and protection of property from damage. (Ministry of Home Affairs)</p> <p>*2 Law providing minimums standards for the site, structure, equipment and use of buildings. (Ministry of Construction)</p>
Sweden	All new underground building space, except mining and subway tunnels, are covered by the Planning and Building Act, and existing underground building spade are covered by the Rescue Services Law.
USA	Controlled by building codes and life safety code as for Underground Building Space. Only special comments for this type of occupancy are given in following tables. Parking is considered a storage occupancy.

**Categories and Hazard Prevention Functions in UNDERGROUND CAR PARKING SPACES FOR HUMAN OCCUPANCY in Each Nation  
Fire and Collapse Resisting Structures**

Function	Basic Structure	Supplementary Structure I	Supplementary Facilities II
Nation	Summary	Basic Structure Related Summary	Mechanical and Electrical Equipment Related Summary
Italy	Material requirements according to law n. 64, 2-2-74, and D.M.I 26-6-84, * if less than 9 cars: not combustible or REI 60; * if more than 9 cars: REI 90 or 120. Min. height = 2m.	Material requirements according to law n. 64, 2-2-74, and D.M.I. 26-6-84: REI 120 non combustible. Min. width of exit height: * if less than 9 cars; 3m (two-way-traffic); * if more than 9 cars: 2 * 3m (one-way-traffic) or 4.5m (two-way-traffic).	All equipments and facilities must fulfill the corresponding dedicated technical codes when existing. Particular attention for water system and supply.
Japan	Reinforced concrete building (Fire-proof building).	There are no particular regulations.	There are no particular regulations.
Sweden	Higher ratings on fire resistance.	Higher ratings on fire resistance.	There are no particular regulations. Underground facilities are handled the same way as other structures.
USA			
Remarks	In principle, fire resisting structure is used in each country.		

**Categories and Hazard Prevention Functions in UNDERGROUND CAR PARKING SPACES FOR  
HUMAN OCCUPANCY in Each Nation  
Fire and Collapse Resisting Structures - cont'd**

Function Nation	Problems and Outstanding Items		Miscellaneous
	Basic Structure and Supplementary Equipment I	Supplementary Equipment II	
Italy	Six underground floors at most allowed.		Four different situations are defined: <ul style="list-style-type: none"> <li>* less than 9 cars, mixed building</li> <li>* less than 9 cars, isolated building</li> <li>* more than 9 cars, mixed building</li> <li>* more than 9 cars, isolated building</li> </ul>
Japan			
Sweden	Water sprinkler as a demand for large, complex and/or highly combustible underground facilities.		The new Building Regulations, which contain mandatory provisions for the Planning and Building Act, are written with functional demands that could be fulfilled in many different ways.  Road and rail tunnels are different from other underground facilities and special regulations have to be established in the future.
USA			
Remarks			

**Categories and Hazard Prevention Functions in UNDERGROUND CAR PARKING SPACES FOR HUMAN OCCUPANCY in Each Nation  
Elimination of Combustibles**

Function Nation	Basic Structure Summary	Supplementary Structure I Basic Structure Related Summary	Supplementary Facilities II Mechanical and Electrical Equipment Related Summary
Italy	No car with GPL fuel parking: No flammable or combustible material storage: No communication with flammable or explosive material storage.	Separation device between water and flammable liquids.	
Japan	Use of inflammable materials.	There are no particular regulations.	Use of heat resistive cables for power and signal lines.
Sweden	There are no particular regulations. Underground facilities are handled the same way as other structures.	There are no particular regulations. Underground facilities are handled the same way as other structures.	There are no particular regulations. Underground facilities are handled the same way as other structures.
USA			
Remarks	Restrict the usage of underground parking space to uncertain types of vehicles. Prohibit storage of flammable and explosive materials.		

**Categories and Hazard Prevention Functions in UNDERGROUND CAR PARKING SPACES FOR  
HUMAN OCCUPANCY in Each Nation  
Elimination of Combustibles - cont'd**

Function Nation	Problems and Outstanding Items		Miscellaneous
	Basic Structure and Supplementary Equipment I	Supplementary Equipment II	
Italy			
Japan			Same as ordinary building.
Sweden	Water sprinkler as a demand for large, complex and/or highly combustible underground facilities.		
USA	Vehicles with high hazard for fire, explosion or toxic chemical release.		
Remarks			

**Categories and Hazard Prevention Functions in UNDERGROUND CAR PARKING SPACES FOR HUMAN OCCUPANCY in Each Nation**  
**Detection and Alarms**

Function	Basic Structure	Supplementary Structure I	Supplementary Facilities II
Nation	Summary	Basic Structure Related Summary	Mechanical and Electrical Equipment Related Summary
Italy	Always flammable mixtures detection system and hydrants; if more second underground floor, automatic fire extinction system too.		If more than 500 cars: mechanical ventilation with automatic control of the gas (CO) and flammable mixtures (alarm limits are; one CO measured value $\geq 100\text{ppm}$ , two CO measured values $\geq 50\text{ppm}$ or flammable mixture $\geq 20\%$ )
Japan	There are no particular regulations.	There are no particular regulations.	Alarm equipments Automatic fire detection equipment Short-circuit alarm equipment Emergency alarm equipment (loud speaker equipment) Communication equipments Communication equipments for use within the facility.
Sweden	There are no particular regulations. Underground facilities are handled the same way as other structures.	There are no particular regulations. Underground facilities are handled the same way as other structures.	There are no particular regulations. Underground facilities are handled the same way as other structures.
USA		Fire detection and alarm for floor areas $>9,300$ sq. m. Requirement does not apply if automatic sprinkler system is used --normally the case.	
Remarks	Standards of Fire detection and alarm systems are defined in relation with the floor area, or follow standards underground building facilities(same as Architectural Standards Law).		

**Categories and Hazard Prevention Functions in UNDERGROUND CAR PARKING SPACES FOR HUMAN OCCUPANCY in Each Nation  
Detection and Alarms - cont'd**

Function Nation	Problems and Outstanding Items		Miscellaneous
	Basic Structure and Supplementary Equipment I	Supplementary Equipment II	
Italy			
Japan		Study on fire detection in its incipient stage.	Underground parking facilities with a telephone do not require communication equipments connected to the Fire Department.
Sweden	Water sprinkler as a demand for large, complex and/or highly combustible underground facilities.		
USA			
Remarks			

**Categories and Hazard Prevention Functions in UNDERGROUND CAR PARKING SPACES FOR HUMAN OCCUPANCY in Each Nation  
Compartmentalization**

Function Nation	Basic Structure Summary	Supplementary Structure I Basic Structure Related Summary	Supplementary Facilities II Mechanical and Electrical Equipment Related Summary
Italy	If more 9 cars: each section must be divided by fire-proof walls and doors, REI 90, and must be 1500-7000m <sup>2</sup> in area vs. depth floor and building insulation rate.	Garage on first underground floor only.	Emergency water supply must be independent sanitary fittings water supply.
Japan	There are no particular regulations.	Less than 1500 m <sup>2</sup> : fire prevent compartment.  Less than 500 m <sup>2</sup> : smoke prevent compartment.	Fire doors and fire dampers.
Sweden	There are no particular regulations. Underground facilities are handled the same way as other structures.	There are no particular regulations. Underground facilities are handled the same way as other structures.	There are no particular regulations. Underground facilities are handled the same way as other structures.
USA			
Remarks	Compartmentalization (fire proof walls and doors) is considered for prevention of fire spread.		

**Categories and Hazard Prevention Functions in UNDERGROUND CAR PARKING SPACES FOR  
HUMAN OCCUPANCY in Each Nation  
Compartmentalization - cont'd**

Function Nation	Problems and Outstanding Items		Miscellaneous
	Basic Structure and Supplementary Equipment I	Supplementary Equipment II	
Italy			
Japan			
Sweden	Water sprinkler as a demand for large, complex and/or highly combustible underground facilities.		
USA			
Remarks			

**Categories and Hazard Prevention Functions in UNDERGROUND CAR PARKING SPACES FOR HUMAN OCCUPANCY in Each Nation**  
**Emergency Systems - Rescue, Escape and Refuge**

Function Nation	Basic Structure	Supplementary Structure I	Supplementary Facilities II
	Summary	Basic Structure Related Summary	Mechanical and Electrical Equipment Related Summary
Italy	<p>Signals are codified by DPR n. 524, 6-6-82.</p> <p>Any door must be REI 60 + REI 120 with automatic closure.</p>	<p>Signals are codified by DPR n. 524, 6-6-82</p> <p>Any door must be REI 120 with automatic closure and larger than 1.2m Max. travel distance to an exit is 40m (or 50m with automatic fire control device).</p> <p>Max. exit capacity values are 37.5 ( the first 3 underground floors) and 33 (next underground floors) person/0.6m width.</p>	<p>Emergency lighting required.</p> <p>Portable extinguishers, standard type "A", "B", "C" of at least "21A" and "89B" capacity.</p>
Japan	<p>Special evacuation stairways must be installed in underground parking facilities with more than three basement levels.</p>	<p>The maximum distance to the evacuation stairway is 60 meters.</p>	<p>Equipment required for fire fighting</p> <ul style="list-style-type: none"> <li>• smoke exhaust equipment</li> <li>• network water sprinkler system</li> <li>• emergency lighting</li> <li>• emergency power outlets</li> <li>• standby power source equipment</li> </ul> <p>Evacuation guidance equipment</p> <ul style="list-style-type: none"> <li>• safety lights and indicators</li> <li>• monitor system</li> </ul>
Sweden	<p>There are no particular regulations. Underground facilities are handled the same way as other structures.</p>	<p>Special staircase for the Rescue Service. This staircase shall not be used as an escape route.</p>	<p>There are no particular regulations. Underground facilities are handled the same way as other structures.</p>
USA		<p>Exit distances &lt; 60 m for parking structures with automatic sprinkler system.</p>	
Remarks	<p>The provision of special staircases for evacuating people and refuge spaces for escape and rescue activities is stipulated by similar standards in each country.</p> <p>The facility grade differs considerable per country.</p>		

**Categories and Hazard Prevention Functions in UNDERGROUND CAR PARKING SPACES FOR  
HUMAN OCCUPANCY in Each Nation  
Emergency Systems - Rescue, Escape and Refuge - cont'd**

Function Nation	Problems and Outstanding Items		Miscellaneous
	Basic Structure and Supplementary Equipment I	Supplementary Equipment II	
Italy			
Japan	<p>According to the Building Standard Law, the evacuation distance should be maximum 60 meters.</p> <p>Keeping of escape routes is important.</p> <p>Keeping of entrance for fire brigade.</p>	<p>Study on fire brigade support system.</p>	<p>Study on following</p> <ul style="list-style-type: none"> <li>• capacity of auxiliary power equipment</li> <li>• display of evacuation direction</li> <li>• means to confirm evacuation in case of fire</li> <li>• Grasp of condition in case of fire</li> </ul>
Sweden	<p>Development of escape and rescue systems for underground facilities. How efficient are staircases? Do we need special provisions such as firefighter elevators and/or refuge spaces.</p>		
USA			
Remarks			

**Categories and Hazard Prevention Functions in UNDERGROUND CAR PARKING SPACES FOR HUMAN OCCUPANCY in Each Nation  
Fire and Smoke Control**

Function Nation	Basic Structure Summary	Supplementary Structure I Basic Structure Related Summary	Supplementary Facilities II Mechanical and Electrical Equipment Related Summary
Italy	All underground floors to must be equipped with separate mechanical ventilation system designs also for heat and smoke control.	All openings to must be equipped with fans and extinguishers.	Sprinkler system required.
Japan	There are no particular regulations.	There are no particular regulations.	Smoke exhaust equipment Extinguishing equipment <ul style="list-style-type: none"> <li>• interior fire extinguishing equipment</li> <li>• foam fire extinguishing equipment</li> <li>• carbon dioxide fore extinguishing equipment</li> </ul> fire doors
Sweden	Fire ventilation for each storey through separate smoke outlets.	There are no particular regulations. Underground facilities are handled the same way as other structures.	There are no particular regulations. Underground facilities are handled the same way as other structures.
USA			
Remarks	Provisional measures are taken into consideration for smoke control with special smoke extractors in case of fire, and smoke extraction with ordinary ventilation equipment.		

**Categories and Hazard Prevention Functions in UNDERGROUND CAR PARKING SPACES FOR  
HUMAN OCCUPANCY in Each Nation  
Fire and Smoke Control - cont'd**

Function Nation	Problems and Outstanding Items		Miscellaneous
	Basic Structure and Supplementary Equipment I	Supplementary Equipment II	
Italy			
Japan		Study on efficient smoke control method without dispersion.	
Sweden	Improvement and validation of the normal ventilation system as mechanical ventilation system for fire and smoke control.		
USA			
Remarks			

**Categories and Hazard Prevention Functions in UNDERGROUND CAR PARKING SPACES FOR  
HUMAN OCCUPANCY in Each Nation  
Maintenance of Safety Systems**

Function Nation	Basic Structure Summary	Supplementary Structure I Basic Structure Related Summary	Supplementary Facilities II Mechanical and Electrical Equipment Related Summary
Italy			Detection and control equipments must be controlled from qualified staff every six months.
Japan	There are no particular regulations.	There are no particular regulations.	Fire protection center <ul style="list-style-type: none"> <li>• fire protection board</li> <li>• monitoring system</li> <li>• central monitoring equipment</li> </ul> Maintenance and inspection <ul style="list-style-type: none"> <li>• regular inspections of fire protection equipment</li> <li>• regular inspections of all electrical equipment</li> <li>• installation of ventilation equipment</li> <li>• installation of lighting that provides the specified luminous intensity</li> </ul>
Sweden	There are no particular regulations. Underground facilities are handled the same way as other structures.	There are no particular regulations. Underground facilities are handled the same way as other structures.	There are no particular regulations. Underground facilities are handled the same way as other structures.
USA			
Remarks			

**Categories and Hazard Prevention Functions in UNDERGROUND CAR PARKING SPACES FOR  
HUMAN OCCUPANCY in Each Nation  
Maintenance of Safety Systems - cont'd**

Function Nation	Problems and Outstanding Items		Miscellaneous
	Basic Structure and Supplementary Equipment I	Supplementary Equipment II	
Italy			
Japan		Study on arson prevention measures. Grasp of contamination of various equipment installed.	Even though there are no regulations however installations of monitor system boards or supplementary wireless communication equipment are recommended.
Sweden	Development of a standardized system for internal control.		
USA			
Remarks			