JRC - ISIS

NEDIES PROJECT

Lessons Learnt from Tunnel Accidents

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Editor

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ABSTRACT

The NEDIES project is being conducted at Ispra by the Institute for Systems, Informatics and Safety (ISIS) of the EC Joint Research Centre (JRC). The objective of the project is to support the Commission of the European Communities, the Member States and other EU organisations in their efforts to prevent and prepare for natural and environmental disasters and to manage their consequences.

A main aim of the project is to produce "lessons learnt" reports based on experience gained from past disasters. This report discusses lessons learnt from recent tunnel accidents. It is based on the contributions presented at a NEDIES meeting held at Ispra JRC on 13 and 14 November 2000.

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1. INTRODUCTION

NEDIES (Natural and Environmental Disaster Information Exchange System) is a project concerned with natural and environmental disasters, which occurred in the EU Member States. It is conducted at the Institute for Systems, Informatics and Safety (ISIS) of the EC Joint Research Centre (JRC).

This report is based on the contributions presented at a NEDIES meeting on lessons learnt from tunnel accidents held in Ispra, at the JRC, on 13 and 14 November 2000.

Chapter 2 presents lessons learnt from the Mont Blanc Tunnel fire that occurred in 1999 (39 fatalities), two tunnel disasters occurred in Austria (Tauer tunnel accidents, 1999, 12 fatalities; Pfänder Tunnel accident, 1995, 3 fatalities). It also contains lessons learnt from other six tunnel disasters, recently occurred in Europe, that fortunately did not provoke fatalities. These are: the Channel Tunnel fire (1996), the fire in the Norwegian Seljestad tunnel (2000), the fire in the Amsterdam metro (1999), two disasters that occurred in 1997 in Italy (the rail-car incident in the Exilles tunnel and the HGV incident in the Prapontin tunnel) and the fire in the Munich Candid tunnel (1999).

Chapter 3 includes a contribution on emergency preparedness in Denmark and a contribution on the safety measures implemented in the Ecumenda tunnel, which recently opened in the Portuguese island of Madera. Chapter 4 gives a summary of the main lessons learnt. Finally, the appendix outlines the role of different international organisations involved in tunnel construction and operation.

The report is addressed to the Civil Protection Services of the EU Member States and organisations, and people involved in the management of any type of natural and environmental disaster. In fact, most of the "lessons learnt" from tunnel accidents discussed in the report are of great interest also for the prevention of, preparedness for, and response to other types of disasters.

2. LESSONS LEARNT

2.1 Fire in the Mont Blanc Tunnel (France)

Aristide CHINAL and Jean-Guy LAURENT (Prefecture of the south-east area, Lyon)

2.1.1 Date of the disaster and location

24 March 1999, Chamonix.

2.1.2 Short description of the event

Wednesday 24 March 1999, the usual mid-morning traffic is heading towards Italy. At 10.46 a Belgian truck enters the Mont Blanc Tunnel. The driver, alerted by flashing headlights, realises that smoke is pouring from his cab. He stops the vehicle halfway through the tunnel, gets out and tries to extinguish the fire, but with the blaze already out of control he abandons the attempt and raises the alarm. The fire in the tractor intensifies and spreads rapidly to the refrigerated semi-trailer, which itself begins to burn, along with its load of flour and margarine. The ventilation system was unable to prevent the air becoming unbreathable for everyone in the tunnel, due to the smoke heat and flames, and the toxic nature of the combustion gases. The natural airflow of the ventilation system, maintained by two ventilation units, carries the combustion gases towards the French end of the tunnel. This means that all those motorists who found themselves between the burning truck and the Italian plaza managed to escape, with help from one another and with assistance from employees of the operating companies. It also meant that those caught between the French plaza and the truck died, regardless of whether they stayed in their vehicles, tried to escape or even managed to reach a refuge point supplied with fresh air.

With no details of the size of the fire or the number of vehicles involved, the emergency services, which responded to the alarm (tunnel and public services, from both the French and Italian sides) failed in their attempt to reach the burning truck. On the French side, where a thick mass of smoke and unburned gases was forming, a fire fighter from Chamonix lost his life. All the other fire fighters came out of the perilous operation alive, but at an enormous technical, physical and psychological expense. An employee of the Italian operating company died trying to help people escape. It was possible to bring the blaze under control only by regrouping all the emergency services on the Italian side, advancing under the protection of mist devices and extinguishing the 34 vehicles caught up in the fire. The scale of the disaster had become fully apparent only after 54 hours of unremitting efforts.

2.1.3 Human consequences

In terms of human lives, the cost was very high: 37 drivers and passengers died asphyxiated by searing toxic gases. Some, having already suffocated, were literally incinerated in their vehicles or on the roadway. Two others did not die until several hours later, killed as the heat of the blaze penetrated the walls of the shelter in which they had taken refuge (one driver and the employee of the Italian Company, the 38th victim). Finally, the member of the Chamonix Fire Brigade appeared to have died of a heart problem coupled with incipient asphyxia.

2.1.4 Economic losses

The Mont Blanc Tunnel, a French-Italian construction providing a passage through the Alps, has been completely out of action for 19 months already. It is due to reopen in the summer of 2001, i.e. after around 28 months of closure encompassing the judicial enquiry, the planning and implementation of repair work, inspection of the repaired tunnel, and the granting of official authorisation to reopen to traffic.

Annual revenue in 1998 was about 120 million Euro. This has fallen to zero. On top of these operating losses come the cost of repairing the tunnel (estimated at 200 million Euro), the legal costs, and heavy economic losses for many French and Italian companies. It will be possible to take full economic stock of the disaster only in a few years' time, once all the details have emerged and can be fed accurately into the calculation.

2.1.5 Prevention measures and related lessons learnt

Construction standards and technical installations

The Tunnel was built in 1965 in accordance with contemporary designs and standards regarding access, ventilation, emergency equipment, shelters, etc. A number of improvements were made over the years, including construction of refuge points, a water supply for fire fighting, radio communications and closed circuit television. Further, improvements suggested by modern thinking would have been difficult or impossible to introduce without a full scale rethink of the tunnel or its access points, e.g. reduction in the incline of the access slope, opening of intermediate vents to feed underground ventilation or smoke-extraction plants, provision of large, specially located refuge areas, etc.. Prevention has to be built into a project ahead of actual construction; afterwards, the options are severely limited.

The core concern, and the purpose of all safety arrangements, is to protect the public. In constructions of this type, factors considered harmless in open-air situations are potentially catastrophic.

The purpose of accident prevention measures must be to limit the risk of untoward events happening in the first place, but also the possibility of them escalating.

Lessons learnt using the tunnel

- The dangers inherent to long, isolated, single-bore two-way tunnels means we can only allow "healthy" vehicles to use them.
- A visual inspection of the state of a vehicle (no sign of leaking fluids on the tank or the load, etc.) is essential. Signs reminding drivers that they must not run out of fuel need to be sited ahead of the tunnel.
- Heat-detecting "portals" can be installed to tackle the problem of vehicle 'hot spots'. These systems still need to be made more reliable, but before too long it should be possible to detect a turbo-charger about to rupture, overheated brakes, or temperature increases in the cargo. At the slightest suspicion, vehicles must not be allowed into the tunnel without further inspection.

2.1.6 Preparedness measures and related lessons learnt

- Inherent in the notion of preparedness is the recognition that accident prevention is not always 100% effective; accidents do occur and measures need to be taken to limit their impact. Planned from the very outset, the preparedness measures drawn up by the operating companies and the public emergency services have been continually refined.
- Unlike the case with prevention, significant improvements to preparedness arrangements can always be sought in order to compensate for structural shortcomings. In the case of the Mont Blanc tunnel, emergency vehicles have been purchased and replaced. A 24-hour rescue team was located at the French plaza. The pressurised water supply was a boon during the operations; water had originally to be sucked out of the tunnel's drainage system through openings in the carriageway.
- Unfortunately, few simulation exercises have been organised since the tunnel opened, and this has limited drastically the potential improvements, which might have followed such exercises.
- For this type of construction, preparedness is now based largely on automatic detection of fires and incidents. Improvements have also been made to emergency equipment, including on-board heat cameras for driving in zero visibility, long-endurance breathing apparatus, and clothing, giving slightly more protection against radiant heat. All these measures need to be tested during exercises to check their suitability and maintain them at peak performance. The cost of such exercises needs to be covered by the tunnel's economic operation. Users are willing to pay that cost on condition that it translates into provision of a proper safety service. Everything needs to be tested:

equipment, procedures, the behaviour of staff on duty in the tunnel, and, today more than ever, the attitude of the public. The fact is that the behaviour of the public is the main precondition for successful operation. Preparedness now needs to incorporate this factor through the use of appropriate signalling systems to guide the actions of all those using the tunnel.

- Special training is required for the tunnel's own safety teams and for the local public Fire Brigade whose services might be called upon, e.g. initial training for all new recruits and on-going training for everyone.

2.1.7 Response actions and related lessons learnt

- In this major accident, the control centre received information on the fire and reacted to it, but perhaps not with the requisite speed. The tunnel's own emergency team responded, but with the airflow pushing the smoke down towards them they were soon unable to make any progress. The reinforcements from Chamonix encountered the same problems a few hundred metres further along, as a thick mass of smoke continued on its deadly course. The fire gained the upper hand and spread quickly, like a fire in a (virtually horizontal) chimney, with which fire fighters are all too familiar. What this accident has shown is that a fire burning freely in a tunnel will rage out of control if not contained within the first 15 minutes. All the members of the rescue services tried to intervene, but in the face of such difficulties (high temperatures, completely opaque smoke, toxic combustion gases, etc.) an orderly retreat was the only way to ensure their own survival. All the resources assembled at the tunnel's entrance ran into one essential problem: they did not know what was happening inside. And so they did not know what to do.
- To remedy this problem, the control centre needs to make a rapid assessment of the situation so that it can trigger the arrangements for its solution. For instance, an opacimeter will detect a large amount of smoke and the controller, assisted by the centralised technical management, including decision-support, will implement all the instructions laid down for such incidents: closure of toll stations, alert given to the emergency services at the plaza, information passed to the other plaza, activation of tunnel signals, public Fire Brigade alerted in both countries, activation of ventilation systems as appropriate, etc.. The controller will try to "read" what is happening in the tunnel using all the means available to him: detectors, traffic surveillance cameras, verbal exchanges with the other access plaza, questioning of drivers leaving the tunnel. As much accurate and reliable information as possible must be gathered. Precise knowledge of what is happening will make for effective action.
- No time must be lost in gathering and analysing the information, selecting a course of action, acting, and monitoring the operation as it proceeds.
- Automation of existing technology should serve to relieve control room operators of all simple tasks so as to leave their minds free for "high added value" work and enable them to bring their expertise to fruition, in collaboration with the head of the emergency team.

2.1.8 Information supplied to the public and related lessons learnt

Prior to the event

- Private motorists using the Mont Blanc tunnel know that it is also used by heavy goods vehicles, that a toll is levied and that the usual signs and signals of the Highway Code apply.
- In addition, truck drivers know that hazardous materials are not allowed through (they may be taken, with an escort, through the Fréjus tunnel located further south). Signs indicate a steep climb (7%) at the tunnel's entrance. Regular users know that the tunnel is narrow, that it is difficult for trucks to overtake one another, that vehicles must keep to the right, and that the tunnel rises to its midpoint and then descends. HGV traffic is increasing steadily, thanks to the international trade stimulated by Europe and the free movement of goods. Drivers are paying to enter and use the tunnel, but the price must also include guaranteed safety precautions.

During the event

- All users arrive at the toll barriers and wait their turn to go through. When the barrier rises, they move forward to enter the tunnel. At what point was the decision taken to halt the traffic? That will be determined by the current enquiry. It would appear that no arrangements were in place for the major operation of closing both the French and Italian toll stations at the first sign of an incident, either automatically or via instructions to the control centre operators.
- Vehicles entered as usual, even though the fire had already broken out and was spreading rapidly. The barriers were lowered a few minutes later, but did the lights change to red? The motorists in the tunnel drove on until they reached the burning truck. The most intrepid among them drove around the stricken vehicle and reached the Italian side unharmed, leaving 23 other vehicles packed in a tight row behind the truck. Some drivers realised what was happening and tried to escape through the tunnel. Some chose to wait in their vehicles, others gathered together collected in another vehicle, and others still found a shelter and reported their presence. Contact was possible for a while with the control centres, which should have given them instructions.
- Death did not come immediately to those who managed to reach a shelter. Though they believed themselves to be safe, the intensity of the fire and the extreme temperatures reached in the shelter (which was protected, but had limited refractory capacity) proved fatal. It seems essential, then, for every long tunnel to be equipped not only with a highly effective audible and visible signalling system, but also regularly spaced refuges providing access to a protected evacuation tunnel equipped with motor vehicles.

After the event

Information of the preventive type

At the two tolls located in front of the entrances of the tunnel, the employee can systematically give the driver of the vehicle a brief security note along with the toll ticket. The security note would explain the use of the various devices available to the drivers in the event of a problem: mechanics, fire, accident, escape, etc..

One kilometre before the entrance into the tunnel, multilingual panels or "speaking" graphics would advise the drivers to regulate their car radio to the tunnel's frequency or, at least, to put it under operation if their system includes RDS.

Information of the curative type

It is proposed to transmit warning messages in several languages to the drivers. According to the type of incident, the message could include:

- stop the vehicle immediately,
- lissen to the tunnel's radio frequency,
- evacuate towards refuge immediately,
- wait for the arrival of help,
- etc..

The messages broadcasted on the tunnel's frequency could also be written on panels, in various languages.

These bulky panels could be systematically installed on the front walls of the garages and lateral niches.

Lastly, a radio system for the tunnel could be considered, with the possibility of choosing the sector of the tunnel where the message should be broadcasted. This would enable the manager to convey targeted messages, according to the tunnel situation at hand. Monitoring cameras make it possible to observe in real time what happens. Efficient messages given at the right time would save lives and avoid crisis situations to degenerate.

2.2 Tauern Tunnel Accident (Austria)

Rudolf Hörhan *(Ministry for Transport, Innovation and Technology, Vienna)*

2.2.1 Date of the disaster and location

29 May 1999, approximately 700 meters from the north-east portal of the Tauern tunnel.

2.2.2 Short description of the event

The Tauern Tunnel has a single shaft with a length of 6,400 m. The daily average traffic is just under 15,000 vehicles, of which lorries account for around 19 % of the traffic on the highway, and many caravans also use this route in summer time. The cross section shows two traffic lanes, each with a width of 3.75 m, with a raised hard shoulder on either side1.00 m wide. The ventilation system consists of full transverse ventilation with 4 ventilation sections. The maximum volume of fresh air, according to the ventilation calculation, is approximately 190 m^3/s km and the maximum volume of exhaust air is approximately 115 m^3/s km. Exhaust air openings are situated every 6 m in the tunnel ceiling. In the spring of 1999, maintenance work in the tunnel was done. The concrete was renewed with a new coat of paint applied over a length of approximately 500 m in the portal area of the tunnel. During repair work, one lane of a length of approximately 500 m was closed for traffic by traffic lights, which were positioned at the northern portal of the tunnel and approximately 600 m from the portal itself.

On 29 May 1999, at 4.53, a lorry loaded with various types of spray cans, including paints of class 9 dangerous goods, was travelling north and had to pull up behind a number of vehicles already waiting in front of the traffic lights. Four other vehicles stopped behind the lorry in a normal way. Then, another lorry approached and rammed into the waiting traffic pushing two cars under the halted lorry loaded with the spray cans and pressing two cars up against the tunnel wall. Eight people died in three of the four cars, presumably as a direct consequence of the rear end collision. Two people with only minor injuries were able to escape from one of the two cars pressed against the wall. Besides the eight victims mentioned above, there were four other fatalities, who died in the fire that followed the accident. For inexplicable reasons, two people from Belgium remained inside their vehicle. A Greek lorry driver, who had already fled to safety, returned to his vehicle to collect some documents. He then goes into the car with the two Belgians. A German lorry driver suffocated approximately 800 m from the scene of the accident while trying to flee. Three colleagues escaped to an emergency call niche, from where they called the tunnel control centre and were ultimately rescued by the fire services.

After the rear end collision the fuel tanks of the cars were ripped open and the fuel poured out and ignited. A major fire then broke out. Initially, the smoke lay essentially along the ceiling with a smoke-free zone created near the ground. According to eyewitness accounts this layering was successfully maintained for at least 10 to 15 minutes. As a result many people, probably around 80, were able to exit the tunnel, partly in their cars and partly on foot. Then, several explosions occurred, generating a great deal of heat and smoke. Although the smoke was still being successfully extracted, the heat and smoke generated was ultimately so great that it was no longer possible to keep the carriageway free of smoke.

2.2.3 Human consequences

The accident and the fire that followed claimed the lives of 12 people, 49 people suffered light injuries, due mostly to slight smoke inhalation and minor burns.

2.2.4 Economics losses

16 lorries and 24 cars burned inside the tunnel.

The damage to the tunnel was mainly in: the intermediate ceiling, the inner concrete of the tunnel walls over a length of 350 m, the concrete carriageway surfacing and the niches over a length of 900 m. The repair work cost around 6 million Euro, with soot cleaning accounting for around 0.7 million Euro.

The total closure of the tunnel was used to make improvements to the ventilation system. Instead of the old small apertures in the ceiling leading to the exhaust-air duct, larger 2.30 by 2.30 m apertures were cut out and filled with exhaust-air louvers. In principle, the louvers are open. In the event of a fire, they are closed down by means of a hydraulic drive system, except for those two closest to the seed of the fire. Beside the ventilation system, the tunnel radio system and the data transmission system were improved. The costs for the improvements of these safety systems are about 2 million Euro.

2.2.5 Prevention measures and related lessons learnt

- In the case of repair or maintenance work, traffic lights must be set up at the portals outside the tunnel.
- Regulations for transportation of dangerous goods for two-way tunnels and accompanying duty plans were issued.

- The driving test should include specific questions concerning the behaviour of road users in the event of a traffic jam, an accident or a break down and a fire in a tunnel.

2.2.6 Preparedness measures and related lessons learnt

Construction measures

- On motorways, in some cases of single shaft tunnels (4 lanes before and after a tunnel) double shaft tunnels were built mostly depending on the traffic volume.
- Emergency tunnels, which are still in the planning and building stages, were enlarged so that emergency service vehicles can pass through (cross section 3.5 x 3.6 m). The traverses are equally passable at a distance of 500 m for emergency service vehicles between two shafts, all 1000 m for all vehicles (trucks too) passable.
- The emergency call, still available in some old tunnels, should be altered on accessible emergency niches.
- In projected tunnels longer than 1000 m, only concrete pavements were authorised.
- At especially dangerous tunnels, portals and lay-by niches, impact dampers were mounted. The impact dampers are designed to absorb energy and offer a high safeguarding protection during frontal impact.
- Doors to electrical operating rooms and emergency exits are to be carried out with fire resistance class T30 (fire resistance for 30 minutes - EI 30 British Standards)
- The tunnel walls must be lighted by renewing the paint.

Electromechanical measures

- The ventilation systems are going to be enlarged, considering a truck fire. Reference terms are a calorific power of 30 MW and a sucking amount of 120 m^3/s.
- Seem transverse ventilation systems with a fresh air supply are going to be raised into tunnels, with air sucking. Big apertures largely 5 m^2 will be built into the ceiling. In the future, only semi-transverse ventilation systems will be approved, with exhaust air sucking. Available semi-transverse ventilation systems have the disadvantage, in the case of a fire, that the fans and airflow must be reversed.
- Adjustable louvers are going to be mounted, in the ceiling of tunnels with transverse ventilation systems.
- Tunnel radio systems are going to be improved for safeguarding against failure.
- For automatic fire detecting systems, the maximum detection time has been defined, depending on the air velocity.
- Maximum allowable data transmission for emergency call system, and the transmission from the equipment to the control centre, have been defined.
- The cables for energy supply, safety current supply and fans, along with the transportation cables for radio, and fire alarm systems, are to be equipped with raised isolation reception.
- Escape route orientation signs along the tunnel are going to be installed. The distance to the next escape route or tunnel portal is to be indicated at a distance of approximately 125 m on the right tunnel wall.

2.2.7 Response actions and related lessons learnt

The information system for the fire brigade must be improved to make possible a quick intervention in the shaft. The fire fighting should start from both sides of the tunnel after 20 to 30 minutes at least.

2.2.8 Information supplied to the public and related lessons learnt

- Information and education of motorists on the correct behaviour in tunnel, will be provided by means of video and safety booklets distributed in driving schools and suitable places.

2.3 Pfänder Tunnel Accident (Austria)

Huber Vetter (Office of the Government of the Province of Vorarlberg)

2.3.1 Date of the disaster and location

10 April 1995, Bregenz (Vorarlberg).

2.3.2 Short description of the event

The Pfänder tunnel is situated at the eastern corner of the Lake of Konstanz (Bodensee). The tunnel, nearly 7 km long, connects the highway between Germany and Austria into the Rhein Valley. It is one of the major traffic ways from the south to north side of the Alps. The traffic frequency is about 7 million vehicles per year in a single shaft.

At 8.40 the accident happened 2.6 km from the south portal. An articulated lorry, two cars and a mini bus with caravan were involved in it. At this time, with only 80 vehicles, the traffic was very low. The crash between lorry and bus caused a fire, and two cars were also involved. This accident was the first biggest tunnel accident in the history of Austria and, as far I know, also in Europe.

2.3.3 Human consequences

Three people died immediately following the crash, and not due to the fire; burnt victims could not be recognised. In the first rescue phase, 10 victims were saved and received first aid; one of these was seriously injured.

2.3.4 Economic losses

Economic losses are not available because the response was based on the action of volunteers. The losses of tunnel concrete, radio communication, lighting and infrastructure were very high.

2.3.5 Prevention measures and related lesson learnt

No information available.

2.3.6 Preparedness measures and related lesson learnt

- The experience of this accident has shown that, in the first phase of the intervention, the members of tunnel Fire Brigade and rescuers need to already know each other, especially because the fight against fire has to start from both sides of the tunnel, at the same time interdependently.

- The accident led to a revision of the emergency plan and to a reorganisation of the inspection and monitoring system.
- The communication system was rebuilt on a very high security level.

2.3.7 Response actions and related lessons learnt

Looking at this event some years later, it can be stated that all the organisations involved have learnt from the disaster. This learning was confirmed during the accident in the Tauern tunnel.

Lessons learnt concerned with Fire Brigade

- A tunnel radio communication system must be built up and connected with systems outside the tunnels.
- A team responsible for press and public relations should be created.
- Fire brigades should be provided with specific equipment to fight against tunnel fires (for example infra red cameras).
- The emergency management system of federal streets and highways should be integrated into the disaster plans of local and regional administrations.

Lessons learnt concerned with medical service

- The search and information procedure for missing persons is to be reorganised and standardised with the Police.
- It is necessary to involve a psychological team directly on site.

Lessons learnt concerned with police

- The radio system must be interchangeable and allow interconnection. It is to be installed in a common press centre.

Lessons learnt concerned with rescue service

- The co-ordination between Fire Brigade and rescue service is to be optimised.
- Rescue service needs a "clear" command to execute inside the shaft.
- Some of the fire fighters needed a debriefing procedure, in the form of personal reports to hand in with their impressions.

2.3.8 Information supplied to the public and related lessons learnt

- The requirement that press and public relation services have to work under control was once more one of the experiences.
- A press centre has to be installed and press information must be exactly planned.
- The public and persons potentially concerned should be informed by a common emergency information centre.

2.4 Channel Tunnel Fire (UK)

William Welsh *(Kent Fire Brigade, Tovil)*

2.4.1 Date of the disaster and location

18 November 1966, Channel Tunnel.

2.4.2 Short description of the event

The County of Kent

The County of Kent is situated in the south-east corner of England and it is well known as the Garden of England. It is also commonly referred to as the gateway to Europe having a number of ports, with Dover being one of the busiest passenger ports in Europe. In addition to this there is, of course, the Channel Tunnel Terminal. The county covers some 1500 square miles, with approximately 1,500,000 people depending on the Kent Emergency Services. Kent Fire Brigade serves these people with 66 Fire Stations, 1000 full time and 900 part time fire fighters.

History

The Channel Tunnel has now been fully operational for a number of years, but prior to this the Kent Fire Brigade had been actively involved in the design and construction phases. The construction, which commenced in 1987, and design of the system, had to be approved by the Intergovernmental Commission (IGC) which was set up under the terms of the fixed link treaty, ratified following the enactment of the Channel Tunnel Act 1987 in the UK and relevant legislation in France. The IGC is advised, where appropriate, by the Safety Authority.

The Safety Authority, on behalf of the IGC, examined the designs and proposals as they were submitted, to ensure that the basic requirements for safety as set out in the Concession Agreement had been met. This included Eurotunnel's analysis of the risks and the measures necessary for dealing with an emergency that might arise. The Safety Authority has had to be satisfied that the necessary consultation has taken place between Eurotunnel and the Emergency Services to achieve this. The Safety Authority oversaw that the construction of the tunnel and its associated works were carried out in a safe manner and, as the system was taken into use, approved the operating rules and procedures, monitored the safety standards including liaison with the Emergency Services and the practising of emergency drills. There is no limitation on the powers of the Safety Authority to consider any matter relevant to safety in the design, construction and operation of the tunnel.

The Kent Fire Brigade has always stated their concern over the design of the Heavy Goods Vehicle (HGV) shuttles and the most likely outcome in the event of a fire in one of the HGV vehicles. This concern was listened to by Eurotunnel and the Safety Authority but it was eventually decided that Eurotunnel's safety case surrounding the design was such, that provision had been made for the safety of passengers in the event of an accident.

The event

At 21.53 hours on 18 November 1996 a call was received by Eurotunnel operators that there was a fire onboard a HGV shuttle, mission number M17539. The shuttle was carrying 31 passengers and 3 crew members all of whom had to be evacuated because of the fire. Six of the passengers and crew received hospital treatment for smoke inhalation.

The fire caused severe damage to 10 HGV wagons, the HGV loader wagon, one locomotive unit and 10 HGV lorries. The tunnel structure and equipment were also severely damaged by direct burning and heat, resulting in over 2 km of tunnel being affected. Due to this, services at the Channel Tunnel were substantially disrupted for many weeks during the busy pre-Christmas period.

As a result of the incident, the Governments of the United Kingdom and the French Republic asked the Anglo-French Channel Tunnel Safety Authority to carry out an investigation. The Authority were asked to investigate the following areas of concern plus more:

- the procedure to be adopted in the event of a fire in the tunnel to ensure safe evacuation of passengers;
- the adequacy of the ventilation system to deal with smoke and toxic fumes;
- the liaison arrangements between the British and French emergency agencies.

Also as a result of the fire, Eurotunnel carried out its own internal inquiry, which had two purposes:

- to consider what lessons could be learned from the accident;
- to establish what changes, if any, were necessary in the physical equipment, training, procedures and staffing.

2.4.3 Human consequences

The shuttle was carrying 31 passengers and 3 crew members all of whom had to be evacuated because of the fire. Six of the passengers and crew received hospital treatment for smoke inhalation.

2.4.4 Economic losses

- Loss of service.
- Loss of customers.
- Loss of faith in service.
- Installed concern about mode of travel.
- Financial cost in the region of 340 million Euro direct losses.
- Review safety case for HGV shuttles.
- Loss of experienced workforce.

2.4.5 Prevention measures and related lessons learnt

Eurotunnel

- *Detection during loading.* Two measures will be taken at the time of loading:
  - more systematic checks of each lorry during loading;
  - surveillance of each departing shuttle by staff located at the ends of the platform and in direct contact with the Rail Control Centre (RCC).
- *The drive-out policy.* The ‘drive-out’ policy for HGV shuttles is to apply only if the train has reached a point close to the exit of the tunnel, in all other cases the driver will carry out a controlled stop and evacuate the train.
- *Decoupling.* The decoupling option has been dropped in order to give priority to the immediate evacuation of passengers.
- *Catenary failure.* Overhead line equipment cable lugs will be secured by crimping.
- *Train location*
  - The visibility of tunnel markers and cross-passage numbers will be improved by fluorescent paint and enhanced lighting.
  - Equipment will be installed to make it possible to identify with greater precision

the location of an incident train.

- *Smoke control in tunnel.* The process of configuring the tunnel (closing piston relief ducts, activating supplementary ventilation) will begin immediately there is a single fire alarm of any type.

Additional staffing and training

- RCC staffing will be strengthened to include, among others, personnel to assist in the handling of an emergency.
- Eurotunnel's training programme will be enhanced, all railways controllers, train crews and FEMC staff, as appropriate, will undergo initial fire training.
- Simulation of the RCC, the tunnel cross passages and Service Tunnel will be provided to ensure realistic emergency training for crews and First Line of Response (FLOR).

2.4.6 Preparedness measures and related lessons learnt

Incident Planning

- From the onset of the construction phase, the Kent Fire Brigade and the other Emergency Response organisations have been involved in the emergency planning process. The initial step was to clearly identify primacy i.e. which organisations were responsible in the event of an incident, for specific areas of operations. In the French Republic this was relatively simple: the Prefect, having control over all operational activity in the event of an incident. In the UK, however, it is somewhat more complex with a number of Emergency Response Organisations (EROs) and other organisations involved. Primacy was defined and recorded in what was termed the Bi-National Plan. There was also a need to define clearly in which country the operations are based, this was achieved through agreement and the concept of lead and support nation was brought about.

Recommendation 15 - Safety Authority Report

- Eurotunnel, with the assistance of the Emergency Planning Committee must review priorities and procedures for alerting the external emergency services.

  This situation has been greatly improved by the enhancement of staff in the RCC, there is now a dedicated post to the monitoring of alarms, etc., and the alerting of the Emergency Services. The new post has been named Fire Detection Controller.

Recommendation 16 - Safety Authority Report

- The review group decided that joint training, as referred to in the recommendation, should be divided into 4 areas of need:
  - Bi-National training First Line of Response (FLOR).
  - National training between FLOR and SLOR (Second Line of Response).
  - Bi-National training for all FLOR and SLOR.
  - National and Bi-National training between Emergency Services and Eurotunnel.

2.4.7 Response actions and related lessons learnt

First Line of Response (FLOR)

- The first indication, at 21.45, of an incident was the actuation of the South Running Tunnel fire detection. By 21.50 the FEMC operator had mobilised both Nations FLOR. This rapid deployment greatly assisted in the evacuation and first aid treatment of the passengers and crew. Had this not been the case and had oxygen resuscitation/therapy equipment and trained personnel not been available the injuries sustained may have been more serious.

Second Line of Response (SLOR)

- The Second Line of Response is made up of a number of levels each level is mobilised as and when required, with Level 1 being mobilised as soon as a call is received.
  The Kent Fire Brigade mobilised its level one response to a report of a fire on board a shuttle at 23.02, some 1 hour 15 minutes after the first fire detection operated. In my opinion, this delay, although not endangering life, resulted in greater uncontrolled fire development and damage.

Main problems encountered by the second line of response

- There was a substantial delay in alerting the Kent Fire Brigade.
- Initial communications via the concession radio were not possible.
- The positioning of some STTS (Service Tunnel Transport System) vehicles caused problems.
- The fire main initially failed to provide the quantity of water required and it took some time to reconfigure the supply routes.
- The refreshments initially available were insufficient.
- A number of leaks on the fire main were apparent; it is believed that these may have been caused by the heat within the running tunnel.
- Personnel were required to wear breathing apparatus twice in extremely arduous conditions.
- Difficulties were experienced in transporting additional personnel to the incident scene.

Principle of the inner cordon layout procedure

- The agreed arrangements between the Kent and Nord-de-Pas-de-Calais Emergency Services were revisited in the light of the experience gained at the incident.
- It is crucial that the Service Tunnel area at the site of any incident is effectively managed. Failure to do so will inevitably lead to delay and confusion. It is important that each service operating within the tunnels are aware of and adopt the principles agreed.
- Effective cordoning will allow operations at the incident site to continue in safety and without interruption. Each incident site must be treated as a 'scene of crime' and preserved as such. It must be recognised that within these restricted areas there may be

specific hazards. The demarcation and control of the inner cordon will be a matter for commanders to take into account according to the circumstances of the incident.

- Only authorised personnel, i.e. those having an accepted function, should be allowed within the inner cordon. The entry and exit of all persons and emergency service personnel must be logged in accordance with service procedures. Authority for access to the incident site for other than necessary emergency services will be sought from the Forward Control Point. Records will be kept for evidential purposes.
- Police Officers from the initial Police response team will be responsible for manning the inner cordon within the Service Tunnel. The normal position for the edge of the cordon will be one cross passage from the front of the incident train and one cross passage to the rear of the incident train. The officers at these locations will stop and log details of all vehicles and personnel. Non essential service tunnel traffic will be held at this location. Officers will ensure a 50 metre zone is created to allow service tunnel traffic to turn round. These procedures should in no way effect the operational requirements of each Emergency Service; they may be altered as appropriate by the forward incident commanders to reflect the specific nature of the incident.

2.4.8 Information supply to the public and related lessons learnt

Information not available.

2.5 Fire in the Seljestad Tunnel (Norway)

Hans Kristian Madsen *(Directorate for Fire and Explosion Prevention, Tonsberg)*

2.5.1 Date of the disaster and location

14 July 2000, Seljestad tunnel, on E 134 in the municipality of Odda.

2.5.2 Short description of the event

On Friday, 14 July 2000, a traffic accident occurred in the Seljestad tunnel on E 134 in the municipality of Odda. Odda is a town in western Norway. The Seljestad tunnel was built in 1964. It is nearly 1300 meters long and has a downhill slope from the east-end to the west, of approximately 6 %. Estimated mean traffic is 1050 vehicles per day, of which 15 % are trucks. The accident was reported at 20.53 to the regional communication central dedicated to handle fire alarms in the county of Hordaland. Eight vehicles were involved, seven passenger cars, and one truck.

The accident occurred 300 meters from the west-end of the tunnel. Two large trucks met and had to slow down speed to a minimum. Because of the speed reduction, five passenger vehicles had to stop behind the west bound truck. From behind this small queue came a single truck, which did not manage to stop in time. The truck crashed into the other vehicles causing a pile-up. Immediately after the pile-up one of the vehicles, possibly the single truck caught fire, and within a few minutes the fire involved all vehicles.

Behind the burning vehicles came a car with two young females and two small children. When they encountered the smoke, they managed to turn the car and tried to escape out of the tunnel the same way they went in. Due to heavy smoke the visibility in the tunnel rapidly became zero. They then left their car and tried to walk out. At that time they were totally engulfed by smoke. These four individuals where found after the fire fighters had extinguished the fire and started searching for victims. They were immediately escorted out of the tunnel and handed over to the ambulance personnel, and transported to hospital. All other persons involved in the pile-up managed to escape the vehicles through open doors and windows to safe area outside the tunnel.

A vital communication cable mounted in the ceiling of the tunnel was destroyed after a few minutes due to the heavy fire. As a consequence the Road Traffic Centre (RTC) in Bergen lost communication with the tunnel. This cable was also the signal cable for the fixed and mobile telephone systems, and the whole telephone system in the area broke down. Therefore, the communication central to handle fire alarms did not manage to call out the Fire Brigade located closest to the scene.

2.5.3 Human consequences

More than 20 people were sent to the two hospitals of the region for a medical check, all of them with minor injuries. The two females and their young sons were sent to Haukeland Regional Hospital under the suspicion of being severely injured by smoke inhalation. They were discharged from hospital a few days later after treatment. No lives were lost. So far there is no knowledge of long-term health effects on the persons involved in the accident.

2.5.4 Economic losses

The road tunnel is owned and operated by the Norwegian road authorities that cover their own losses. The damage on the tunnel is therefore not fully known, but we estimate that the overall economic losses were more than 250,000 Euro. This sum does not include costs generated by the response of the police, Fire Brigade and ambulance services, nor does it include medical costs concerning the treatment of the persons involved.

2.5.5 Prevention measures and related lessons learnt

Prevention measures

According to the Norwegian act of fire prevention, the owner of the tunnel is responsible for the fire safety. This includes technical measures, such as ventilation systems, emergency lightning systems, carbon monoxide indicators, fire extinguishers, red lights outside the tunnels to stop other traffic, and public emergency phones. This also includes risk analysis and planning by the owner, including the assigning of a dedicated person responsible for fire prevention in general, exercises and emergency reaction.

Lessons learnt

- Vital communication cable must be fireproof or fire protected. It is not acceptable that tunnel communication systems breaks down in case of fire. (In fact, most of the Norwegian road tunnels have fireproofed or fire protected communication cables.)
- Traffic moving into a tunnel where fire is developing must be stopped on the outside. This requires at least red light signals outside the tunnel entrance, and if the tunnel is long, red light signals, in addition, inside the tunnel. To ensure more efficiency, the red light should be reinforced with bars outside the tunnel entrances.
- It is vital that the public may call for help using public emergency phones. Emergency phones must be installed frequently inside the tunnel. Together with the emergency phones there must be fire extinguishers. The removal of a fire extinguisher should give

a signal at the Road Traffic Centres, and lead to immediate response. Combined with this automatic signal system attached to the fire extinguishers there must be other fire alarm systems.

2.5.6 Preparedness measures and related lessons learnt

Preparedness measures

Since no Norwegian road tunnels have dedicated emergency response personnel it is up to the local Fire Brigade to intervene when accidents happen. All municipalities are obliged to have fire response services, either on a full time basis or part time basis/retained. Most of the 435 local municipalities have Fire Brigades based on part time employed fire fighters (retained). Most Norwegian road tunnels are located in sparsely populated parts of the country with long response distances for the Fire Brigade. Due to this fact it is obvious that the Fire Brigade can do little to save the lives of people who are trapped in a burning tunnel. A lot of the Norwegian fire fighters are not trained and properly equipped for action in smoke-filled areas.

Concerning tunnel operations, preparedness measures for the local Fire Brigade consists of describing the level of competence, exercises, equipment and fixed action plans concerning how to respond to a tunnel fire. This includes establishing a co-ordination centre, how to approach the fire scene and how to return safely. Furthermore, it includes description of the communication systems, where to get regular water supply and how to control the tunnels ventilation system.

Lessons learnt

- Nearly all road tunnels in Norway have longitudinal ventilation systems. As long as the fire fighters can operate with the wind from behind it is possible to operate safely. From a Norwegian point of view this is perhaps the most important issue when it comes to fire fighting and rescue operations in tunnels. Never try to turn the draught by reversing ventilation when a fire has broken out. If this is absolutely necessary the decision to do so must rest upon the fire chief in charge.
- All Fire Brigades with responsibility for fire and rescue operations in tunnels must pre-plan their operations. The plans must be co-ordinated with the police, the ambulance and healthcare service and the owner of the road tunnel.

2.5.7 Response actions and related lessons learnt

Response actions

First rescue unit on scene was a single ambulance, 15 minutes after being alarmed. The fire service reached the fire scene 30 minutes after they were alarmed. The first fire unit on scene was a fire fighting vehicle manned with four fire fighters and carrying 2000 litres of water, and rescue tools. They immediately started to plan the engagement and then entered the tunnel according to their pre-planned procedures. The fire fighting operation was said to be rather easy, and because of the heavy draught (the speed of the wind was said to be around 8 meters per second) they were able to move close to the fire scene. There was shortage of water, but this was solved by pumping water into the tank on the fire fighting vehicle with hoses from an open water source outside the tunnel.

The local Fire Brigade from the city of Odda used a so-called “Pluto-carrier”, a large reservoir for pressurised air. The carrier consists of a bank of breathing apparatus and it supplies the fire fighters with pressurised air so that they are capable of staying longer in action. The benefit of using such equipment is that the fire fighters know it well and it is also easy to maintain. Breathing apparatus, that allows the fire fighters to operate for up to 3 - 4 hours on scene, is expensive to purchase and demands a much more sophisticated training and maintenance.

Lessons learnt

- In this particular disaster the Fire Brigade was in luck. The wind in the tunnel blew with a speed of about 8 meters per second. This gave the Fire Brigade the opportunity to approach the fire rapidly and fight the fire without any major problems. Furthermore, the heavy draught supplied the atmosphere in the tunnel with enough oxygen, making the smoke-filled air possible to breathe in. The four individuals who were trapped in the tunnel may have stayed there for more than one hour before the fire fighters escorted them out. A little less wind or draught would have resulted in four casualties.
- None of the involved persons in the piled-up vehicles were stuck in their seats and that gave them the opportunity to escape by themselves or with the help of others involved. The Fire Brigade will almost certainly never reach the fire scene in time to rescue individuals stuck in a burning vehicle, but public arriving early at the scene may save lives given they have fire extinguishers within reach.

2.5.8 Information supplied to the public and related lessons learned

Prior to the event

The dialogue concerning fire safety in tunnels has been going on for many years. The media has supplied the public with a lot of information. The Norwegian Fire Brigade, as well as the Directorate for Fire and Explosion Prevention focuses on fire safety both when it comes to prevention and response measures. Both departments mentioned addresses the public about these issues whenever there is a chance to do so.

During the event

The event did not last for long, so there was really no necessity for information to the public during the event.

Following the event

The event was investigated both by the local police who has a responsibility for doing so and by the Directorate for Fire and Explosion Prevention. A full report on this event is at the moment available in Norwegian, but the report will be translated into English due to inquiry from different European countries. The translated report is available through the Directorate for Fire and Explosion Prevention Web site www.dbe.no, look under Oppslagsverk and DBE's publications in English.

2.6 Amsterdam Metro Fire (The Netherlands)

Sjirk Mejier *(Ministry of the Interior, Fire Service, The Hague)*

2.6.1 Date of the disaster and location

12 July 1999, underground metro station “Weesperplein” in Amsterdam.

2.6.2 Short description of the event

On a warm summer day, an express tram caught fire in an underground station. Despite the efforts of both the tram-driver and a member of the station staff to extinguish the fire, the entire station got filled with smoke very soon. Happily the smoke production appeared relatively low and few people were involved at that time. It was possible to evacuate people from the station and underground shopping mall. The station staff and the tram-driver initiated the evacuation. Firemen helped evacuate ten persons trapped in a café at the shopping mall. Only after the third rail had been grounded by an electrician, the Fire Brigade could use water. Eventually the fire was extinguished.

2.6.3 Human consequences

Two persons were slightly injured (smoke poisoning). The casualties were hospitalised and could leave the hospital a few hours later.

2.6.4 Economic losses

During the rush hour the metro was out of order for passengers. This inconvenience cannot be expressed in specific economic losses.

2.6.5 Prevention measures and related lessons learnt

Prevention measures

The tram-driver can call the tram traffic control centre and there is a special button to send a distress signal. In the station a video monitor system has been installed. At the time the fire was discovered, it was not possible to call the traffic control centre. The distress signal was working. The traffic controller however couldn’t see what was going on because of the video cameras being out of order (for some time). The traffic controller sends a metro filled with passengers to pass and observe the accident; the metro-driver had to watch and report what was going on.

In the tunnel and stations, there had been no smoke detectors installed. The traffic control and the driver didn’t know the tram was on fire.

Each coach has two CO_2 extinguishers. The tram-driver grabbed for the first one but it was stuck. He had to go to the other end of the coach to fetch the second one.

When the metro-system was designed, fire safety had been taken into account. The coaches were designed with less inflammable material. The floor of the metro is for instance a metal construction with only a thin layer of wood on top of it. When the express tram has been introduced as a new form of transport in Amsterdam, it had been designed as an ordinary tram, which could ride on the metro track. Fire safety was not an issue. The floor of the tram had been made of two centimetre thick wood. The brake system had been designed too small and the rubbers protecting the axis had been made of inflammable material.

The metro and the tram have both separated traffic control centres. They both can influence the railway system. The metro traffic centre is however leading. In an emergency they can and should inform each other. During this incident however the two traffic control centres worked independently and they failed in working together. A passing metro-driver had reported to the metro traffic centre that the express tram was smoking heavily. The metro traffic centre didn't pass this information to the tram traffic centre.

Although there have been several fires in tram coaches over the past few years, no action was planned to prevent fires. The previous fires occurred in open air and caused no problem.

Lessons learnt

- The attention of the management of the transport organisation was only focused on transporting as many passengers as possible. Safety issues were of less concern and had a low priority. When the express trams were allowed to go underground, safety was not an issue to be seriously discussed.
- The express trams were not designed to go underground, so all the express trams have to be evaluated whether they are suited to function as if they were metros.
- The maintenance process has to be evaluated. Problems have to be taken into account as soon as possible.
- The system with two separate traffic control centres and one metroline to control is not functioning. The metroline should have only one traffic control centre. The express tram should be handled as if it was a regular metro.
- Detection devices, such as a video monitor system, should be working under normal conditions at all times. If the traffic control centre doesn't know what is going on they can not take the adequate actions.

2.6.6 Preparedness measures and related lessons learnt

Preparedness measures

The preparedness for accidents in the metro transport system was not sufficient. Both the transport organisation and the Fire Brigade had no up-to-date procedures. The training and knowledge of the traffic controllers on how to act if an accident occurs was inadequate. The procedures available were incomplete and the status of the existing procedures was vague. In the past there has never been made an analysis of what might occur in the metro tunnel. No "what-if scenarios" were made.

There was no clear procedure to evacuate the station. If the platform had been crowded, the announcement made during the event might have caused panic. The evacuation was only successful thanks to the actions taken by the staff members at their own initiative.

In case an accident should happen, it was decided that the electricity should be switched off and an electrician had to short-circuit the electricity conductor with the earth at the place of the event. During the fire in the express tram the electrician arrived shortly after he had been called. He met the Fire Brigade only by accident. There was no pre-arranged rendezvous point where they should meet. Luckily, the electrician had learned to work with a breathing device. Not all of the electricians of the transport organisation have been trained in using those breathing devices.

In the underground station, emergency services can use their communication equipment. To do so they have to switch to another channel. During the event, several couples of the Fire Brigade had problems to communicate with the leader. Switching to the other channel was frequently forgotten.

The emergency services had no contingency plan for an accident in a tunnel or metro station. In fact for years they hadn't exercised on fire fighting in the metro.

Lessons learnt

- The development of scenarios is of vital importance to test whether and where the system is vulnerable. They can serve as a basis for procedures. The traffic-controllers should be better trained in facing accidents and following the correct procedure. It should be clearly described how to evacuate a platform without creating panic.
- At each station there should be a pre-arranged rendezvous point (for Fire Brigade, ambulance, station staff, electrician). This was also proposed after the King's Cross Fire. However, as mentioned before, the management of the transport organisation failed to manage safety properly.
- Of each possible scenario there should be a contingency plan. The emergency services should train to operate in underground structures and exercise with realistic scenarios. Problems in communication can be solved by better training.
- During the accident the smoke production was the largest problem. In the metro system no adequate measures were taken to control smoke by ventilation. They have to be made.
- Wide smoke production can cause that large parts of the metro system, including stations, are not accessible, not even with breathing devices. Therefore the electrical grounding procedure should be improved. It is very important that the Fire Brigade can use water as soon as possible. The electrician in service should be trained working with a breathing device and he should meet the Fire Brigade as soon as possible.

2.6.7 Response actions and related lessons learnt

Response actions

After the fire was detected by the tram driver, who was walking aside the coaches to the other end of the tram, the driver pushed the emergency button and tried to extinguish the fire. He was using a CO_2 extinguisher. Another driver (not in service) came to help him. After they concluded that the attempt failed, they started to evacuate the platform. Because they took this decision rapidly, all the people could be evacuated before the station was filled with smoke. The Fire Brigade was alarmed by the traffic controller. The Fire Brigade with two fire appliances arrived at the station six minutes after having been alarmed. The Fire Brigade called the ambulance service for assistance. Afterwards this call seemed to be lost. An ambulance driver accidentally passing the station entry observed the smoke production and stopped to help.

The Fire Brigade used two strategies. Firstly they tried to extinguish the fire. Secondly they started searching for trapped persons.

To extinguish the fire the Fire Brigade had to use water. CO_2 extinguishers had no effect. After an electrician with a breathing device grounded the conductor, the firemen could extinguish the fire. In a cafe at the shop floor the Fire Brigade found ten trapped persons. They could be evacuated.

Lessons learnt

- The two strategies used by the Fire Brigade to deal with the fire worked well. As mentioned before, most of the problems were caused by failures in the prevention and in the preparation of accidents. The absence of a contingency plan made it difficult for the emergency services to take the right decisions. Only because it was not a major fire, it worked out well this time.

2.6.8 Information supplied to the public and related lessons learned

Prior to the event

The public is neither actively nor passively informed about how to act when an accident occurs in the metro.

During the event

The sound system in the station was malfunctioning. The traffic controller tried four times to make a public announcement. Only one time the announcement "everybody should leave the station at once" was heard. The message was apparently not heard in the shops and the cafe.

Following the event

After publication of the inquiry report, the papers published several articles with large headlines.

2.7 Rail-car Fire in the Exilles Tunnel (Italy)

Fabrizio Colcerasa *(Ministry of the Interior, Civil Protection Directorate General, Rome)*

2.7.1 Date of the disaster and location

1 July 1997, Chiomonte (Turin).

2.7.2 Short description of the event

The Exilles rail tunnel is managed by Ferrovie dello Stato (National Railway Co.) and is located on the Turin-Modane railway (at the 60.7 km mark). The entrance to the tunnel is in the municipality of Chiomonte and the exit in the municipality of Exilles (both in the province of Turin). The tunnel is made up of two one-way traffic tunnels. There is no transversal connection between the tunnels and ADR (Accord européen relatif au transport international des marchandises Dangereuse par Route) transport is allowed. The tunnel is 2.1 km long, with an average gradient of 5% and a cross sectional area of 35 m^2. The train involved was made up of 2 locomotives and 18 wagons transporting cars (total length of the train: 460 m). Each wagon carried 12 cars (for a total of 216 units).

Rescue vehicles can reach the tunnel following first the SS24 motorway and then a 3.5 km long gravel road leading to the ballast of the tracks. Rescue vehicles can enter the tunnel only on a rail car. Access features meet railway requirements, but no rescue areas exist in the tunnel; only on the southbound downhill stretch is some open space available along the ballast, which might be used. The portals are the only emergency exits. Natural ventilation is provided through the portals. There are no hydrants. The tunnel is equipped with ordinary lights and the transmission system is composed of fixed telephones along the tracks.

The fire broke out on July 1, 1997. The alarm reached the fire station at 13.30. The fire was started by the open back door of one of the transported cars, which caused friction on the electric lines inside the tunnel. The ignition point was 1.1 km from the downhill entrance (towards Modane) and flame spread first to the affected car, then to the other ones.
The rescue operations were as follows:

- notification of the fire at 13.30;
- arrival, after 20 minutes, of Fire Brigade teams from Susa (12 km from the tunnel);
- arrival, 45 minute later, of Fire Brigade teams from Turin (45 km from the tunnel);
- total personnel employed: about 60 fire fighters divided into 10 teams;
- rescue vehicles at the site: 5 fire engines, 2 water tenders with built-in pumps, 4 land-rovers, 1 helicopter, 1 command vehicle radio equipment, 1 electric generator, 1 locomotive, 1 earth scoop on wheels.

Upon the arrival of the Fire Brigade teams, natural ventilation was flowing uphill towards the Modane portal. The fire produced a thick smoke that totally impaired the visibility uphill in the Tunnel, while downhill it was possible to enter the shaft without B.A. (Breathing Apparatus) and to reach the burning cars. The two locomotive drivers (who escaped uphill) were found outside the portal slightly asphyxiated.

Fire extinction operations started entering the tunnel from the Turin portal (downhill) to reach the fire from inside. 'Ferrovie dello Stato' was required to interrupt the electricity supply, to block the traffic on the other track and to send a locomotive for the rescue (which arrived an hour later). Emergency lights went off and an electric generator was started. It was impossible to use radios in the tunnel, as this was not equipped with a slotted cable. 900 m of hoses were laid out to supply water. High temperatures in the proximity of the fire made the extinction of the fire difficult and required the use of B.A. Flames caused the explosion of parts of the concrete lining of the tunnel ceiling. The fire was put under control at 19.00 and completely extinguished one hour later. It involved one locomotive and 13 freight wagons for a total of 156 transported motorcars.

2.7.3 Human consequences

Neither rescue teams nor train crew suffered injuries.

2.7.4 Economic losses

No data available to the Fire Brigade.

2.7.5 Prevention measures and related lessons learnt

- Lack of any water supply system. Under these circumstances, fire fighters had to lay out 900 m of hoses to fight the fire. It is obvious that operations were delayed in a way that is incompatible with rescue needs.
- Lack of radio communications. In this type of accidents for rescue teams it is essential to get radio communications. In this particular case, intervening teams faced serious problems due to the impossibility of using their radios.
- Lack of a lighting system. It was necessary to start an electric generator and to install the lamps.

2.7.6 Preparedness measures and related lessons learnt

Preparedness measures for this type of accident are included in the ordinary training of fire fighters. Some exercises organised at provincial and regional level by the Prefects concerned fire in tunnels.

2.7.7 Response actions and related lessons learnt

- Smoke. Impossibility for downwind rescue teams to carry out any operations. In emergency planning it is necessary to take into account the possibility of entering a tunnel from only one entrance, depending on atmospheric conditions.
- Lack of by-pass tunnels. In spite of the tunnel length, there were no transversal tunnels that would have ensured a better management of rescue and fire extinction operations.
- Response time. Because of the particular scenario (with access problems), operations were delayed to an extent which is incompatible with more complex scenarios. Rail tunnels present no positive aspects except an accident frequency, which is lower than in road tunnels, but consequences are more serious. It is necessary to identify all structural defects of rail tunnels to safeguard people who may be involved in accidents.

2.7.8 Information supplied to the public and related lessons learnt

During rescue operations, no information was provided by the Fire Brigade to the public. 'Ferrovie dello Stato' took all measures required to stop trains on the affected railway and to inform involved passengers.

2.8 HGV Fire in the Prapontin Tunnel (Italy)

Fabrizio Colcerasa *(Ministry of the Interior, Civil Protection Directorate General, Rome)*

2.8.1 Date of the disaster and location

13 January 1997, Susa (Turin).

2.8.2 Short description of the event

The event took place on 13 January 1997. The alarm reached the local Fire Brigade at 15.07. The Prapontin tunnel is managed by SITAF (Société International Tunnel Autoroutier Frejus) and is located on the A32 highway connecting Turin with Frejus (at the 35 km mark). The entrance to the tunnel is in the municipality of Bussoleto and the exit at Susa (both in the province of Turin).

The Prapontin road tunnel is divided into two one-way traffic tunnels connected by 10 transversal tunnels (called by-passes). ADR (Accord européen relatif au transport international des marchandises Dangereuse par Route) transport is allowed in the tunnel, which is 4.9 km long, with a cross sectional area of 35 m² and an average gradient of 4%.
Rescue vehicles can reach the Tunnel through the highway. Access from one tunnel to the other is granted by the transversal tunnels and a service tunnel located halfway from the tunnel portals. It is perpendicular to the main tunnels and accessible through a gravel road.

The access features of the Prapontin tunnel meet highway requirements, but there are no dedicated rescue areas, thus the main thoroughfare must be used. The "by-passes" are the only emergency exits. There is a longitudinal ventilation system made up of fans below the ceiling. The fire extinguishing system is composed of fixed UNI 45 and 70 hydrant fittings. There is an ordinary light system, and image transmissions are ensured by closed circuit TV cameras.
When the fire broke out inside the tunnel, there were only light weight vehicles and traffic was flowing smoothly. The HGV involved in the accident was an articulated lorry with trailer, transporting 36 tons of synthetic textile bales. The source of the fire was the overheating of the lorry's brakes. Flames spread first to the wheels and then to the cargo. The fire ignited halfway in the tunnel, approximately 2.5 km from the Susa entrance.
The operational response was as follows:

- notification of the accident at 15.07;
- arrival, after 5 minutes, of a first Fire Brigade team from Susa (5 km from the tunnel);
- arrival, 20 minute later, of Fire Brigade teams from Turin (30 km from the tunnel);
- total personnel employed: 60 fire fighters divided into 10 units;
- rescue vehicles at the site were: 4 fire engines, 2 water tenders with built-in pumps, 2 land-rovers, 2 helicopters, 1 command vehicle radio equipment, 1 light emergency vehicles, technical equipment/tools, 1 electric generator, 1 foam gun.

The Fire Brigade teams arriving from Turin noticed that the thick smoke impaired the visibility for both the vehicles inside the tunnel and those on approach. There was some panic among the involved motorists; five of whom slightly asphyxiated by the smoke.
Turin fire fighters started operations entering the second tunnel (direction Turin-Susa) and reaching the fire through a "by-pass".
The second team arriving from Susa reported that thick smoke emerged from both tunnels as some "by-passes" were open. All rescue teams noticed that the fans were not working and there was no water in the hydrants.
The second Susa unit entered the tunnel thinking that the first unit was already inside fighting the fire (before the arrival of the command vehicle it was impossible to use radios inside the tunnel). The second unit met the first one after 2 km and was told of the impossibility of reaching the fire because of the thick smoke. The first unit abandoned the fire engine inside the tunnel and joined the team on the second fire engine. They reached the fire through the service tunnel, which was also filled with smoke.
During rescue operations the lights went off and a Fire Brigade electric generator was started. Upon request of the fire fighters the ventilation flow was started and later inverted by highway personnel who opened other "by-passes" near the fire, including the last two ones (direction Susa) to let the smoke out also through the second tunnel.
High temperatures caused the explosion of some parts of the concrete lining of the tunnel ceiling and made the extinction of the fire difficult. Fire fighters used without B.A. (Breathing Apparatus) and several water tankers were employed to supply water.
The fire was extinguished at 19.00. At midnight the operations ceased.

2.8.3 Human consequences

The 5 motorists were moderately asphyxiated by inhaling the smoke. Rescue teams suffered no injuries.

2.8.4 Economic losses

No data available to the Fire Brigade.

2.8.5 Prevention measures and related lessons learnt

- Hydraulic system without water. Necessity to provide for the maintenance of the systems.
- No radio communications in the tunnel. In this scenario it is essential to ensure radio communications among rescuers. Serious problems arose due to the lack of communications.
- Lack of emergency lights. During the fire fighting operations lights went off. Necessity of installing suitable emergency fire resistant lights.

2.8.6 Preparedness measures and related lessons learnt

Preparedness measures for this type of accident are included in the ordinary training of fire fighters. Some exercises, such as fires in tunnels, are organised at provincial and regional level by the Prefects concerned.

2.8.7 Response actions and related lessons learnt

- Smoke. It was impossible for the downwind fire units to carry out rescue operations. Emergency planning should take into account the possibility of entering a tunnel from one single portal, depending on atmospheric conditions.
- Ventilation system. There was a significant production of thick smoke, giving way to breathing and visibility difficulties. Effective and efficient ventilation systems are essential and rescue teams require long-lasting oxygen supplies (B.A.s).
- Lack of traffic control. During the first stage of the accident other vehicles entered the tunnel. Need for a remote control system able to stop the incoming traffic.
- Presence of by-pass tunnels: many motorists could escape through these tunnels.
- Rescue time. As the fire station was not too far, it was possible to reach the tunnel in a very short time.
- Tunnel with two one-way traffic tunnels. This feature limited the human consequences, the second tunnel provided free access for the first rescue operations and for the highway traffic after the fire was extinguished.

2.8.8 Information supplied to the public

During the fire no information was given to the public by the Fire Brigade. Injured people were rescued and sent to hospital. Police forces diverted the traffic onto other roads.

2.9 Fire in the Munich Candid Tunnel (Germany)

Wolfgang Schäuble (Fire Department, Munich)

2.9.1 Date of the disaster and location

30 August 1999, Munich.

2.9.2 Short description of the event

The so-called "Candid Tunnel" is only 252 metres long and belongs to the first category of Munich road tunnels, which requires no fire prevention equipment. It is part of Munich's most frequented city highway.

On 30 August 1999, at 7.30, a burning car was reported. A simple motor defect was the reason for the fire. So the car burned until the forces of Munich Fire Brigade fought the fire.

2.9.3 Human consequences

No injured or killed persons, but the smoke was ignored by the drivers.

2.9.4 Economic losses

The cost of the directly damaged cars and buildings was estimated about 40,000 Euro. The cost of economic cannot be assessed (morning rush hour).

2.9.5 Prevention measures and related lessons learnt

Prevention measures

Concerning prevention measures, the road tunnels in Munich are grouped into three categories, according to their length.

1. *Tunnels longer less then 250 m.* These tunnels are considered similar to road underpasses and there are no requirements.
2. *Tunnels long between 250 and 500 metres.* These tunnels are considered as dangerous and there are the following requirements:
   - separation walls between the directions (parallel shafts)
   - fireproofed (30 min) doors every 60 m going to the neighbour shaft
   - stand-by lightings
   - automatically fire detection
   - wall hydrants
   - fire extinguishers
   - turning possibilities in front of the tunnel entrance.
3. *Tunnels longer then 500 metres.* These tunnels are considered as very critical, therefore there are the following additional requirements:
   - exit to open-air every 200 until 300m
   - ventilation (usually radial vacuum ventilation)
   - special radio communication network
   - catch pot of 50 cubic metres (minimum) for flammable and dangerous liquids
   - traffic lights controlled by automatical fire detection (stop lights).

Lessons learnt

The fire confirmed Munich fire department's prevention requirements and showed that they are necessary for tunnels longer than 250 meters, especially concerning:

- Parallel shafts with connecting doors.
- Automatical fire detection.
- Traffic lights and ventilation programming.

- Water supply in front of the portals.

2.9.6 Preparedness measures and related lessons learnt

Preparedness measures

The following preparedness measures are provided.

1. *Special programme for traffic lights and ventilation,* in two different cases:
   (a) the emergency programme is started by automatic fire detection,
   (b) the emergency programme is started by an emergency fire phone call.

   In case a) the following programme is implemented:
   - traffic lights turn red;
   - ventilation in the concerned tunnel shaft turns on maximum power;
   - ventilation in the parallel shaft stops;
   - in the smoky tunnel shaft, a vacuum will be built and so the other shaft will be smoke free.

   In case b) the following programme is implemented:
   - the traffic control centre of the police starts the above described programme, after checking the video monitors of the Munich Fire Brigade special turn out for fire.

2. *Special turn out of fire fighting forces in case of road tunnels:*
   - chief officer in charge;
   - two water tenders;
   - breathing apparatus van;
   - two engine companies each consist of
   - control car
   - first company engine
   - turn table ladder with basket
   - second company engine
   - ambulance car.

3. *Special operation plans*
   are given to the officers in charge showing the situation and the fire prevention standards of the concerned tunnel.

4. *Special tactical rules were created for fighting tunnel fires:*
   - at each entrance one company with a water tender is send to;
   - the chief officer of charge decides on his own which entrance he will be used;
   - first company enters the concerned tunnel shaft through the smoky entrance; starts fire fighting by using their own water and fire hoses;
   - second company is able to use the smoke-free parallel tunnel shaft and enters the concerned shaft through the door near to the place where the fire was detected using the wall hydrant system.

Lessons learnt

The fire confirmed Munich fire department's preparedness, especially concerning:

- Special operation plan. Each tunnel is shown with the special situation and preparedness measures on his own for the chief officer. He is able to have an overview from the turn out start until the end of the operation

- Special turn out. There are always enough forces at the concerned tunnel to respond quickly also at greater fires with the special turn out team (see above).

2.9.7 Response actions and related lessons learnt

Response actions

As described in the tactic rules, both companies were sent to an opposite entrance. At the concerned entrance a tailback of several kilometres built up in a few minutes. At the opposite side of the tunnel the drivers ignored the smoke and drove into the tunnel until a police car blocked the road. At the concerned entrance the tailback was extreme, therefore one of the two companies needed 15 minutes for the last 750 meters. The other company was hindered by smoke at the opposite entrance. The smoke was so rough that the company that was hindered by the tailback, was the first to fight the fire!

Lessons learnt

Tactical rules and preparedness were confirmed, especially concerning:

- Fighting the fire from both entrances as standard.
  Described like above, the fixed tactical standard of fighting fire from two dependent ways is the best possibility to locate and find the fire as quick as possible

- Water supply by water tender.
  The public water supply may not be used immediately because the fire hydrants are usually not so closed to the intervention area and long hoses have to be used.

2.9.8 Information supplied to the public and related lessons learnt

Prior to the event

No special information was given by Munich Fire Brigade.

During the event

No special information by Munich Fire Brigade, only the first cars of the tailback got one.

Following the event

Printing of a special information flyer on behaviour in case of a tunnel fire, which was sent in a special mailing to each household in Munich (about 800.000).

3. OTHER EXPERIENCE

3.1 The Emergency Preparedness Issue and Fixed Links (Denmark)

Claes Morch *(Danish Emergency Management Agency, Birkerod)*

3.1.1 Introduction

Fortunately, Denmark has never experienced major tunnel accidents. The probability, however, has increased as Denmark has implemented two major tunnel and bridge projects in the past two decades: The Great Belt Link, and The Fixed Link across Øresund (hereafter the Sound) between Sweden and Denmark (Øresundsbroen).

One major tunnel project is still under construction in Copenhagen: the Metro Project. The first stage of the Metro is to be opened in less than two years.

In the future, another fixed link may be a reality: the Fehmarn Belt link. The type of fixed link is yet to be decided. A tunnel is an option.

Compared to other countries, and especially the countries that are represented at this meeting, Denmark has not got much experience within tunnelling. In Denmark there are only a handful of tunnels, and apart from The Great Belt Link railway tunnel, none of them are more than 5 km. When operational, the 10 km Copenhagen Metro tunnel will be the longest tunnel in Denmark.

The Metro, The Great Belt Link and The Fixed Link across the Sound are all important infrastructural projects. Much prestige has been invested in the projects. They are almost constantly subject to attention.

When major tunnel accidents occur abroad, the question subsequently is: “Can it happen in Denmark too?” The emergency preparedness issue therefore has been given a very high priority in the projects.

Using the Fixed Link across the Sound as an example, this report briefly describes how the organisations responsible for the projects have dealt with the emergency preparedness issue.

3.1.2 The Fixed Link across the Sound (Øresundsbroen)

The Fixed Link across the Sound consists of an artificial peninsula, a tunnel, an artificial island, the bridge and finally the toll station. A graphic description of the entire link is given in Fig. 1. The link has a total length of approximately 16 km. The immersed tunnel makes up 22% of the total length of the link. The fixed link is an international link. It has been necessary to declare some zones of jurisdiction.

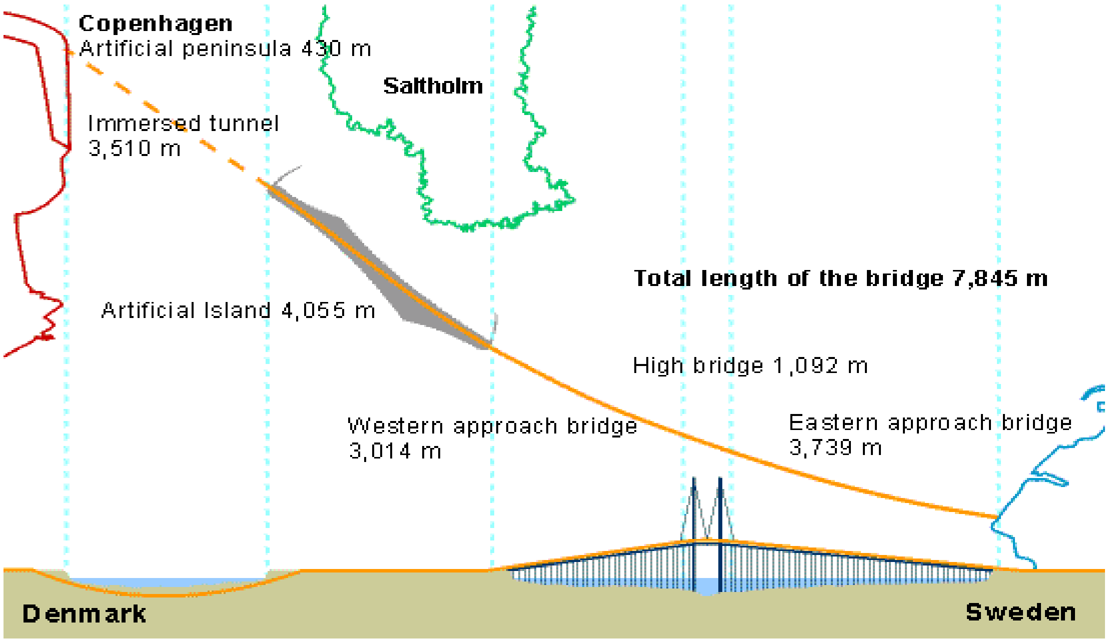

Fig. 1 - A graphic description of the Fixed Link across the Sound (Øresundsbroen)

The limit of the territorial waters is marked on the western approach bridge, 2.5 kilometres east of the artificial island. This also marks the jurisdiction of the rescue authorities in Denmark and Sweden. The limit of distress calls is marked where the western approach bridge encounters the artificial island. The discrepancy between the limits mentioned above does not give reason for any concern. The two countries have worked out a joint contingency plan, which deals with this problem.

As mentioned above, the tunnel is an immersed tunnel, whereas the Great Belt and the Metro tunnels are both drilled. The tunnel comprises both motorway and railway in separate shafts, as shown in Fig. 2.

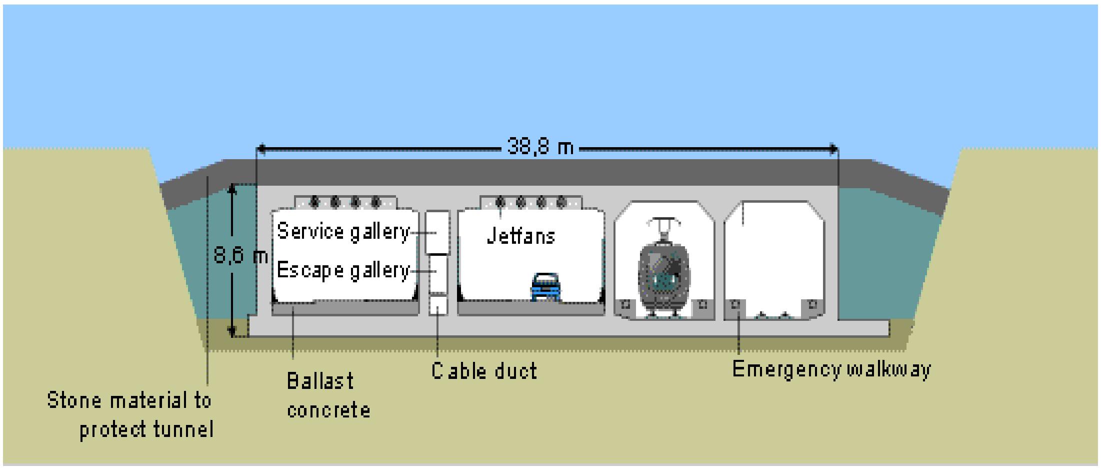

Fig. 2 - A view of the shafts of the tunnel

The tunnel is the longest immersed shaft tunnel for both road and rail traffic in the world. It consists of 20 tunnel elements, and is approximately 9 metres high and 40 metres wide. Each motorway shaft is approximately 10 metres wide and the railway shafts are 6.5 metres wide.

Between the motorway shafts, there is an escape gallery, which is fire and traffic proof. Emergency exits are located at 88 metre intervals.

3.1.3 Emergency preparedness issues

The overall aim is to ensure that the fixed link is designed in a way that prevents accidents from happening

The design of the fixed link must ensure that:

- rescue and evacuation are possible,
- road users, passengers and staff can be evacuated, and
- normal operations can be restored quickly

should accidents occur.

A group of experts, the so-called KKSURR-group, was formed under the Øresunds Konsortiet long before the link was inaugurated. KKSURR is a Danish abbreviation for "kyst til kyst – sikkerhed – uheld – redning – rydning", translated in English "coast to coast – safety – accidents – rescue – clearance".

The responsibility to finance, construct, own and operate the fixed coast-to-coast link between Sweden and Denmark lies on the Øresunds Konsortiet, which is own equally by the Danish and Swedish states.

The Danish Emergency Management Agency has been represented in the KKSURR-group. It is important to note that according to Danish law, the Danish Emergency Management Agency has no authority to lay down requirements on the Øresundskonsortiet. The Agency only acts as advisor.

The group of experts was tasked, as advisors, to assist the Øresundskonsortiet in assessing the design of the link. In other words the group advised on:

- constructions and systems (accessibility, escape ways, etc.),
- technical installations (illumination, ventilation, drainage, etc.),
- surveillance (traffic, air pollution, fire, etc.),
- traffic redirection (closing off, passages, etc.).

On the basis of the recommendations of the group, a design basis was made. The design basis sums up the overall requirements to the entire fixed link. The design basis includes among other things a design basic safety.

Based on the design basic safety, Øresundkonsortiet has drawn up a safety description. Suggestions made by the KKSURR-group have been weighted and to some extent incorporated into the safety description. Recommendations that have not been incorporated are listed in a separate passage in the safety description.

3.1.4 The emergency preparedness organisation

The recommendations of the safety description were operationalised through the "Project organisation", which is structured as shown in Fig. 3.

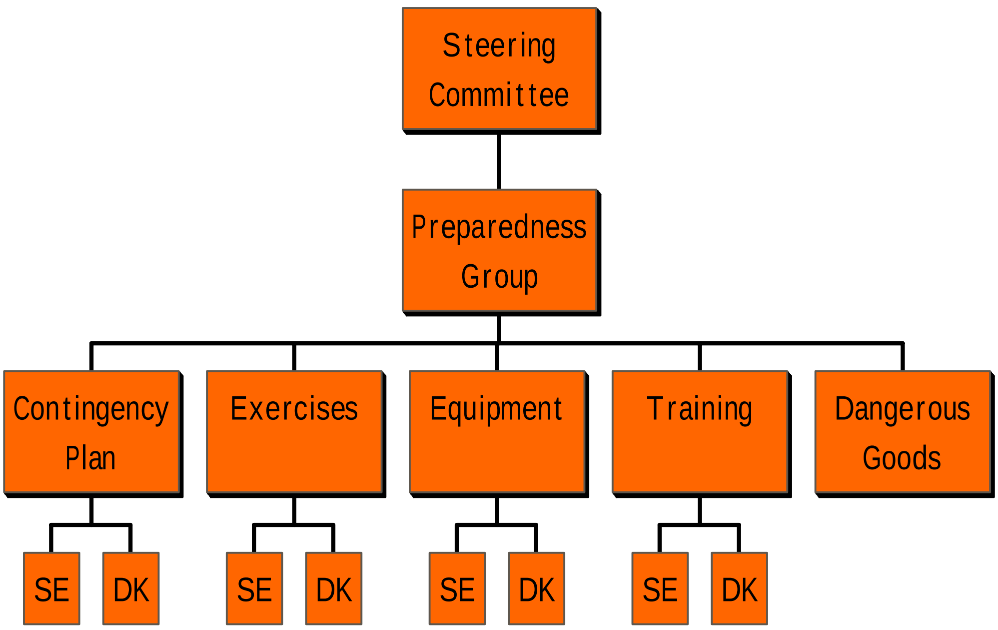

Fig. 3 - Structure of the Project organisation

The Danish Emergency Management Agency was not represented in the organisation. Primarily local authorities and emergency services and other experts carried out the work.

The Dangerous goods group was bilateral. The other groups (Contingency-planning, Exercises and Equipment were all divided into Swedish and Danish subgroups. The Preparedness Group co-ordinated the entire work, and reported back to the Steering Committee. The Steering Committee laid down the general guidelines for the organisation's work.

Two months before the inauguration, the organisation concluded their job by carrying out three full-scale exercises. The aim was to test procedures etc. described in the contingency plan, and to evaluate the work.

Two exercises were carried out in the tunnel; one as a motorway accident and the other as a railway accident. The evaluation of all exercises resulted in a few modifications of the contingency plan.

3.1.5 The contingency plan

The contingency plan covers all incidents and major accidents at the fixed link between the toll station and the artificial peninsula. The plan is a general plan, which covers Danish and Swedish emergency authorities' duties and responsibilities. The aim is to:

- ensure an effective and efficient call of emergency services,
- rescue and save human lives by means of a joint, co-ordinated co-operation in the initial attack, and subsequently to limit casualties and damages as much as possible,
- ensure a clear and unambiguous area of duty and responsibility,
- ensure a clear and unambiguous line of communication between the participating parties.

The emergency authorities have classified all incidents and accidents into three Dispatch Levels. Dispatch Level 1 indicates a need for limited rescue resources. Dispatch Level 2 indicates a need for normal rescue resources, and Dispatch Level 3 indicates a need for reinforced rescue resources.

Double turnouts are initiated on Dispatch Levels 2 and 3, and result in the dispatch of Danish as well as Swedish response units.

In case of an accident on the part of the fixed link that is covered by the motorway, all three Dispatch Levels can be activated. On the part covered by the railway Dispatch Level 2 or 3 will always be activated.

A major part of the contingency plan outlines the different response plans. On the basis of the plan, involved emergency services and rescue preparedness are required to work out their own standard procedures.

Quality control of the emergency preparedness on the fixed link is being performed as well. Exercises are being held regularly, and the contingency plan is updated at least once every other year.

So far, there have not been any incidents or major accidents on the Fixed Link. The efficiency of the contingency plan procedures still remains to be proven.

3.2 Safety Measures Implemented in the Encumenda Tunnel (Portugal)

Luis Sousa *(Regional Service for Civil Protection, Madeira)*

3.2.1 Introduction

Fortunately, I have to say that I am not able to report any experiences concerning tunnel accidents, as the few that occurred in our island are not relevant enough. Being so, I will skip to a brief exposition concerning the areas of the Portuguese territory where the most significant tunnels are located and finalise with a description of the safety measures which were implemented in order to increase security and reduce the sinister levels in the biggest tunnel of my country.

3.2.2 General information on Madeira island

Located on the south of the Atlantic Ocean, approximately one thousand kilometres from Lisbon, Madeira is a very beautiful island with an exuberant plant life. The archipelago is composed by the following islands: Madeira, Porto Santo and the uninhabited Desertas e Selvagens.

Resting in the Atlantic Ocean, 545 kilometres from northern Africa and 978 kilometres from Lisbon, Madeira has an area of 41 square kilometres, it is 57 kilometres long and 22 kilometres wide. Madeira has a population around 260,000 inhabitants, thus a population density of about 440 inhabitants per square kilometre; 120,000 inhabitants live in the city of Funchal. The origin is Volcanic, the maximum altitude is Pico Ruiivo: 1861 meters. The climate is very mild, medium temperatures: Summer 21ºC, Winter 16ºC. Cultivation: near the sea, sugar cane, bananas, etc.; on the terraces half way to the mountains, vines, cereals, fruit trees, etc.. The highest mountains are usually covered by dense forests.

3.2.3 Road network

Madeira's pronounced orography has always been a very strong obstacle in what concerns the construction of our regional road network. Thus, and in a way to shorten the distances, we have resorted to master pieces (viaducts and tunnels). The biggest tunnel, called Encumenda, is over 3 km long and has been recently opened to the public. It is presented here.

3.2.4 Encumenda tunnel

General Information

- Single cement shaft and bidirectorial (it is possible to drive in the two directions);
- Length: 3080 meters;
- Transversal profile: 12 meters, 2 driving lanes 3.5 meters width each and side walk 1 meter large;
- 442,000 cubic meters of land movement;
- 4,355 tons of iron;
- 155.000 cubic meters of concrete;
- Approximate cost (including the accesses): 80 million Euro;
- Working since 8h October 2000.

Safety Measures Implemented

- Dangerous substances are forbidden to circulate in the tunnel;

- Total and coloured supervision of the tunnel's interior (24 hour), through the control centre;
- Linear fire detection system with fibrolaser (CERBERUS);
- Calling posts inside the tunnel, which enables users to call for help in case of accident or fire;
- Water stations in both entries;
- 240 cubic meters of water reservations destined to fire fighting (two water reservoir of 120,000 litters each, in both entries);
- Two pumping stations, one on each entry, to feed the fire fighting network, which includes: firehoses' holders every 50 meters, water stations every 100 meters and several portable fire extinguishers;
- Longitudinal ventilation;
- Automatic system for controlling carbon dioxide (CO) levels;
- Informative panels in both entries and inside the tunnel;
- Road signs for speed controlling;
- Semaphores;
- Physical barriers in both entries;
- Sound system (still being developed).

4. SUMMARY OF LESSONS LEARNT

Alessandro G. Colombo *(EC, Joint Research Centre, Ispra)*

This document presents tunnel accidents that occurred in different European countries, of diverse gravity, involving persons, vehicles and structures, written by experts from various organisations, e.g. Fire Service, Prefecture, Ministry for Transport. Consequently, the language is not always the same and, particularly in the nine paragraphs of section 2, there is a variety in the level of detail of the information given.

Nevertheless, a lot of lessons learnt are reported in the document. They are summarised here, grouped according to the main phases of the management of a disaster: prevention, preparedness and response. Furthermore, where relevant, the lessons learnt have been subdivided into the following paragraphs:

- General
- Regarding regulation
- Regarding the public
- Regarding staff training
- Regarding equipment, maintenance and co-ordination of activities
- Regarding type of tunnel/project
- Regarding the Fire Brigade
- Regarding the Police.

In addition, lessons learnt regarding the dissemination of information to the public are also summarised.

The lessons are not ordered according to their importance, but mainly according to "logical" considerations. It has to be underlined that some of the points reported as "lessons learnt" appear trivial, in fact all of them refer to real situations related to the accidents analysed.

4.1 Lessons learnt concerning prevention measures

General

- First, it must be recognised that prevention has to be built into a project ahead of actual construction; afterwards, the options are severely limited. A list of improvements suggested by modern thinking, but difficult to be implemented in a tunnel opened to the public include: reduction in the incline of the access slope, opening of intermediate vents to feed underground ventilation, smoke extraction plants, provision of new refuge areas.

Regarding regulation

- Each tunnel should have specific regulations for transportation of dangerous goods and accompanying duty plans.
- A visual inspection of the state of the vehicles entering a tunnel is essential (e.g. no sign of leaking fluids on the tank or the load, etc.).
- Heat-detecting "portals" should be installed to tackle the problem of vehicle 'hot spots'. These systems still need to be made more reliable, but before too long it should be possible to detect a turbo-charger about to rupture, overheated brakes, or temperature increases in the cargo. At the slightest suspicion, vehicles must not be allowed into the tunnel without further inspection.

Regarding the public

- The driving test should include specific questions concerning the behaviour of road users in the event of a traffic jam, an accident or a break down, or a fire in a tunnel.
- Signs reminding drivers that they must not run out of fuel while they are in the tunnel are to be sited ahead of each tunnel.

Regarding staff training

- Traffic control centre staffing must be improved in almost all tunnels. It should include, among others, personnel to assist in the handling of an emergency, particularly fire.

Regarding equipment, maintenance and co-ordination of activities

- Vital communication cables must be fireproofed or fire protected. It is not acceptable that tunnel communication systems break down in case of fire. (In fact, most of the road tunnels have fireproofed or fire protected communication cables.)
- In many tunnels, the visibility of tunnel markers and cross-passage numbers should be improved (e.g. by fluorescent paint and enhanced lighting).
- Generally, during the fire fighting operations, light goes off. It is essential to dispose of an electrical generator and suitable emergency fire resistant lights.
- In the future, only transverse ventilation systems should be approved, with exhaust air sucking. Available semi-transverse ventilation systems have the disadvantage, in the case of a fire, that the fans and the airflow must be reversed.

- Adjustable louvers should be mounted in the ceiling of tunnels with transverse ventilation systems.
- Equipment should be installed to make it possible to identify with great precision the location of an incident.
- It is vital that the public may call for help using public emergency phones. Emergency phones must be installed frequently inside the tunnel. Together with the emergency phones there must be fire extinguishers. The removal of a fire extinguisher should give a signal at the traffic control centre, and lead to immediate response. Combined with this automatic signal system, attached to the fire extinguishers there must be other fire alarm systems.
- In the case of repair or maintenance work, traffic lights must be set up at the portals outside the tunnel.
- Traffic moving into a tunnel where fire is developing must be stopped on the outside. This requires at least red light signals outside the tunnel entrance, and if the tunnel is long, red light signals should also be located inside the tunnel. To ensure more efficiency, the red light should be reinforced with bars outside the tunnel entrances.
- To control the smoke in a tunnel, the process of its configuration (closing piston relief ducts, activating supplementary ventilation) should begin immediately, once there is a single fire alarm of any type.
- The maintenance process is usually under evaluated. It must be continually and conscientiously followed in any tunnel.
- Detection devices, such as a video monitor system, should be working under normal conditions at all times. If the traffic control centre does not know what is going on they cannot take the adequate actions.
- Water supply systems, situated in front of the portals, should be operational in case of a fire. Maintenance of the system is essential.

4.2 Lessons learnt concerning preparedness measures

General

- Inherent in the notion of preparedness is the recognition that accident prevention is not always 100% effective; accidents do occur and measures need to be taken to limit their impact. Planned from the very outset, the preparedness measures must be continually refined.
- Unlike the case with prevention, significant improvements to preparedness arrangements can always be sought in order to compensate for structural shortcomings.
- Particularly in the case of a tunnel connecting two different countries, primacy, i.e. which organisation is responsible in the event of an incident, must clearly be defined, for specific areas of operations. There is also a need to define clearly in which country the operations are based.

Regarding staff training

- Simulation exercises can help to improve preparedness measures.
- Special training is required for the tunnel's own safety teams and for local public Fire Brigade whose services might be called upon: initial training for all new recruits and on-going training for everyone.
- The experience has shown that, in the first phase of the intervention, the members of tunnel Fire Brigade and rescuers have already to know each other. Especially because, often, the fight against fire has to start from both sides of the tunnel, at the same time, interdependently.
- All Fire Brigades with responsibility for fire and rescue operations in tunnels must pre-plan their operations. The plans must be co-ordinated with the police, the ambulance and healthcare service and the owner of the road tunnel.
- The development of scenarios is of vital importance to test whether and where the system is vulnerable. They can serve as a basis for procedures. The traffic controllers should be well trained to face accidents and follow the correct procedure, e.g. concerning evacuation, without creating panic.
- Of each possible scenario there should be a contingency plan. The emergency services should train to operate in actual structures and exercise with realistic scenarios. Better training can solve problems in communication.

Regarding regulation

- In projected tunnels longer than 1000 m, only concrete pavements should be authorised.
- Maximum allowable data transmission for the emergency call system, and the transmission from the equipment to the control centre, must be defined.
- Priorities and procedures for alerting the external emergency services must be clearly defined.

Regarding equipment, maintenance and co-ordination of activities

- Preparedness against tunnel accidents is now based largely on automatic detection of fires and incidents. Improvements have also been made to emergency equipment, including on-board heat cameras for driving in zero visibility, long-endurance breathing apparatus, and clothing giving slightly more protection against radiant heat. All these measures need to be tested during exercises to check their suitability and maintain them at peak performance. The cost of such exercises needs to be covered by the tunnel's economic operation. Users are willing to pay that cost on condition that it translates into provision of a proper safety service. Everything needs to be tested: equipment, procedures, the behaviour of staff on duty in the tunnel, and, today more than ever, the attitude of the public. The fact is that a correct behaviour of the public is the main precondition for successful operation. Preparedness now needs to incorporate this factor through the use of appropriate signalling systems to guide the actions of all those using the tunnel.

- At especially dangerous tunnels, portals and lay-by niches impact dampers should be mounted. The impact dampers should be designed to absorb energy and offer a high safeguarding protection during frontal impact.
- Doors to electrical operating rooms and emergency exits must be fire resistant.
- Emergency tunnels, which are still in planning and building stage should be enlarged so that emergency services vehicles can pass through (cross section 3.5 x 3.6 m). The traverses should be equally passable at a distance of 500 m for emergency service vehicles between two shafts, all 1000 m for all vehicles (trucks too) passable.
- The emergency call, still available in some old tunnels, should be altered on accessible emergency niches.
- For automatic fire detecting systems, the maximum detection time have to be defined, depending on the air velocity.
- The experience gained in an accident may help in revising the emergency plan and reorganising the inspection and monitoring systems.
- An important experience from Norway. In Norway, nearly all road tunnels have longitudinal ventilation systems. As long as the fire fighters can operate with the wind from behind it is possible to operate safely. From a Norwegian point of view, this is perhaps the most important issue when it comes to fire fighting and rescue operations in tunnels. Never try to turn the draught by reversing ventilation when a fire has broken out. If this is absolutely necessary, the decision to do so must rest upon the fire chief in charge.
- During a fire accident, the smoke production is the largest problem. Adequate measures must be taken to control smoke by ventilation.

4.3 Lessons learnt concerning response actions

General

- No time must be lost in gathering and analysing the information, selecting a course of action, acting, and monitoring the operation as it proceeds.
- A team responsible for press and public relations should be created.
- The emergency management system of national streets and highways should be integrated into the disaster plans of local and regional administrations.
- It is necessary to involve a psychological team directly on site.
- Rescue service needs a "clear" command to drive inside the shaft.
- Should deployment of rescue teams greatly assists in the evacuation and first aid treatment of the passengers and crew. If this is not the case, and oxygen resuscitation/therapy equipment and trained personnel are not promptly available, thus the injuries to be sustained may increase seriously.
- It is crucial that the Service Tunnel area at the site of any incident is effectively managed. Failure to do so inevitably leads to delay and confusion. It is important that each service operating within a tunnel is aware of and adopts the principles agreed.

- Effective cordoning will allow operations at the incident site to continue in safety and without interruption. Each incident site must be treated as a ‘scene of the crime’ and preserved as such. It must be recognised that within these restricted areas there may be specific hazards. The demarcation and control of the inner cordon will be a matter for commanders to take into account according to the circumstances of the incident.
- Only authorised personnel, i.e. those having an accepted function, should be allowed within the inner cordon. The entry and exit of all persons and emergency service personnel must be logged in accordance with service procedures. Authority for access to the incident site for other than necessary emergency services must be sought from the Control Point. Records should be kept for evidential purposes.
- In emergency planning it is necessary to take into account the possibility of entering a tunnel from only one entrance, depending on atmospheric conditions.
- In a tunnel, traffic control is essential. Immediately after an accident, a remote control system must stop the incoming traffic.

Regarding equipment, maintenance and co-ordination of activities

- The Chamonix fire has shown that a fire burning freely in a tunnel will rage out of control if not contained within the first 15 minutes. All the members of the rescue services tried to intervene, but in the face of grave difficulties (high temperatures, completely opaque smoke, toxic combustion gases, etc.) an orderly retreat was the only way to ensure their own survival.
- To remedy a big fire, the control centre needs to take rapid stock of the situation so that it can trigger the arrangements. For instance, an opacimeter will detect a large amount of smoke and the controller, assisted by centralised technical management including decision-support, will implement all the instructions laid down for such incidents: closure of toll stations, alert given to the emergency services at the plaza, information passed to the other plaza, activation of tunnel signals, public Fire Brigade alerted in both sides of the tunnel, activation of ventilation systems as appropriate, etc.. The controller will try to “read” what is happening in the tunnel using all the means available to him: detectors, traffic surveillance cameras, verbal exchanges with the other access plaza, questioning of drivers leaving the tunnel. As much accurate and reliable information as possible must be gathered. Precise knowledge of what is happening will help for effective action.
- Automation of existing technology should serve to relieve control room operators of all simple tasks so as to leave their minds free for “high added value” work and enable them to bring their expertise to bear, in collaboration with the head of the emergency team.
- A tunnel radio communication system must be in operation and connected with systems outside the tunnels; the radio system must be interchangeable and allow interconnection.
- In the case of a fire tunnel, effective and efficient ventilation systems are essential and rescue teams require long-lasting oxygen supplies.
- The presence of by-pass tunnels is vital: many motorists could escape through these tunnels.

Regarding the Fire Brigade

- Fire Brigades should be provided with specific equipment to fight against tunnel fires (for example infra red cameras).
- The co-ordination between Fire Brigade and rescue service is very crucial.
- Fire fighters may need a debriefing procedure, in the form of personally written reports, with their impressions.
- The following problems encountered by the second line of response in the case of the Chamonix fire are to be considered:
  - there was a substantial delay in alerting the pertinent Fire Brigade;
  - initial communications via the concession radio were not possible;
  - the positioning of some STTS (Service Tunnel Transport System) vehicles caused problems;
  - the fire main initially failed to provide the quantity of water required and it took some time to reconfigure the supply routes;
  - the refreshments initially available were insufficient;
  - a number of leaks on the fire main were apparent; it is believed that these may have been caused by the heat within the running tunnel;
  - personnel were required to wear breathing apparatus twice in extremely arduous conditions;
  - difficulties were experienced in transporting additional personnel to the incident scene.
- Another important lesson from the Seljestad fire. None of the involved persons in the pile-upped vehicles were stuck in their seats and that gave them the opportunity to escape by themselves or with the help of others involved. The Fire Brigade will almost certainly never reach the fire scene in time to rescue individuals stuck in a burning vehicle, but public arriving early at the scene may save lives given they have fire extinguishers within reach.
- Wind is very helpful in the case of a tunnel fire, as proved in the case of the Seljestad fire. The wind in the tunnel blew with a speed of about 8 meters per second; this gave the Fire Brigade the opportunity to approach the fire rapidly and fight the fire without any major problems. Furthermore, the heavy draught supplied the atmosphere in the tunnel with enough oxygen making the smoke-filled air possible to breathe in. The four individuals who were trapped in the tunnel may have stayed there for more than one hour before the fire fighters escorted them out. A little less wind or draught would have resulted in four casualties.
- In the case of the Amsterdam metro fire, the Fire Brigade used two strategies, which worked well. Firstly they tried to extinguish the fire. Secondly they started searching for trapped persons. Most of the problems were caused by failures in the prevention and in the preparation of accidents. The absence of a contingency plan made it difficult for the emergency services to take the right decisions. Only because it was not a major fire, it worked out well this time.

Regarding the Police

- The search and information procedure for missing persons is to be co-ordinated with the Police.
- An important decision concerning the Mont Blanc Tunnel: Police Officers from the initial Police response team will be responsible for manning the inner cordon within the Service Tunnel. The normal position for the edge of the cordon will be one cross passage from the front of the incident train and one cross passage to the rear of the incident train. The officers at these locations will stop and log details of all vehicles and personnel. Non essential service tunnel traffic will be held at this location. Officers will ensure a 50 metre zone is created to allow service tunnel traffic to turn round. These procedures should in no way affect the operational requirements of each Emergency Service; they may be altered as appropriate by the forward incident commanders to reflect the specific nature of the incident.

Regarding type of tunnel/project

- By-pass transversal tunnels ensure a better management of rescue and fire extinction operations.
- In rail tunnels, accident frequency in lower than in road tunnels, but consequences are more serious.
- Tunnel with two one-way traffic tunnels can limit the human consequences. The second tunnel provides free access for the first rescue operations and for the traffic after the fire is extinguished.

4.4 Lessons learnt concerning information to the public

- Information and education of motorists on the correct behaviour in tunnel must be provided by means of video and safety booklets distributed in driving schools and suitable places.
- Concerning the Mont Blanc tunnel, private motorists using it are informed that heavy goods vehicles also use the tunnel, that a toll is levied and that the usual signs and signals of the Highway Code apply. Truck drivers know in addition that hazardous materials are not allowed through (they may be taken, with an escort, through the Fréjus tunnel located further south). Regular users know that the tunnel is narrow, that it is difficult for trucks to overtake one another, that vehicles must keep to the right, and that the tunnel rises to its midpoint and then descends (signs indicate a steep climb (7%) at the tunnel’s entrance.
- The requirement that in the case of an accident press and public relation service have to work under control was once more one of the experiences.
- A press centre has to be installed and press information must be exactly planned. A common emergency information centre should inform the public and persons potentially concerned.

- After the fire in the Munich Candid tunnel, a special information flyer on behaviour in case of a tunnel fire was sent in a special mailing to each household in Munich (about 800.000).

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Appendix THE ROLE OF INTERNATIONAL ORGANISATIONS INVOLVED IN TUNNEL CONSTRUCTION AND OPERATION

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1. INTRODUCTION

Two tragic accidents occurred in 1999 in road tunnels. It was on the one hand the fire in the Mont Blanc tunnel (France and Italy) on 24.03.1999 causing 39 casualties, and on the other hand the accident and the fire in the Tauern tunnel (Austria) on 27.05.1999, with 12 casualties. A third accident just occurred few days ago, in a tunnel in Austria for a mountain funicular. The number of casualties seems much higher than those of the two other road tunnels that I quoted. The mentioned road accidents have made the concerned authorities aware, at the local, regional, national and European levels, of the nuisances provoked by the increase of road traffic in sensitive areas, such as the Alps, as well as the need to re-evaluate the safety of road tunnels.

As a delegate of international associations, it is in my opinion that classification is needed on the following:

- roles of the various involved international technical Associations in the preparation of recommendations or standards concerning safety, notably regarding fires in tunnels, since a few decades already;
- actions that have been taken by the same organisations, and others, since the two tragic accidents.

In conclusion, it is necessary to foresee a number of elements in disaster management, which need to be taken into account by all actors involved in the construction safer tunnels and in the preparation of intervention plans, along with intervening in a co-ordinated way during any type of tunnel accident. A corollary herefrom is the need to inform the wider public, especially the drivers, about the required behaviour in the tunnel and the safety measures taken by the tunnel management, so as to make them aware that effort has been made to reduce the risk in tunnels, and to give them confidence in case of any type of tunnel accident.

2. INTERNATIONAL TECHNICAL ASSOCIATIONS

2.1 World Road Association (PIARC) and its Road Tunnel Operation Committee (C5)

The World Road Association is an association of governments. About 80 countries are represented in PIARC, and about 30 in the Road Tunnel Operations Committee, being one of the 25 or 30 Committees at the moment active. In developing or transition countries, its action is completed i.e. by the Committee "Transfer of Technology". In what is the Road Tunnel Operation Committee active? The environment, the geometry (thus the number of lanes, the number of shafts, the need and the width of footpaths, the lowered gauges), all the equipment's, the prevention of fires and explosions, the emergency exits, the drainage of not yet burning products and all what concerns management, maintenance and operation. All this can be found back in the reports published each four years, before each World Road

Congress (the last being the one of Kuala Lumpur in October 1999). The domains of activity in the last cycle are:

- the reduction of exploitation costs;
- the pollution and the ventilation: in our countries, essentially in Europe, CO and CO_2 create less and less problems in our road tunnels, our cars and our trucks became clean; but this is not true for nitrogen oxides: this becomes more and more serious, and one has to start thinking about it during the coming years;
- the covered roads: creation of light or partial coverings limiting the propagation of noise and pollution, without needing heavy investments in civil engineering and equipment's (lighting, ventilation);
- the transport of dangerous goods (see point 2.5: work carried out together with OECD);
- the fires and smoke control: an important report was prepared and published in the beginning of 2000; it deals with all principal and dimensioning elements of the ventilation, not to keep a good quality of the air in the tunnel, but to use it in an adequate way in fighting an eventual fire.

2.2 International Tunnelling Association (ITA)

The International Tunnelling Association gathers national tunnelling associations, representing in each country the community of bodies and persons concerned by underground works in general, and particularly by tunnels, as well as private associations and individuals. It covers 50 countries. The Association has two main objectives: encourage the use and the planning of the underground and promote progress in construction and use of these achievements. ITA does thus not cover operation problems: for the road tunnels, it is the role of PIARC, and specially its Road Tunnel Operation Committee. Both Associations have the same secretariat in the *Centre d'Etude des Tunnels* in Lyon. When they have to deal with parallel subjects, they create common working groups on the theme (example: fires in tunnels and their effects on the structure of the achievements).

It is indeed obvious that, i.e. for environmental reasons, the use of the underground will increase, as well for transport (traditional tunnels) as for numerous activities linked to it (commerce's, services) or not, as storage of goods needed for daily life (aliments, all kinds of supplies) in the profit of making the surface free for more "interesting" uses, and even storage in general, at greater depth, as for nuclear or other deposits.

At another level, the localisation, the alignment of a tunnel, particularly in the mountains, were up to now essentially imposed by geology. After the fires of 1999, and specially the lack of links to safe places (emergency exits), a new way of thinking started, tending to take into account, for the choice of the general alignment of a tunnel, the accessibility from the surface. In cases where the choice exists between two equivalent alignments, one permanently under 1500 or 1800 m of mountain, and the other where shafts or shafts can be carried out with level differences of 300, 500 or 800 m, there is at least interest in studying that possibility, as well for ventilation, as for intermediate exits. This is of course more difficult for under sea or under river tunnels, where other means are more appropriate, as the realisation of (or the provision for) a second shaft, or, in the case of immersed tunnels, a slight increase of the width (less than 10 %) allowing to create a safety gallery.

2.3 International Railway Union (UIC)

Railway safety is a primordial point, and the risk of a fatal accident in a train is 10 times lower than on the road. In inverse, the cost to improve the safety of the train (cost per avoided fatal accident) is about 10 times higher than on the road. The preoccupations of the railway networks are as follows: the increase of rules increases the price of rail and makes it less competitive compared to the road, although it is much more safe. The separation between infrastructure and operation increases the interfaces and thus the risks. On the other hand, the risk in tunnel is about 40 % lower than on the total network, and the fire risk represents about the half of the risks in a tunnel. The interoperability of trains has nevertheless to lead to apply common rules:

- a train should be able to drive 15 minutes at 80 km/h, even on fire;
- the alarm signal should not stop the train in a tunnel;
- it is needed to foresee temperature detectors;
- it is needed to avoid smoke to enter in the vehicles.

2.4 International Union of Public Transport (UITP)

The International Committee for Metros, the most concerned by the underground works, is involved in:

- operation;
- rolling stock;
- fixed installations;
- electrical installations and safety systems.

Following carried out studies, one should not account on the user to give the alarm and fight the fire. One thus needs smoke detectors (better than temperature detectors), visual and voice means and a good training of operating personnel. A reflection has now started on the mutual influence of underground urban transport and connected activities, mainly commercial, in other underground parts of the urban stations.

2.5 Organisation for Economical Cupertino and Development (OECD)

The OECD started in 1994, with the technical collaboration of C5 of PIARC (see 2.1) and the technical support of the European Commission, a study to evaluate on a scientific basis what are, in safety terms, the best routes for a vehicle transporting dangerous goods: has it to go trough a tunnel, has it to take another road, even a mountain road. This study is now carried out, and is available since end 2000 for the operators of all road tunnels; it includes i.e. a QRAM (Quantitative Risk Assessment Model) and a DAM (Decision Assisting Model) tool aimed to assist each tunnel operator.

2.6 European Union (EU)

In the framework of the common transport policy, the European Union is allowed to take measures to improve the safety of transport. It is one of the objectives of this policy, following article 75 of the Treaty of the Union. But the application is limited by the principle of subsidiarity, meaning that the Union should only act if the measures taken at its level are more effective than those taken directly by the Member States. If, at the level of the European Union, much has been done at the level of safety of transport, it was more the case in the field of vehicle safety or the harmonisation of the drivers licence or the technical control, and less in the domain of safety on the technical level of the transport infrastructure.

3. OTHER INTERNATIONAL ASSOCIATIONS

3.1 International Road Transport Union (IRU)

IRU is speaking for the world-wide industry for people and goods transport by bus and by road. Tunnels cover various aspects, mainly since they acquired a great importance in the long distance international transport from North to South in Europe. As far as safety is concerned, the question is to know if trucks are really a danger on the roads, and particularly in tunnels. Some figures show that trucks are proportionally less implicated in accidents (in Germany, 10.5 % of the vehicles are trucks, and the percentage of trucks implicated in road accidents is 6.2 %).

3.2 International Road Federation (IRF)

IRF is an NGO. Due to its network structure, IRF represents a wide range of adherents from private and public sector, from companies active in the construction and operation of roads to research institutes and world-wide national road administrations. This diversity allows the various streamings and sensibilities to meet in a spirit of dialogue and complementarity. For IRF, and beyond the immediate preoccupations, tunnels represent a strategical interest.

4. ACTIONS TAKEN SINCE THE FIRES IN THE MONT BLANC AND TAUERN FIRES

Since these two tragic accidents, as well the international circles since ever concerned by safety in (road) tunnels (seesections2 and 3 above) as the authorities of some specifically concerned countries and an important number of other public and private organisations dealt with this subject, as well in the public interest as a "subject" able to increase the turnover of organisers, specialised or not n this field. As few internal contacts exist between the numerous public bodies, some of them participate voluntarily, considering this as a part of their information task, and others refuse systematically any collaboration to create any profit from these accidents.

4.1 World Road Association (PIARC): Road Tunnel Operation Committee

After the Kuala Lumpur Congress, the Executive Committee of PIARC was of the opinion that C5 should increase its profile even more, as a specialised body dealing with operation of road tunnels; this was confirmed by the changing of its name. The Committee was of the opinion that:

1. The reports proposed at the Kuala Lumpur Congress kept all their value after the fires of 1999.
2. An important element to add was the human behaviour in case of a fire in a tunnel, as well as the levels of:
   - preparation and the training;
   - real immediate behaviour (including help to others);
   - reactions of the specialised services, either depending on the tunnel, or operating more widely.

Thus a specific Working Group was created in the beginning of 2000. The majority of the other activities were kept, such as the assistance to the use of the models created for the transport of dangerous goods through road tunnels, and the research on theoretical curves temperature-time in cases of several fire-models, allowing a better dimensioning of the structure and the equipment (including the ventilation and their time to be fully operational).

4.2 International Tunnelling Association (ITA)

Its role, in this framework, is in principle limited, via a common Workgroup with WG5 of C5 of PIARC, to make applicable the temperature-time curves to the structure of existing and new tunnels. It also organised, with the *Office fédéral des Routes* of Switzerland, a specific seminar in Lausanne held on 23-24.03.2000. It will of course use all its possibilities to regain world-wide confidence from decision makers and the public, in the use of all kinds of underground facilities.

4.3 International Public Transportation Union (UITP)

The following recommendations were put forward:

- the rolling stock has to have a low calorific potential;
- the electrical wires should not contain halogen;
- in case of fire in a train, it has to join the next station;
- measures have to be taken to allow the evacuation of travellers located in a tunnel;
- intervention procedures have to be set up with the rescue teams, and periodically tested.

As approaches in the various countries are different, it seems necessary to go deeper into the following points:

- smoke removal: can the location of safety exits at regular intervals replace the installation of smoke removing ventilators?
- fire brigade accesses: is the distance of 800 m between accesses to the tunnel adapted for obtaining short intervention times?
- various: the development of commercial activities and animations in the whole of the metro stations needs to think about the safety measures to be adopted.

4.4 European Union (EU)

The European Council (Heads of State and Governments) has asked to the Council of Ministers of Transport to think and take measures. The last one has asked to the Commission to make recommendations in this field. The Commission has organised, on 28.09.1999, a meeting with European experts in the field of safety of road tunnels. The inventory was made of the existing or going on works, and it has been evaluated in which domains the EU could bring an added value to what had already been done. For the infrastructure works, the civil engineering and the equipment, it appears that what has been carried out by ITA and PIARC allows to know the best available technologies.

For the reaction in case of big fire, it appears that the reaction time of the emergency teams in case of fire should not exceed about 10 minutes, which is very short if one considers the times for detection and alert, the progression difficulties, the distances. This means that an effort remains to be done in the prevention of accidents and fires in tunnels. The prevention is part of the precaution measures. In this field there is a possibility to try to develop techniques for controlling fires.

As the existing systems give no satisfaction, it was decided to put it forward as a research theme in the framework of the Research Programme for Transports. The experts have underlined that the people in an accident should be informed and could escape without waiting for the rescue teams. For the traffic management, the communication system with the users to give directives in case of accident is a domain needing harmonisation.

The call for offers for the Research Programme has provided four proposals about safety of tunnels, but no one was kept by the selection experts as reaching a sufficient level. The services of the European Commission will nevertheless try to obtain financing for a combination or an integration of some of these proposals.

4.5 Economic Commission for Europe of the United Nations

The Economic Commission for Europe has carried out a tremendous job in the field of transport in achieving numerous international agreements and conventions. But the safety inside the infrastructures is also important, as well as to take account of tunnels, what was not done until now. The accidents of the Mont Blanc and Tauern tunnels have taught us that this topic was previously looked at only in a very vague and general way.

The singularity and the complexity of the construction of tunnels, as well as their costs, have brought governments to rely, perhaps more than needed, on specialised companies, possessing the appropriate technologies. The regulation of tunnels exists only at national level. At the international level, only NGO's (PIARC, ITA, etc.) have carried out research work and developed safety measures for tunnels. After the accidents of the Mont Blanc and the Tauern, the transport companies have looked at the main legal instruments, mainly AGR (Agreement on the main international roads, from 1975), AGC and AGDC, as well as the Conventions of Vienna on road traffic and road signalling. It has been discovered, not without some surprise, that the safety measures in tunnels were almost non-existing and, when existing, were not effective. In this situation, and taking into account the forecasts about traffic announcing an increase of goods traffic (increase of 80 % through the Alps), the Economic Commission for Europe transmitted these documents to the intergovernmental authorities. It was concluded that the existing legislation should be improved.

The main domains in which to develop international agreements, reference frames, are first the infrastructure and the equipment of tunnels. One will find there the following sub-themes: improving of existing tunnels, construction of new ones, evacuation and protection of users, access to tunnels for emergencies and maintenance services, control of fires.

The second domain for developing rules is the control in the tunnels, with the following sub-themes: intervention rules for emergency themes, rules concerning traffic and signalling, usefulness of specialised vehicles, information for the users, regulation of the transport of dangerous goods, control of safety in the tunnels and of the standards of these controls.

The complexity and the inter-relation between the various aspects of the problem imply the creation of a group of experts of which the task is to develop recommendations for minimal safety rules in tunnels. These recommendations could become legal instructions.

The discussion themes are ready and include an inventory of all road and rail tunnels in Europe of more than 1,000 m, the preparation of a list of all accidents that happened during the last years (and if possible the causes of these accidents), the collection of information about safety rules in tunnels, about safety measures prepared and adopted by the international organisations, the preparation of recommendations to improve the infrastructure of existing tunnels and the rehabilitation of tunnels.

These recommendations should reduce accident risks in tunnels, and maximise their effectiveness. The group of experts started its work in June 2000 and will finish it in the autumn 2001. It is a challenge for the Economic Commission for Europe of the United Nations.

During the first meetings of this multidisciplinary group, it has been revealed that the invited countries and institutions have only poorly answered the invitation, and only for the road sector, by nominating their members of C5 of PIARC.

The small size of the group of experts, used to work together, allowed a good progress, the final report being based on the structure created by the *Office fédéral des Routes* of Switzerland (OFROU), and includes measures about:

- the road users (training, behaviour, control of the drivers);
- the operation (dangerous goods, control of the vehicles, convoys, safety distance, Co-ordination centre (designation of responsibility exercise);
- the infrastructure (continuous geometry, safety issues, cross passages, equipment's);
- the vehicles (technical control, fire extinguishers).

The group has also set up a provisional list of the international rules already under application, and where a modification could be envisaged. This includes:

- the Conventions of Vienna about road traffic and signalling;
- the European Agreement on main international traffic roads (AGR);
- the European Agreement on international transport of dangerous goods by road (ADR);
- regulations on the construction of vehicles.

Proposals could moreover be made for any other point that not should depend on the agreements or regulations depending from the ECE/UN.

4.6 Conference of Road Directions of Western Europe

This non-official organisation created in 1994 by the European Union includes, above the 15 Member States, Iceland, Norway and Switzerland. It examined and approved in its principle the propositions of OFROU (see sections 4.5 and 4.8) with the view of a transposition in national recommendations.

4.7 International Tourism Alliance

An enquiry carried out immediately after the Mont Blanc accident, lead to a classification of about 20 road tunnels in 4 categories (good, average, poor, very bad), based on a series of factors (not known, neither in description, nor in weight) influencing safety.

The conclusions, rejected by most of the specialists, concerned:

- the categorisation of tunnels itself (no distinction between, for instance, mountain tunnels and urban tunnels);
- the absolute and general necessity to build always unidirectional shafts, independently of the real or forecasted traffic volumes.

4.8 National Guidelines

Various countries did not wait for the preparation of international guidelines for establishing compulsory rules, either national or for the public services in charge of the main road network. This is the case for:

- Switzerland (OFROU report mentioned in 4.6);
- France (ministerial note of 25.08.2000).

It still remains to check if these rules will be able to comply with the international guidelines under preparation.

5. PERSONAL CONCLUSIONS

The accidents of Mont Blanc and Tauern, in the beginning of 1999, have started an important number of national and international actions, coming from the public sector or international technical or scientific organisations, or sometimes from the private sector, mainly with good aims. This led to a number of duplications of efforts, which will only be avoided by an increased co-ordination and a systematic cross-participation of the main actors.

The technical organisations (mainly PIARC and ITA) have long worked together and have precise delimitation's of competencies and responsibilities. The European Commission, DG Transport and Energy, have reoriented their efforts to the specific sector of research, in domains which could be proposed by the quoted associations. The Economic Commission for Europe of the United Nations, having already proved its capacity in setting up important regulations for road safety and signalling, could complete them with the support of the same organisations, that are de facto the driving forces in the started actions. The other associations quoted under sections 2, 3, and 4 can usefully bring in the standpoints of the users that they represent. This meeting could be an important step in this direction.