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Meeting of the Multidisciplinary Group
of Experts on Safety in Tunnels (rail)
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agenda item 2)

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RECOMMENDATIONS OF THE GROUP OF EXPERTS ON SAFETY IN TUNNELS (RAIL)

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A. INTRODUCTION AND MANDATE

A.1 INTRODUCTION

The importance of safety in transportation tunnels was dramatically emphasized by the accidents and fires in the Mont Blanc, Tauern and St Gotthard road tunnels. In addition, to the tragic loss of life, the impact of the interruption in the use of these international routes was considerable. As a consequence, the UNECE Inland Transport Committee created an Ad Hoc Multidisciplinary Group of Experts on Safety in Tunnels to consider and report on the issues, in the first place those pertinent to road tunnels. Their work was finalized in the report to the Inland Transport Committee published as TRANS/AC.7/9 dated 10 December 2001.

The Inland Transport Committee subsequently invited a further group of experts from the UNECE member countries to consider this issue of safety in railway tunnels. The International Union of Railways (Union Internationale de Chemin de Fer – UIC), an important non-governmental organization, was also included. The European Association for Railway Interoperability (AEFI), the joint representative body co-founded by UIC, UNIFE and UITP and mandated by the EU Commission to lay down the Technical Specifications for Interoperability (TSIs) bringing together representatives of the infrastructure managers, railway companies and industry, also participated in the work of the Group. Eurotunnel as the operator of the current longest tunnel in Europe was also invited to send a representative.

The Group began defining the area of its activity by asking members to indicate the scale of the problem in their country and if their Governments had rules or regulations or were likely to introduce new or revised rules or regulations to control safety in railway tunnels. The responses were published on the UNECE web site, http://www.unece.org/trans/main/tunnels/html.

The Group decided to limit its field of interest to tunnels longer than 1000m and up to 15000m. It noted that tunnels longer than 15000m may require further safety measures as may underwater tunnels, those typically having a rising gradient when leaving the tunnel. It also decided to limit its present work to heavy rail main lines, as likely to be found on international and interoperable routes. Underground or sub-surface stations and light rail or metro systems were not considered at this time.

Note was taken of the work already done by the UIC and its consultant, available in draft form as UIC-Codex 779-9, Safety in Railway Tunnels, and made available as an informal document on the UNECE Transport Division Internet site. In particular, the Working Group felt that the general principle set out in that document would be very suitable for its own deliberations. This principle sets out the preferred actions in order and can be summarized as:

1. Prevent accidents,

2. Mitigate the consequence of accidents,

3. Facilitate escape,

4. Facilitate rescue.

The Group also took note of the development of international railway routes and the impact that this might have on the safety of tunnels on the route. Specifically it noted the EC Directive, 96/48/EC, on the interoperability of high-speed trains, which contains Essential Requirements for the safety of long tunnels.

A. 2 MANDATE OF THE AD HOC MULTIDISCIPLINARY GROUP OF EXPERTS ON SAFETY IN TUNNELS (RAIL)

During its first session (27-28 June 2002), the Group has adopted as its mandate the following items:

- To make an inventory of all long road and rail tunnels in the UNECE region on the basis of a reference length (e.g. 1,000 metres or longer) for rail*/road tunnels to be determined by the working group;
- To prepare a list of all serious fires and, if possible, major traffic accidents that have occurred in European tunnels in the last 40 years (if possible) indicating their causes (if known) and collect the most relevant findings for all these major accidents (if known);
- To obtain, if possible, information on safety provisions in tunnel management systems;
- To collect existing tunnel safety documentation (regulations, reports, recommendations, conclusions, etc.), within the European Union and relevant international organizations (UIC*, OSZhD*, CER*, ECMT, OTIF*, etc.) and draw up a list of ongoing work within these organizations;
- To prepare recommendations for improving safety in tunnels to be built in the future;
- To prepare in a coordinated manner, in the form of recommendations and/or proposals for amendments to existing legal instruments, minimum safety provisions for the operation, maintenance, repair, upgrading, rehabilitation and refurbishment of tunnels of various types and lengths, and traffic conditions in these tunnels particularly as regards: signals, rolling stock*/vehicles, dangerous goods, driver training, etc.;
- The above recommendations and/or amendments should, inter alia, minimize the risk of accidents in tunnels and maximize at the same time the economic efficiency of tunnel construction and operations.

It was proposed that the Multidisciplinary Group of Experts on Safety in Tunnels should be composed of representatives of SC.2 and WP.15 as well as relevant international governmental and non-governmental organizations and experts in tunnel matters appointed by the States members of the United Nations Economic Commission for Europe.

In responding to the mandate, the Group made an inventory of all long road and rail tunnels in the UNECE region on the basis of a reference length which could be found on the UNECE Transport Division Internet address: http://www.unece.org/trans/main/ac9/ac9inf1.html.

In addition, the Group has collected the available information from member countries about railway accidents in tunnels and associated injuries and fatalities. The collected evidence

showed that very few, if any, accidents leading to major injury have occurred in railway tunnels over the last 30 years. It might have been possible that reported injuries, even fatalities, had occurred during maintenance or repair but none have involved members of the public.

Moreover, the Group solicited information on safety provisions in tunnel management systems and collected existing tunnel safety documentation (regulations, reports, recommendations, conclusions, etc.), from the member Governments, the European Union and relevant international organizations (UIC*, OSZhD*, CER*, ECMT, OTIF*, etc.) and made them available at the Internet address: http://www.unece.org/trans/main/ac9/ac9age.html.

After collecting and reviewing this documentation, the Group became aware of the fact that some member countries were far more advanced in regulating the safety provisions and setting up the safety requirements for railway tunnels than other countries of the UNECE. This finding had further strengthened the Group's conviction that a lack of internationally harmonized railway tunnel safety principles and measures need to be brought to the attention of the Governments as it might have serious consequences for the safety of rail transport, lives and health of users and transport operators. Aware of the strong necessity for developing commonly agreed recommendations with the aim of harmonizing safety principles across Europe, the Group made an effort to offer to the member Governments a set of recommendations that might be instrumental in preventing the tunnel accidents and increasing the overall level of safety in rail tunnels.

The Group's recommendations for improving safety in tunnels to be built in the future and prepared in a coordinated manner, including safety measures related to the infrastructure, rolling stock and operations, aimed at minimizing the risk of accidents in tunnels and maximizing at the same time the economic efficiency of tunnel construction and operations, are presented in part C of this document.

The Group concluded with some recommendations on general safety policy which the Inland Transport Committee may care to adopt.

B. GENERAL PRINCIPLES OF SAFETY IN RAILWAY TUNNELS

System view

Cost effective safety in rail tunnels is the result of the optimum combination of infrastructure, rolling stock and operational measures.

Effectiveness

The objectives of the recommended safety measures are:

1. Prevention of accidents
2. Mitigation of the consequence of accidents
3. Facilitation of escape
4. Facilitation of rescue

The order in which these are listed reflects their decreasing effectiveness, especially in the case of fire.

Optimum safety

Application of the recommended measures does not necessarily guarantee adequate or optimum safety in rail tunnels. It is therefore appropriate that they should be considered in the context of a coherent safety plan adapted to local conditions. Consideration needs to be given to the balance of costs for increasing safety in tunnels against the overall resources available to mitigate safety risks within the entire rail system.

Cost effectiveness

Some of the safety measures proposed in Part C, such as for example, C1.10, C2.10, C3.04, C3.05, C3.06 and others cannot provide a clear and unique recommendation, as their cost effectiveness varies in a wide range depending on local circumstances. Their effectiveness and adequacy may be quite different from one case to another. It is, therefore, necessary for safety authorities to spend the available finances for desired safety levels in the most efficient way. Therefore, the authorities will have to make decisions and select among the proposed measures according to the safety plan adapted to the local conditions.

All tunnels

The recommended measures apply to all railway tunnels. They can be reduced for short tunnels (less than 1 kilometre long), they should be adapted or enhanced for

very long tunnels (longer than 15 kilometres), for underwater tunnels, underground railways (subways), underground platforms and steep Alpine tunnels.

In existing tunnels, measures requiring civil engineering modifications can generally be applied at reasonable cost only in the course of upgrading operations. Otherwise, the required safety level has to be reached through measures in the field of rolling stock and operations.

The aim of the set of recommendations is to promote a harmonized safety level in Europe, taking into account the interoperability of infrastructure and rolling stock.

For this purpose, the Group propose minimum recommendations that should ensure a harmonized minimal safety level in rail tunnels across Europe. The Group also proposes to define some binding interoperability rules in order to oblige railways to harmonize safety procedures.

C. RECOMMENDED SAFETY MEASURES FOR NEW TUNNELS

C.1 Prevention of accidents

Recommendation C1. 01 (see also Recommendation C2.09)

In case of fire on board of a train passing through a tunnel, the first preference of the train driver must be to get the train out of a tunnel and stop it in an optimal position to allow the self-evacuation of passengers and easier access to emergency and rescue services.

With the new European regulations on fire resistance for railway passenger wagons, application of this recommendation could be carried out relatively easily.

Infrastructure measures

Recommendation C1.02

Speed monitoring

As with all railway lines the train control system should prevent collision or derailment by suitable signals or train controls which will prevent the train passing a signal at danger or exceeding the permitted speed.

Recommendation C1. 03

The signalling system

Should prevent collisions including driver errors such as passing of the signal and exceeding the speed limits.

Recommendation C1. 04

Tracking the status of the train before entering tunnels

Other types of train detection, such as thermo checking, effectuated by scanning of particular control points on the train engine and rolling stock for occurrence of heat out of the permissible range, are also recommended as a preventive measure that could indicate possible fire danger.

Recommendation C1. 05

Train control equipment

Appropriate train control equipment (blocked brake, hot boxes), is particularly important for sections with many tunnels. Fixed line side temperature sensors for the detection of hot axles and wheels prevent fire caused by overheating and derailments due to broken wheels and axles.

Recommendation C1. 06

Installation of switches and crossovers

Whenever possible, switches should not be installed in tunnels and on the approach to tunnel entrances to avoid that a derailed coach is thrown out of track before an obstacle such as a tunnel portal.

Recommendation C1. 07

Control of access to tunnels and regular inspection of tunnel conditions

Prevention of unauthorized access to tunnel portals should be a standard measure in respect of not only safety but also security of the traffic in tunnels. If carried out systematically and thoroughly, at tunnel entrances, emergency exits, technical buildings, rescue areas and access roads, both measures reduce risks and increase safety in tunnels.

Rolling stock measures

Recommendation C1. 08 Train radio

A particularly effective device, it is highly recommended since it provides a communication channel between the operations centre, train crew and passengers. It should include both fixed installations in tunnels and equipment on board of trains.

Recommendation C1. 09 Fire protecting measures and onboard fire detection

Should be built in the rolling stock where such installations would be most required (locomotives, power systems, below the floor) and concentrated in places where the potential for fire is highest. It may not be absolutely necessary to install fire detection installations in passenger wagons. In the case of freight wagons, fire detectors are much more important and should be considered. However, passenger sleeping cars should have fire detectors and automatic extinguishers. This is considered as a relatively cheap measure that significantly increases safety in general. Communication between passengers and the train driver is crucial in the case of fire on passenger wagons.

Operational measures

Recommendation C1. 10 Regulations for operations

Complete separation of operations for passenger and freight trains, applicable only to double-track tunnels, may not be feasible in all tunnels. Therefore, this measure is recommended only for high-risk tunnels, and if operating conditions allow it. High-risk tunnels are considered those tunnels that are very long and/or have a lot of traffic, traffic mix with passenger and dangerous goods transport, etc. Although effective as a preventive safety measure, total separation of traffic may not be necessary if an optimized timetable could prevent passenger and freight trains from passing through a tunnel at the same time. Very heavy traffic through particular tunnels could be made safer by separation of operations of passenger and freight trains into day and night. Restrictions on passage of freight trains carrying dangerous goods and passenger trains through tunnels at the same time are also recommended only for high-risk tunnels and if operating conditions permit. In practice, restrictions on dangerous goods means that all freight trains are concerned, as it is not feasible to sort out single loads or wagons containing dangerous goods as well as all possible combinations of

different freight loads that could be dangerous. The total separation of dangerous goods and passenger traffic might be extremely costly and more rigorous safety standards for freight wagons for dangerous goods could be more economical as well as an equally safe solution in cases of networks with high density of traffic. This measure thus should primarily concern block trains carrying dangerous goods. In any case, the possible risk of accident involving dangerous goods should be reduced by closely evaluating each specific situation whether it concerns a particular type of dangerous goods or a particular tunnel.

The train crew is usually informed about the nature of dangerous goods in the train. The risk category of goods, fire risk, toxic hazard and other relevant information in each particular transport operation should determine the operational and eventual emergency procedures. Common operational regulations for the transport of dangerous goods may also require more harmonized training and education of train drivers at the international level.

Risk analysis of safety measures involving dangerous goods are based on cost-benefit considerations of various options. For example, if freight trains carrying dangerous goods are diverted on routes without tunnels, risk on these routes may increase if the line passes through densely populated areas, through a sensitive environment or on lines with a lower track standard.

C.2 Mitigation of the consequence of accidents

Infrastructure measures

Recommendation C2. 01 Double-bore single-track tunnels

In relation to safety both single-tube double-track and double-tube single-track tunnels have their advantages and disadvantages. Single-bore double-track tunnels might be less costly to construct than double-bore tunnels. Single-tube single-track tunnels might be safer as they avoid accidents caused by derailments obstructing the adjacent track and they provide the second tube as a safe place. On the other hand, double-track tunnels have more space for an eventual rescue operation but they also have more space for smoke and fire spreading. For high-speed trains, double-track tubes might be preferable and for mixed traffic, taking into account aerodynamic factors, a single tube single track might be more appropriate. The choice should be the result of a thorough evaluation of all parameters related to safety as well as costs considerations.

Recommendation C2. 02 Cross section of double-track tubes

Double-track tunnels should have a sufficiently large diameter so that, when two trains are passing, hazardous pressure transients do not occur. Definition of the cross sections of double track tunnels needs to take into account such elements as: train speed and type of traffic, aerodynamic aspects, geology of terrain, construction method, space for escape routes and construction costs. Cross sections should be sufficiently large to reduce possible interaction related to the aerodynamic effects, enable larger walkways, reduce the possible collision in the event of a derailment, etc.

Recommendation C2. 03 Fire protection requirements for structures

Fire protection for structures represents an important element of higher safety in rescue areas and safe places in tunnels. Similar fireproof standards for tunnel structures need to exist in all countries. They need to be based on temperature curve, type of construction material used and related to the nature of structures (with people or without). Tunnels should have such fireproof features that would allow sufficient time for rescue and evacuation operations. Certain fireproofing materials may cause certain problems (i.e. limited life, need for costly replacement and renovation, and may have faults that may damage trains). The temperature curve should be commonly used to assess the fire resistance of concrete and other structures in tunnels and specified fire-resistance material, capable of sustaining specific fire and temperature maximums for a specified time, should already be used in the construction phase.

Recommendation C2. 04 Fire, smoke and gas detectors

Fire, smoke and gas detectors in tunnels enable a rapid location of fire in the ignition phase. Available technology allows fast and reliable detection of visible fire and smoke. Problems might sometimes occur due to false alarms caused by ambient or brake dust, sea mist, etc. The distinction should be made between location of these detectors in the main tunnel and technical rooms. While installation of fire, smoke and gas detectors might not be necessary as a standard measure in all tunnels (relatively low frequent traffic), their installation is highly recommended in all technical rooms as it could alert technical crew to quickly leave. Gas detectors are recommended for tunnels with a low point in the tunnel (u-shaped) and if gas could enter the tunnel from surroundings. Another approach suggests that fire and smoke detectors installed on rolling stock and locomotives themselves might be more effective than those installed in tunnels. On-train detectors signal to the train crew the presence of the potential fire risk, and in combination with a radio communication, allow the crew to transmit this information to the operations centre. This solution, however, might require special training for the train crew.

Recommendation C2. 05 Fire extinguishing systems

The type of fire extinguishing systems, for both main tunnel and technical rooms should be determined depending on the potential causes of fire. An automatic-triggered fire extinguishing system might be less reliable, due to potential malfunctions or false alarms, and it is not recommended for main tunnels but is recommended for technical rooms with highly sensitive technical installations.

Recommendation C2. 06 Smoke extraction and system

If the natural airflow in the main tunnel is sufficiently strong, it may guarantee one smoke-free side where people would be safe and rescue operations could take place. Installation of smoke extraction/ventilation systems in such a case might not be necessary. Ventilation and smoke extraction might be useful or essential in providing access to safe areas. Smoke extraction in specific places in the main tunnel (double-track/double-tube single-track and passages between double-tube single-track tubes) could prevent smoke spreading into sections defined as safe parts and reduce the likelihood of smoke reaching other trains. Smoke extraction and ventilation systems must be designed in such ways (produce overpressure) to keep emergency exits, cross passages or a parallel safety tunnel free of smoke and might need to be installed in these safe places.

Recommendation C2. 07 Track drainage system

Track drainage system is an important safety feature provided that it has appropriate dimensions and retaining basins. It might not be an essential measure for tunnels only reserved for passenger traffic, but is highly recommended for tunnels used for freight traffic, especially if dangerous goods are frequently transported. The system facilitates extraction of snow or rain brought into the tunnel by trains, spills or water from the fire extinguishing. It could also retain polluted extinguishing water or run-out of dangerous goods if there is such a transport, and thus it has an additional role in reducing environmental damage at tunnel portals.

Rolling stock measures

Recommendation C2. 08 Derailment indicators on train

In some countries, derailment indicators are standard equipment in freight trains and are recommended for trains transporting dangerous liquids and other dangerous goods because tanker trains and other trains transporting dangerous goods represent special concern in case of derailment.

Recommendation C2. 09 Emergency brake neutralization and maintaining the movement capability

Emergency brake neutralization and maintaining the movement capability are safety measures that increase the likelihood that, in the event of fire, a passenger train will be able to leave the tunnel. However, the application of this measure needs to be further discussed. As different systems of brake neutralization exist in practice today, an agreement might be necessary on international level about the type of the system to be used in international traffic. In addition, wagons belonging to different rail operators coupled together may not all have the possibility of emergency brake neutralization. Considering these facts, one approach argues in favour of a complete removal of emergency brakes from trains, and their replacement by an alarm system. This approach is based on the concept that the decision about stopping the train should be a responsibility only of the train operator, and misuse or abuse by passengers could be detrimental to the safety of the train. Another approach argues that an emergency brake could be active on all passenger trains up to a certain speed, after which the train operator should be responsible to disabling it.

Recommendation C2. 10 Onboard fire extinguishing equipment

Installation of portable onboard fire extinguishing equipment is recommended on both traction units and passenger wagons as they allow rapid fire fighting in a very early stage of fire development. In some countries, installation of portable fire extinguishing equipment in locomotives and passenger wagons is obligatory. Smoke detectors and portable extinguishing equipment are considered particularly important for sleeping cars. Installation of automatic and portable fire extinguishing systems in passenger cars might not be necessary. Automatic or manually operated extinguishing systems are particularly important and recommended on traction units. Installation of fire extinguishing equipment in technical compartments, restaurant cars, toilets, etc. has advantages and disadvantages. A false alarm may trigger a train to stop and provoke new risks (e.g. people leaving the train) and operating disturbances. Installation is relatively expensive and maintenance costly. The advantage is that fire could be neutralized relatively quickly without a major emergency.

Recommendation C2. 11 Central control of air-conditioning

The purpose of central control of air conditioning in an emergency is to slow down the spread of fire and smoke in wagons. The problem may emerge when the cause and location of smoke is unknown, as it may come from the outside of the train or be caused by a false alarm. It is recommended that air conditioning could be switched off centrally and that the train crew/driver could operate it quickly.

Recommendation C2. 12 Ability to split trains

A train splitting measure is recommended in some specific situations. The decision to evacuate passengers by moving them into the intact part of a train, splitting this part, and pulling it out with a traction unit should be based on time calculation and quick evaluation of each particular emergency situation. Due to different coupling systems, decoupling of a passenger train may take too much time and thus endanger passengers and crew. For freight trains on fire, it is recommended to decouple wagons able to move and not caught by fire and pull them out of the tunnel.

Recommendation C2. 13 First aid equipment on board

This measure is recommended as a general safety measure. Each train should be equipped with at least one first aid box. The first aid equipment must be located so that it is easily accessible by the train staff, and it must be secured and protected from vandalism. It is also recommended that, in addition to train driver, all crew members be trained to use first aid equipment.

Operational measures

Recommendation C2. 14 Stop following or encountering trains (out of the tunnel) in case of incident

In the event of an incident other trains should be stopped before they enter the tunnel. Trains in the tunnel should be allowed to continue and leave the tunnel but it may be necessary to restrict their speed in order to minimize any adverse aerodynamic effect on the incident train. Following trains already in the tunnel should be stopped as soon as possible in order to minimize any risk of them encountering any trailing smoke from the incident train.

If the incident train is unable to run out of the tunnel, the driver should bring the incident train to a controlled stop at a known marker at a cross-passage or intervention point.

C.3 Facilitation of escape

Self-rescue practice and rescue procedures are different from one country to another. It is recommended that procedures need to be harmonized at the international level. Passengers need to be properly instructed in advance how to behave in case of accident or fire in the tunnel because train crew might not be available to assist them. It is recommended that all rail operators must develop and introduce methods for instructing passengers on procedures in emergency situations. It is further recommended that these plans are discussed with fire brigades and other rescue services involved in rescue operations, as different standards may need to be applied to

different networks (high-speed, freight, etc.). These plans should also be integrated in railway operators' operating procedures as well.

Infrastructure measures

Recommendation C3. 01 Escape routes, handrails, marking

Escape routes are essential for allowing easier and faster self-rescue. It is recommended that the escape routes, handrails and markings be planned in the tunnel construction phase. Tunnels should be equipped with handrails at an appropriate height, properly lit and should be marked with standard signs (pictograms). It is recommended to have escape routes on both sides of the double-track tunnels. The height of the walkway depends on the specific tunnel situation. It is recommended that the minimum width of the walkway in new tunnels should be larger than 70 centimetres, and preferably 120 centimetres. In tunnels used exclusively for freight traffic escape routes might not be necessary, but are highly recommended in tunnels with passenger-only or mixed traffic.

Recommendation C3. 02 Emergency tunnel lighting

It is highly recommended to have emergency tunnel lighting, on one or both sides of the tunnel, especially in tunnels used by passenger trains. Emergency lighting should be reliable and operating under autonomous conditions, visible under smoke and other poor visibility conditions.

Recommendation C3. 03 Emergency telephones/communication means

It is recommended to have emergency telephones installed always at the key points in tunnels – cross passages, on escape routes and shafts. Telephones should be able to function properly and work in a specific tunnel environment with a potentially high noise and poor light. It is recommended that they should be installed in an enclosed space, sound hood, where the noise could not affect conversation. Emergency telephones should be linked to the emergency centre in the railway operations centre. Emergency telephones should not be linked directly to fire or other rescue service. If the direct radio link between the train and the operations centre exists, installation of emergency telephones might not be absolutely necessary. Passengers should not normally operate emergency telephones. Only the rail staff should be allowed to operate telephones as they are trained how to operate them. It is recommended to set up, plan and practice management of communications in an emergency situation in advance.

Recommendation C3. 04 Escape distances

The distance between escape exits still differs in practice from one country to another. The determination of the maximum and safe escape distance is connected, among other elements, with the type of rolling stock, length, type and topography of the tunnel. It is recommended that

a maximum distance between two safe places (portal of the tunnel, cross passage, emergency exit) be defined in such a way that it enables easy and quick self-rescue. The exact distance varies depending on the local situation, operating parameters and the safety concept. In double-tube single-track tunnels and parallel safety tunnels, this distance could be set at 500 metres. It is recommended to use cross passages between two parallel tubes rather than exits to the surface. Construction shafts and places close to the surface should be used for emergency exits. It is recommended that a maximum distance between escape exits should not exceed 1,000 metres.

The distance between safe areas in the tunnel is also a function of the expected situation (such as a smoke spread and the need for rapid evacuation). Short escape distances ensure rapid escape in the event of fire and smoke, and the quicker and shorter access for emergency services. The optimum distance between escape exits will be a function of an evaluation which takes into account all relevant parameters influencing safety, daily traffic, traffic mix, tunnel length, type of rolling stock, rescue concept and other safety measures present in the tunnel.

Recommendation C3. 05 Vertical exits/access

It is recommended that vertical exits/access should be provided in single-tube tunnels. They may be feasible only if the tunnel lies near the surface. Their maximum height should not be over 30 metres. It is recommended that vertical exits are equipped with proper lighting and communication means. Exits should be designed in such a way that smoke is prevented from spreading into the safe areas (locks, ventilation system). The higher the exit is, the less it is practical. Stairs should not be higher than 6 metres. Above that height, it might be necessary to install lifts that could also be used for faster and easier access of fire brigades with their equipment, medical assistance services and evacuation of people with injuries and handicaps. Both stairways and lifts should be pressurized and/or equipped with installations to ensure a smoke free environment.

Recommendation C3.06 Lateral exits/accesses

It is also recommended that lateral exits/access should exist in single-tube tunnels. Optimally, they should be located in the areas near the surface as well as locations convenient for lateral exit and access by emergency services. A cross section of exits will be determined on the basis of other safety elements but ideally their dimension should be 225x225 centimetres with a maximum length of about 150 metres. The same installations that ensure a smoke-free, visible and otherwise safe environment in vertical exits should also be installed in lateral exits.

Recommendation C3. 07 Cross passages

Cross passages are built to connect the main tunnel with safe places. It is recommended that they should be constructed between the tubes of double-tube single-track tunnels or a double-track tunnel and a safety tunnel. Cross passages should be equipped with lighting and communication means and designed to prevent spreading of smoke into safe areas. It is also recommended that, at the minimum, doors on exits to cross passages should be able to sustain fire for 30 minutes. It is further recommended that they should be easy to operate by hand, whether heavy and with a fully motorized or mechanical opening system or of the other type. In some cases where natural ventilation does not exist, installing two doors (several metres apart) would ensure increased safety both by raising resistance to fire and by ensuring a pressurized environment.

Recommendation C3. 08 Parallel service and safety tunnel

The decision to construct parallel service and safety tunnel should be based on an evaluation of optimal conditions and cost-effectiveness considerations for each tunnel.

Rolling stock measures

Recommendation C3. 09 Escape equipment and design of coaches

It is recommended that passenger coaches (doors, windows, body shell) should be built with incorporated emergency exits/accesses. Such exits/accesses should be easily visible and clearly indicated for passengers and rescue services (from both inside and outside the wagon). It is also recommended that the train crew is equipped with megaphones (for communication with passengers in the event of evacuation) and lamps (which must be located in an easily accessible place). Future specifications of passenger coaches should incorporate aspects of escape design (hammer and easily breakable windows, easily removable doors, etc.).

Operational measures

Recommendation C3. 10 Emergency information for passengers

It is recommended that timely and straightforward emergency information should be provided to passengers as it represents an important measure for facilitation of escape and rescue. As different systems of emergency information provision exist on different railways, it is recommended that the content of emergency information in international transport takes into account all possible difficulties in communicating such a measure to a variety of passengers (language). It is further recommended that emergency information for passengers

should be communicated and presented in a simple language, and should include only basic rules and general recommendations ("in case of fire alarm by the crew, go to the next wagon", "do not leave train unless instructed by crew", "do not pull emergency brake in tunnel"… and similar).

Recommendation C3. 11 Training of train crew

It is recommended that train crew, operators and other staff should be trained. The training should correspond to their functions and responsibilities and should enable staff and operators to prevent and handle incidents in tunnels, verify an incident, report to the operations centre, make quick and accurate decisions, provide first aid, initiate, carry on fire fighting and trigger self-rescue actions, etc.

Recommendations C3. 09 (Escape equipment and design of coaches), C3. 10 (Emergency information for passengers and C3. 11 (Training of crew) should be considered together as linked elements of a same safety concept.

C.4 Facilitation of rescue

Infrastructure measures

Recommendation C.4 01 Disconnection of traction current

It is recommended that disconnection of the overhead electricity lines for the entire tunnel should be made possible from entrances, portals and emergency exits of the tunnel. Only the railway company (through operations or tunnel control centre) should have the authorization to disconnect the main power supply (in order to prevent the train or its safe part from being trapped in the tunnel and to guarantee the safety of rescue services). In a situation when fire brigade or other rescue services have to carry out disconnection, it is recommended that clear and stringent rules and procedures, including training, should be introduced and respected.

Disconnection of the power supply could be done either manually or automatically. Automatic, remote disconnection is faster and safer. The disadvantage of manual disconnection is that it has to be done by someone (fire brigade, rescue service, etc.) at the tunnel portals without information about conditions of power lines inside the tunnel. In very long tunnels, it is recommended to segment overhead power lines so that only sections could be switched off if necessary.

Recommendation C.4 02 Access and rescue areas at tunnel entrance and exit

It is recommended that, where possible, road access to the portal of the tunnel should be made available and a free area (500 m^2) should be set aside for rescue vehicles. The exact location (both ends of the tunnel or only one, access by road vehicles or dual-mode vehicles) and size of these areas should be set up in agreement with emergency and rescue services. It is, however, recommended that rescue areas should be set up at both ends of the tunnel as well as at emergency exits. The area at the entrance of the tunnel should include solid surface access road drivable with fire engines, possibility for two vehicles to cross on the way, power supply, lighting, fixed communication installations, water supply, etc. Similar facilities should exist at the other end of the tunnel. If fire brigades or rescue services use dual-mode vehicles (road-rail), it is recommended that platforms for mode changing should be installed before the tunnel entrance.

Recommendation C.4 03 Track accessible for road vehicles

Suitability of railway track for road vehicles is only recommended if access for road vehicles is part of a comprehensive intervention and rescue concept based on fire brigades plan.

Recommendation C4. 04 Water supply for rescue service

It is recommended that water supply in tunnels should be made available for fire and rescue services. It is also recommended that, in the designing phase, the tunnel designer should consult with the fire brigade regarding elements of the water supply design. The water supply system should be regularly tested and checked and water should be occasionally completely discharged. Water discharge will also, at the same time, be used for testing the tunnel drainage system.

Recommendation C4. 05 Electrical supply for rescue service

It is recommended that the electricity power distribution system should be suitable for emergency/rescue services' equipment in tunnels. It is also recommended that standard socket outlets with residual current circuit breakers should be installed in the tunnel. All power outlets for rescue services should be regularly maintained and checked.

Recommendation C.4 06 Radio installation for rescue service

It is recommended that radio installation for emergency services should be a standard measure in tunnels to ensure communication between emergency services, the operation centre and railway personnel. The exact location in the tunnel depends on engineering and other features of each tunnel. The system used may differ from continuous feed to several antennas at intervals, but it must be reliable. As an alternative to fixed installations, another possibility is to have mobile telephones, mobile

radio network or other technical solutions for other types of communication.

Recommendation C.4 07 Reliability of electrical installations

It is recommended that electrical installations (technical components, wiring, cables) in tunnels must be protected against mechanical impact, heat or fire. Emergency lighting, communication systems, and other users of power should have an independent supply by two sources available to provide power for at least 60 minutes.

Recommendation C.4 08 TV monitoring

TV monitoring (CCTV) of portals and interior of the tunnel is not recommended as the safety measure but rather as a security measure.

Recommendation C.4 09 Provision of rescue equipment

It is recommended that rescue equipment, in particular, breathing equipment, should be provided for rescue and fire service interventions in tunnels. In practice, breathing equipment could be stored either at the nearest fire station or secured in the tunnel. It should be provided by rail operators and regularly checked and tested. It is, however, recommended to place breathing equipment with the fire brigade, which should carry out more reliable and regular check-ups, than if the equipment is stored in tunnels. The standard breathing apparatus must have capacity to allow breathing for 30 minutes at the minimum, although trained professionals may use long-time breathing equipment in special circumstances. It is recommended that the fire brigade not only regularly maintain breathing equipment but also practice with it in regular circumstances in order to accustom itself for use in tunnel accidents.

Recommendation C.4 10 Control system

Shorter tunnels with simple equipment may be operated locally (by technicians attending as needed) or remotely from the railway control centre. Generally, the control of the tunnel systems in an emergency should be collocated with the railway control centre, to enable full coordination of the response.

A very long heavily equipped tunnel could be better controlled by equipment and railway from a control room adjacent to the tunnel.

In any case, the system must ensure full coordination between the railway control and the tunnel control.

Recommendation C.4 11 Rail (tunnel rescue train) and road/rail vehicles for rescue

Specialized rail vehicles are recommended as a part of the rescue concept. Railway operators should operate railway rescue vehicles and provide particular staff for rescue operations. Rail/road vehicles for

rescue are only recommended as a part of the comprehensive rescue equipment provided by the fire brigade. It is recommended that rescue trains be manned by railway operator's staff and not fire brigade staff which may not be familiar with the use of railway vehicles, equipment and special railway procedures. It is recommended that fire brigade utilize either road vehicles they use in their daily work or rail/road vehicles. The most important recommendation is that the fire brigade and other rescue services should get into the tunnel with their equipment as fast as possible, regardless of the type of vehicles used.

Operational measures

Recommendation C.4 12 Emergency and rescue plans

Preparation and regular maintenance of emergency and rescue plans is recommended as a standard safety measure. The laws governing emergency and rescue service deployment differ from one country to another. Although an emergency situation is directed by different services in different countries (United Kingdom – fire, police, medical service; France – emergency manager, etc.) it is recommended that the response time of rescue and emergency services should be minimized. Any train incident in the tunnel might involve multiple players (train operator, tunnel operator, railway operations centre, fire brigade, rescue services, police, medical services) and there is, therefore, the need to avoid confusion. It is recommended that emergency service planning should be developed during the tunnel construction phase. If the safety concept and emergency services' intervention envisages separate plans or standard intervention strategies for railway operator and fire/rescue brigades, it is recommended that separate actors not only prepare together and regularly review their plans but also exercise jointly in various scenario situations.

Recommendation C.4 13 Exercises with rescue services (communication and co-ordination railway/rescue services)

Joint exercises on tunnel accidents of rail operators and rescue services are recommended. Their objective is to ensure better cohesion, communication and coordination during a rescue operation. Exercise also maximizes the effectiveness of rescue services, reduces time delays for rescue operations under specific tunnel conditions and minimizes possible communication and coordination problems during the real accident. As full-scale exercises are quite costly and difficult to organize (they may require closing down of the tunnel) it is recommended to have a "table-top" type of exercise. This type of exercise allows maximum flexibility in testing communications, contributes to stronger cohesion between railway personnel and rescue services and allows testing of various scenario cases. It is further recommended that each tunnel should have a unique name, numerical identifier and particular description for each end of the tunnel. This identification should be used in all communications between railway operators and emergency and rescue

services in order to minimize response time, avoid possible confusion and facilitate rescue.

Recommendation C.4 14 Information on transport of dangerous goods

Although not considered a specific tunnel safety measure, it is recommended that the information on movements of exceptionally dangerous goods should be provided in advance to rescue services This information would allow emergency and rescue services to be prepared in the event of an emergency, to select the appropriate emergency response and operation in advance, and to reduce the risk for themselves. For safety purposes, an information system, in accordance with the RID regulations, defining relevant goods, must exist at international level and specific information must be passed quickly to the responsible operations' centre and rescue services. Although, information about freight is already available through train numbers and freight information systems, it must be available within the required time and the degree of precision needed for fire and emergency services.

D. CONCLUSION

The Ad hoc Multidisciplinary Group of Experts on Safety in Tunnels (rail) has carried out a brief survey of the European railway system in tunnels, as to whether Governments have enacted laws or regulations specific to tunnel safety and obtained information where possible about accidents in tunnels.

The Group has noted the low occurrence of accidents in main line railway tunnels but equally noted the potential high consequences of hazardous events.

The Group also prepared and noted several general principles of safety in railway tunnels - see Part B.

The Group reviewed the work done by various national bodies and by the UIC, (the UIC-Codex 779-9, Safety in Railway Tunnels). Detailed technical recommendations are contained in Part C of this report.

In conclusion, the Working Group has prepared the following general recommendations for consideration by the Inland Transport Committee.

Recommendation 1

All countries should require their railway infrastructure and train operators to have and publish a comprehensive safety plan to ensure the health and safety of all persons (passengers, staff and contractors) using any long tunnel.

Recommendation 2

This safety plan should be supported by suitable analysis to show that the risk to passengers and staff has been reduced to as low as reasonably practicable.

Recommendation 3

Track in tunnels should be plain track, i.e. points and crossovers should be eliminated as far as possible.

Recommendation 4

New and reopened tunnels should incorporate the measures outlined in this report or in national standards.

Recommendation 5

Existing tunnels should incorporate as many safety provisions as is reasonably possible during any maintenance replacement actions.

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