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Publisher's version / Version de l'éditeur:

ASHRAE Journal, 49, August 8, pp. 50-60, 2007-08-01

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NRCC-49696

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A version of this document is published in / Une version de ce document se trouve dans:
ASHRAE Journal, v. 49, no. 8, August 2007, pp. 50-60

INTERNATIONAL TUNNEL SAFETY DESIGN PRACTICES

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Introduction

The catastrophic consequences of the tunnel fires (e.g., the Mont Blanc tunnel, 1999, the Austrian Kaprun funicular tunnel, 2000, and the Swiss St. Gotthard tunnel, 2001) not only resulted in loss of life, severe property damages, but also left the public with a lack of confidence in using such systems. Fire safety in rail and road tunnels is challenging because of the specific features of the tunnel environment. The sustainability of existing tunnels, given the increased road traffic and changed vehicle mix, or the new rolling stocks, needs innovative design practices. For example, reliable and early fire detection in tunnels can provide the tunnel operator with early warnings of fire and its location, allowing for timely activation of the emergency response such as the emergency ventilation system.

International collaborations have been working to develop and harmonize design guidelines, such as the Permanent International Association of Road Congresses (PIARC) and the International Union of Railways (UIC). It's impossible to address all tunnel fire-safety issues in an article. Instead, a number of selected topics, such as international design practices are discussed here.

Design Practices and Examples

North America

In the United States, several government agencies and associations provide regulations and guidance for tunnel integrity and safety. The Department of Transportation (DOT) includes specialized agencies providing guidance for tunnel design and operation. The Federal Transit Administration (FTA) in collaboration with the Volpe National Transportation Systems Center, the Transit Cooperative Research Program of the Transportation Research Board, and American Public Transportation Association (APTA) issued a document titled "Transit Security Design Considerations," addressing the high-risk security demands for the transit systems, particularly for tunnels and stations.

Tunnel ventilation technology evolved concurrently with the development of a dedicated computer program in the 1970s, as part of the U.S. Department of Transportation's Subway Environmental Research Project. The Federal Highway Administration (FHWA) provides expertise, resources and information on the nation's 4 million miles of highways and roads, including many tunnels. FHWA develops regulations, policies and guidelines, and provides federal funds to finance projects and techniques of national interest. It is an active participant in PIARC activities, sponsor of national research projects and cosponsor of international research programs.

ASHRAE. Rail and road tunnels, underground stations, parking garages, tollbooths, bus garages and terminals, locomotives maintenance and repair areas are all grouped in the category of enclosed vehicular facilities (EVF). ASHRAE and its predecessors have dealt with this group of facilities for many years, pioneering research and standards for better, sustainable design of a safe environment (see *ASHRAE and NFPA Resources* sidebar).

National Fire Protection Association (NFPA). In 1972, a tentative standard for limited access highways, tunnels, bridges and elevated structures, was adopted by the National Fire Protection Association. The NFPA 502 standard[1] evolved and the current edition includes new requirements for the protection of tunnel structures, emergency lighting, updates on the vehicle tunnel fire data, and clarification of the travel distance to emergency exits. In 1975, the Fixed Guideway Transit Systems Committee was created within the NFPA and began work on the development of a set of recommendations applicable to most guided transit systems[2] (see *ASHRAE and NFPA Resources* sidebar).

An important factor in advancing the design methodology for tunnel ventilation was the tremendous progress in computer technology applicable to tunnel safety. Faster and more affordable computers allowed a wide use of applicable computer programs, such as Subway Environment Simulation (SES) and computational fluid dynamics (CFD),[3] to provide quick and inexpensive answers to complicated network models for airflow and smoke control.

The concept of smoke management[4] was developed as a solution to the smoke migration problem, and various specific methods have been proposed. The objectives of a smoke management system are to reduce deaths and injuries from smoke, reduce property loss from smoke damage, and aid firefighting. A modern smoke management system should be designed to provide a safe escape route, a safe refuge area, or both. Current safety standards provide guidance for the implementation systems using pressure differentials to accomplish one or more of the following:

- ⇒ Maintain a tenable environment in the means of egress during evacuation;
- ⇒ Control and reduce the migration of smoke from the fi re area;
- ⇒ Provide conditions outside the fire zone that assist emergency response personnel in conducting search and rescue operations, and locating and controlling the fi re; and
- ⇒ Contribute to the protection of life and reduction of property loss.

The natural driving forces of smoke movement are the stack effect, wind-induced action, and buoyancy of smoke. Action of these forces on the facility can produce significant pressure differences between different parts inside the facility preventing smoke movement from places with higher pressure to places with lower pressure.

North American Examples

The existing U.S. infrastructure includes some 400 highway tunnels in 35 states and thousands of kilometers/miles of transit tunnels. The tunnels for the transit systems in New York and Boston were constructed at the beginning of the 20th century, followed by Chicago in the 1930s and 1940s; Toronto in the 1950s; BART San Francisco-Oakland in the 1960s; Atlanta, Baltimore, and Washington in the 1970s and 1980s; and Los Angeles and Dallas in the 1990s, etc.

The construction of the Interstate Highway System was at its peak in the 1960s and 1970s, when several of the existing road tunnels were built. The largest network of road tunnels was built in the 1990s, as part of the Central Artery Project in Boston. By comparison with other countries in Europe and Asia, U.S. has a relatively small number of road tunnels.[5] Two new manuals for the tunnel management system have been produced jointly by the FHWA and the FTA, including a software program to collect data on tunnel components.

The subway system in Boston, built just before the end of the 19th century is the oldest in North America. More than 100-years-old, the New York City subway system consists of more than 1,000 km of revenue line and 468 stations, with approximately 60% underground. The weekday daily ridership on this system exceeds 4.8 million passengers.

The Toronto subway system in Canada is an older extended underground system with a ridership in excess of 1.1 million trips per weekday. Its emergency fire ventilation system is being upgraded to comply with the current safety standards.

The subway of Montreal was inaugurated in 1966 and now contains 65 stations distributed out of four lines. The construction of an extension subway towards Laval was recently completed.

The new extension adds a course of 5.2 km (3.2 miles) and three new stations: Cartier, Concorde and Montmorency. The project also includes the construction of eight auxiliary structures. The cost of the extension is estimated to be $803.6 million ($154.5 million per kilometer [$249 million per mile]).

The recent and new transit projects under construction or advanced design in Los Angeles, San Francisco (airport extension) and San Jose (Silicon Valley Corridor), Seattle, and others running through tunnels are equipped with modern ventilation systems capable of maintaining acceptable environment conditions in stations and controlling smoke and heat in case of a major fi re underground.

New road tunnels that have been built (almost four miles in Boston, Wolf Creek Pass in Colorado), are under construction (Devil's Slide in California, PR Route 53) or under design (Kicking Horse in British Columbia, Canada, 4th Bore Caldecott and Coronado in Calif., LBJ Corridor in Dallas, Pine Mountain and Drumanard Louisville in Kentucky, SR 71 in Wisconsin, 3rd Harbor Crossing and Elizabeth River in Virginia, Port of Miami, and so on) will have modern ventilation systems to control the emissions and provide for smoke control and safe evacuation routes in case of tunnel fires. Some of the existing tunnels have been or are being retrofitted and provided with upgraded ventilation systems (I-90 and Mt. Baker Ridge in Seattle, Eisenhower in Colorado, Detroit-Windsor, Wilson in Hawaii).

Tunnel	Length m	Length ft	Date of Opening	State	Comment	Road
Anton Anderson Memorial	4184	13,727	7/6/2000	AK	Road and Railway Tunnel, Whittier City	
Brooklyn Battery	2779	9,117	5/15/1950	NY	Second Tube, Same Length, East River, New York City	I-478
Eisenhower Memorial	2731	8,960	12/21/1979	CO	Second Tube, 8,940 ft (2725 m)	I-70
Holland	2608	8,556	11/13/1927	NY-NJ	Shortest Tube, 8,369 ft (2551 m), Hudson River, New York	
Ted Williams	2600	8,530	12/15/1995	MA	Two Tubes, Immersed Tunnel, Boston Harbor	I-90
Lincoln Center	2504	8,215	12/22/1937	NY	Hudson River, New York City	
Lincoln South	2440	8,005	5/25/1957	NY	Hudson River, New York City	
Baltimore Harbor	2332	7,651	11/1957	MD	Immersed Tunnel	I-895
Hampton Roads	2280	7,480	1976	VA	Immersed Tunnel, –108 ft (–33 m), Second Tube, Same Length	I-64
Lincoln North	2280	7,480	1/2/1945	NY	Hudson River, New York City	
Fort McHenry	2184	7,165	11/23/1995	MD	Immersed Tunnel, Baltimore	I-95

Table 1: U.S. tunnels longer than 2000 m (7,000 ft).

Europe

From 2000 to 2001, the United Nations (UN) Economic Commission for Europe (ECE) formed an ad hoc multidisciplinary Group of Experts and developed recommendations on road tunnel safety under four categories of road users, operations, infrastructure and vehicles.[6] In April 2004, the European Commission approved Directive 2004/54/EC on minimum safety requirements for tunnels in the Trans-European road network.[7] This is to ensure a uniform and high level of safety by prevention of incidents and reduction of their consequences. The directive applies to both new and existing tunnels more than 500 m long, and mandates 10 to 15 years for each member state to bring its tunnels in compliance.

Classification of tunnels is developed based on tunnel length and traffic volume for each of which a minimum safety requirement is established for all aspects of fire safety, such as the emergency exit sign arrangement, which also is being considered in the next revision of NFPA 502. The Directive calls for regular information campaigns on road user behavior, especially in such situations as vehicle breakdown, congestion, accidents and fires. Safe driving in tunnels under these circumstances has been developed as an official EU document.[8] The directive has included specific requirements on tunnel ventilation, some of which are:

- ⇒ Mechanical ventilation is required for all tunnels longer than 1 km (0.6 miles) with an annual average daily traffic volume higher than 2,000 vehicles per lane;
- ⇒ Transverse or semitransverse ventilation is required for tunnels with bidirectional traffic and higher traffic volumes, or when tunnel length exceeds 3 km (1.9 miles);
- ⇒ Longitudinal ventilation only is allowed through risk analysis for bidirectional or congested unidirectional tunnels; and
- ⇒ New tunnels should not be designed with a longitudinal gradient more than 5% unless geographically impossible. Risk analysis is needed for gradients higher than 3%.

ASHRAE & NFPA Resources

Chapter 13 of *2007 ASHRAE Handbook—HVAC Applications,* covers ventilation requirements for normal climate control and emergency situations in EVF, as well as design approaches for mechanical ventilation for various emergency scenarios.

ASHRAE Technical Committee 5.09, Enclosed Vehicular Facilities, has members from various U.S. and international organizations and administrations equally representing train and bus operators, university professors, researchers, consultants and designers, equipment manufacturers and suppliers, government bodies, etc.

ASHRAE Technical Committee 5.06, Control of Fire and Smoke, and Handbook Chapter 52, Fire and Smoke Management, are dedicated to fire protection and smoke-control systems, providing useful information applicable to EVF as well.

The first edition of NFPA 130, Standard for Fixed Guideway Transit Systems, including fire protection requirements, was adopted by NFPA in 1983. The newest version was published in 2006.[2]

Transverse and semitransverse ventilation is advantageous as the smoke extraction can be used to limit the smoke spread in the tunnel (*Figure 1*). Using controllable smoke exhaust dampers and a steering process to adjust the longitudinal air velocity is mandatory for bidirectional tunnels with a traffic volume higher than 2,000 vehicles per lane and a tunnel length more than 3 km (1.9 miles). A semitransverse ventilation system is installed in Mont Blanc tunnel, whereas St. Gotthard tunnel has full transverse ventilation. A report on “System and Equipment for Fire and Smoke Control in Tunnels” addresses various types and installations of tunnel ventilation systems, (it will be published in 2007 by PIARC).

For tunnel ventilation design, the UN ECE recommendations suggested a minimum fire size of 30 MW (102 MBtu/h). This is used in many countries such as Austria, Germany and Switzerland, whereas provisions of 50 MW (170 MBtu/h) can be found in the design standards of Germany and Britain. However, a much higher fire heat release rate could develop, as demonstrated in the Runehamar tunnel tests, where fi re from ordinary heavy goods vehicles could reach as high as 200 MW (680 MBtu/h).[9] A comprehensive and systematic implementation of the safety measures including ventilation, egress, rescue and training is necessary.

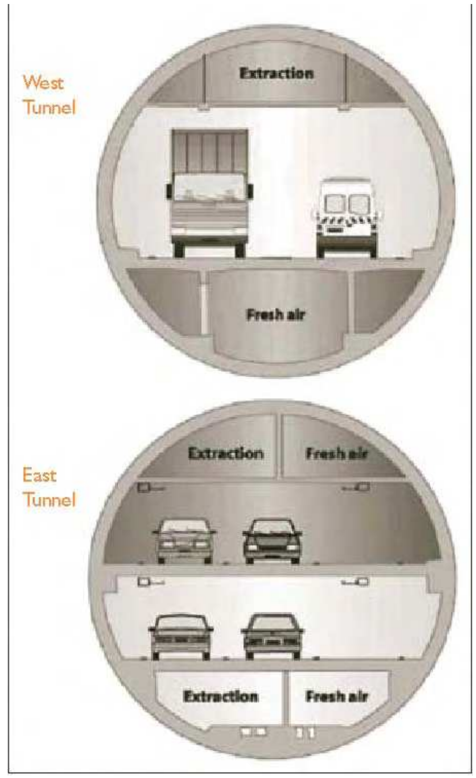

Figure 1: Tunnel cross-sections.[8]

European Examples

Europe has some of the world’s longest road tunnels, in operation and under construction: Laerdal Tunnel in Norway, completed in 2000 is 24.5 km long (15.3 miles); St. Gotthard in Switzerland is 16.9 km (10.5 miles); Frejus between France and Italy 12.9 km (8 miles). The new Rogfast subsea tunnel in Norway will be 24.2 km (15 miles) and the A86 West Tunnel on the ring road around greater Paris, currently under construction, includes an innovative 10 km (6.2 miles) double deck for light vehicles and a separate 7.5 km (4.7 miles) single deck for all traffic, including heavy goods vehicles. After the completion in 1994 of the 50.5 km (31.4 miles) Channel Tunnel between France and England; 34.6 km

(21.5 miles) Loetschberg in Switzerland; and 28.4 km (17.6 miles) in Spain, even longer rail tunnels are under construction; such as the Gotthard Base at 57.1 km (35.5 miles), which will be followed by another one in Stage 2 (2015–2020) of 75 km (46.6 miles).

The London Underground, one of the oldest in the world, has more than 400 km (248 miles) of line, 274 stations and up to 2.7 million passenger trips per weekday.

Another old subway, built in the late 1890s, is in Budapest. Many other systems are in Western Europe (Paris, Lille, Lyon, Madrid, Lisbon, Berlin, Frankfurt, Rome, Milan, etc.) and are continually expanding. Also, there are many subway systems in Russia and Eastern Europe, but it would be difficult to describe all of them in an article. Moscow’s “Metropoliten” has the highest ridership in the world (up to 9 million passengers a day).

Asia/Far East

In Hong Kong, the fi re-safety strategies10 optimize fire protection and fire prevention measures to attain specified fire-safety objectives.

Three main fi re-safety goals[11] should be clearly defined to develop these fire-safety objectives: life safety; property and building protection; and minimum disturbance to normal operation of business. All these goals are important for designing fire safety for the new railway lines and for upgrading provisions of the existing lines. The goals also should be supported by specific fire-safety objectives.

Fire engineering systems should be specified[12] clearly and include at least three parts: detection and alarm system; fire control system; and air and smoke control system. Other auxiliary systems include emergency lighting, exit signs, essential power supplies and others. Fire suppression system such as the automatic sprinkler systems could be used to control a fire, pre-wet the areas and cool the air temperature before the freighters entered the stations. However, the hot steam generated might hurt the occupants, including the passengers, staff and freighters. Therefore, the operation time of the fire suppression system should be watched.

Keeping the thermal and toxic effects to acceptable and tenable limits are extremely important for evacuation. Tenability limits commonly considered in Hong Kong[13] are:

- ⇒ Radiative heat flux: 2.5 kWm^{-2};
- ⇒ Carbon monoxide concentration: 6,000 to 8,000 ppm for five minutes exposure;
- ⇒ Smoke layer temperature: 120°C (248°F); and
- ⇒ Smoke layer interface height: 2.5 m (8 ft).

For railway transit systems in Hong Kong, the proposed "total fire-safety concept"[14] must include, as a minimum, provisions to ensure that all the hardware fire-safety provisions on passive design and active fire protection systems work and people know what to do in a fire. There must be well-planned software for fire-safety management.

In Beijing, ventilation and smoke exhaust systems were designed based mainly on Metro Design Code, GB-50517-2003.[15] Smoke compartmentalization is set at the platform and lobby level, and each area is not to exceed 750 m^2 (8,100 ft^2). The smoke exhaust rate is estimated at 1 m^3/min (35 ft^3/min) for 1 m^2 (10.8 ft^2) floor space, downward air velocity over 1.5 ms^{-1} (4.9 fts^{-1}) in the staircase or escalator exits accessible to the platform. When a fire occurs in the tunnel, the required smoke exhaust rate is determined to achieve a cross-sectional velocity in the tunnel more than 2 ms^{-1} (6.5 fts^{-1}), but less than 11 ms^{-1} (36 fts^{-1}). As stated earlier, performance-based design also is accepted for the old system upgrades, as well as for the new lines or system design.

In Taipei, smoke control systems in subway stations were implemented in four timeframes:

Before 1996. Consultants were appointed and NFPA 130 was referred to while designing the tunnel ventilation fans (TVF) and the under platform exhaust (UPE) systems. Air is drawn from the ambient and exhausted at the platform floor level with a downstream velocity of more than 2.5 ms^{-1} (8.2 fts^{-1}).

1996 – 2003. A fire prevention and fire service installations code was established, with a more vigorous assessment on the smoke control design. Consultants had to follow NFPA 130 and the associated fire regulations in Taiwan. Simulation results of the fire environment and evacuation procedures were justified.[16] Hot smoke tests were required for all stations with design fire size from 2 to 25 MW (6.8 to 85 MBtu/h). The effect of smoke movement on evacuation was observed. The assessment and inspection procedures took over one year.

2004. New fire codes were introduced by the Building Authority, with a mandatory inspection by the China Building Centre, a non-profit organization. CFD began to be widely used. Now, the Fire Dynamics Simulator (FDS)[17] is used in almost all projects. Inspections of smoke control systems became more complicated by including the following key points:

- ⇒ Smoke control and evacuation studies on the same space and fi re scenarios;
- ⇒ The worst scenario identification or;
- ⇒ Clarification of all simulation details;
- ⇒ Inclusion of visibility and thermal radiation;
- ⇒ Requirement of on site hot smoke test; and

⇒ Submission of an all emergency plan.

2006. The fire-safety code for subway stations and railway tunnels was implemented by the Highway and Traffic Department. The smoke control in all subway systems should follow NFPA 130 and CFD should be used when necessary. The code is no more prescriptive, but performance-based or scenario-based.

Asia/Far East Examples

Asia has some of the longest tunnels, for rail and road. In Japan, the Seikan tunnel is 53.9 km (33.5 miles) long; Hakkoda is 26.5 km (16.4 miles); Iwate 25.8 km (16 miles); and Kanetsu road tunnel is

11.1 km (6.9 miles). Long tunnels exist in China (Wushaoling rail at 21.1 km [13.1 miles], Zhongnanshan road at 18 km [11.2 miles]) and Taiwan (Hsuehshan road tunnel of 12.9 km/8 miles).

In Hong Kong passenger railway and subway systems are operated by two organizations that are proposed to be merged soon. The existing systems are East Rail, Kwun Tong Line, Tsuen Wan Line, Island Line, Tung Chung Line, Airport Express Line, Tseung Kwan O Line, West Rail, Ma On Shan Rail and Disneyland Resort Line. Fire-safety strategies were planned carefully in new stations and there are plans for upgrading the old stations for fire life safety.

Project Name	Duration	Description
FIT	2001-05	Fire in Tunnels thematic network (www.etnfit.net)
DARTS	2001-04	DurAble and Reliable Tunnel Structures (www.dartsproject.net)
SAFE TUNNEL	2001-04	Improvements to driver safety in road tunnels (www.crfproject-eu.org)
SIRTAKI	2001-04	Safety Improvement in Road & Rail Tunnels Using Advanced ICT and Knowledge Intensive DSS (www.sirtakiproject.com)
VIRTUALFIRES	2001-04	Development of a virtual reality real-time simulator for fire emergency in tunnels
UPTUN	2002-06	Cost-effective, sustainable and innovative UPgrading methods for fire safety in existing TUNnels (www.uptun.net)
SafeT	2003-05	Safety in Tunnels, a thematic network aimed at harmonization of best practices and development of guidelines (www.safetunnel.org)
L-surF	2005-08	Large Scale Underground Research Facility for safety and secruity in enclosed underground spaces (www.l-surf.org)

Table 2: European tunnel safety research projects.

Beijing has four subway lines at the moment, but eight will be in operation by 2008. Lines 1 and 2 are being operated since the 1960s, with a passenger loading of more than 1.3 million per day. Smoke exhaust and emergency ventilation systems are provided for underground stations and tunnels. Due to space limitations, the normal ventilation and air-conditioning systems are integrated with the smoke control system. Normal ventilation mode can be shifted to emergency mode immediately once a fire is detected.

For the first two lines, the fire-safety provisions were designed based on old fire codes. There is an action plan to upgrade the fire-safety provisions with three main tasks: upgrading ventilation and smoke exhaust systems, installing fi re suppression, water piping systems, automatic fi re detection and alarm systems.

Research

In the 1990s a major research program was carried on in an abandoned tunnel in West Virginia. The Memorial Tunnel Fire Ventilation Test Program (MTFVTP) was cosponsored by the Massachusetts Turnpike Authority, FHWA and ASHRAE for the Central Artery Project in Boston and included 98 controlled fire tests of up to 100 MW (680 MBtu/h), leading to valuable technical information and enhancements of tunnel ventilation engineering and applicable software.

An unprecedented number of research projects were launched in Europe in the last decade, in response to several tragic fi re accidents in tunnels. These projects (*Table 2*) constitute a comprehensive assessment of tunnel fire safety. For example, the FIT thematic network serves as data gathering, DARTS explores technologies for new tunnel constructions and UPTUN develops innovative and sustainable technologies for existing tunnels, whereas the Safe-T thematic network aims at harmonization of a global approach to tunnel safety. Although most of the projects focus on road tunnels, they also include metro and rail tunnels, such as FIT, Safe-T and UPTUN. However, fire safety in rail tunnels can be improved through regulations for the rolling stock and operational procedures.[3] This is in contrast to road tunnels, in which road users, traffic and vehicle variations must be considered.[6]

Lessons Learned and What's Next

The lessons learned from recent tunnel fire tragedies require attention and implementation of credible and economically feasible recommendations such as the following:

- ⇒ The emergency ventilation system must be capable of handling combinations of worst-case fire conditions: fi re size, location, fan availability, second train nearby, etc.
- ⇒ Vehicles are the main causes of fire, due to technical or mechanical faults or due to people's negligence or malicious intentions (such as arson).
- ⇒ Simultaneous/coincidental occurrence of other factors that contribute to the worst-case conditions should be considered including: · Activating the emergency ventilation system as soon as
- ⇒ possible after the fire is detected and its location is confirmed, and applying the preestablished scenario measures; and · Ensuring fans are never reversed once activated in one direction.
- ⇒ Further investigational work is needed and the fi re-safety objectives[3,18] for public transport must be reviewed carefully. Total fi re safety[14] can be used to provide passive fi re protection, active fire system and fi re-safety management. The following are suggested to be considered in further in-depth investigations.
- ⇒ A fire in the train and a fire in the railway terminal are not the same. In the train, the thermal response of the train system to an ignition source should be evaluated.
- ⇒ Materials with fire retardants should be tested under high radiative heat fluxes in a cone calorimeter and supported by full-scale burning tests. Attention should be paid to smoke toxicity of materials. The materials used should be controlled by proper assessment tests.
- ⇒ New active fire protection systems and extinguishing concepts are needed.
- ⇒ During a tunnel fire, crowd movement and control tend to be poor. The presence of platform screen doors might affect evacuation away from the train.
- ⇒ The following fi re-safety related issues must be considered in the analysis:

- Luggage and baggage (especially tourist groups traveling to the airport),
- Fire retardants to be tested under high heat flux with full-scale burning tests,
- New technology on active protection systems · Improved fire-safety management (including crowd movement and control),
- Total fi re-safety concept,
- Smoke toxicity of materials and its control.

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Safety & Security in Tunnels

Underground infrastructures are considered high-order terrorist targets because of their high visibility and cost. They have been the target of 40% of all terrorist acts worldwide. The type of threats can range from a fire incident (vehicle fuel, flammable cargo, liquid fuel tankers, flammable gas tankers), explosions (car bombs, truck bombs, boiling liquid expanding vapor explosion, emplaced charges), radioactive, chemical, to a biological attack. The damage can be somehow limited (casualties, vehicle damage, cosmetic, damage to ventilation and lighting systems, traffic sensors, etc.) and structurally major (liner, roadway, ceiling collapse, portal structural damage, tunnel flooding for submerged tunnels, complete tunnel collapse). Resulting repair costs can be in the range of thousands to hundreds of millions of dollars and the down time can be a couple days to more than a year. Such costs often can be dwarfed by the costs associated with business disruption from these incidences, which often can be much greater than the physical repair costs.

Over the past 10 years, terrorist attacks on transportation systems have claimed many lives and caused major disruption. Events such as those on the Tokyo subway (1995: 12 deaths and thousands sick), on the train station in Madrid (2004 and 2005: 191 deaths), on the Moscow Metro (2004: 39 deaths) and London (2005: 56 deaths) resulted in raised awareness of the vulnerability of infrastructural systems to terrorists' attacks. They have raised many questions with regards to the management of safety and security issues of existing and projected infrastructure in enclosed spaces, which require consideration and solutions.

Given the current gaps in technical knowledge and the complexity of such transportation systems, a new effort in research to improve safety and security in these systems is vital. The need for technical improvements, as well as consideration of various human factors, has already been recognized worldwide. The U.S. Federal Highway Administration (FHWA) has released a report, developed by the Office of Infrastructure Research and Development (R&D), proposing a plan to support national disaster preparedness and response and recovery efforts, as well as to initiate and facilitate research and technology development in support of a more secure highway bridge and tunnel system. Other offices of the FHWA are addressing research and development associated with securing other parts of the national highway system. Agencies and organizations like FHWA, American Association of State Highway and Transportation Officials (AASHTO), and the Intelligent Transportation Society of America (ITS America) have developed several publications. In an effort to strengthen transportation security, several long-term challenges have been identified. These include developing a comprehensive risk management approach; establishing effective coordination among the many responsible public and private entities; ensuring adequate workforce competence and staffing levels; and implementing security standards for transportation facilities, workers, and security equipment. In the description of the seventh framework program of the European Community (EC), "safety and security" is explicitly addressed as an individual topic for R&D activities and a first "European Conference on Security Research" was held in February 2006. Moreover, the EC strategic initiative on safety and security in underground and enclosed spaces includes several research projects. The L-surF (large scale underground research facility) project uses large-scale R&D, testing, training and education as tools to improve the safety and security of underground and enclosed spaces. The UPTUN project aims at developing innovative technologies in the areas of detecting, monitoring, mitigating measures, and protecting against structural damage. It also aims at developing risk-based evaluation and the upgrading of models.

It is not possible to protect everything against everything. Therefore, choices must be made in a logical manner as to which facilities/personnel/paraphernalia (critical assets) need most protection and what measures should be taken to protect them.

To decide as to which objects should be protected, a vulnerability assessment (risk analysis identifies the probability and consequences of an undesirable event) should be conducted on all national assets. A vulnerability assessment identifies weaknesses that may be exploited by identified threats and suggests options to address those weaknesses. The more vulnerable an object is, the higher the probability of attack.

In general, five basic categories characterize the protective countermeasures systems: deterrence, detection, defense, defeat, and strengthening of assets by structural hardening. The countermeasures commonly take the form of site work (associated with everything beyond 1.5 m (5 ft) from an asset and can include perimeter barriers, landforms, and standoff distances), building (measures directly associated with buildings including walls, doors, windows, and roofs), detection (elements detect such things as intruders, weapons, or explosives including intrusion detection systems (IDS), closed-circuit television (CCTV) systems, guards, etc.), and procedural elements (protective measures required by state or local security operation plans to provide the foundation for developing the other three elements).