COMPARED SAFETY FEATURES FOR RAIL TUNNELS

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ABSTRACT

Three international guidelines on railway tunnel safety will be published in the years 2003-2005. The first one is a UIC leaflet, a compendium of best practice for railways (2003). The second is a set of UNECE recommendations to the organisation's 55 member states (2004) and the third one will be a Technical Specification for Interoperability, a binding regulation for EU countries (2005). The three documents differ with regard to their target audience and the level of obligation of their recommendations. They have in common the objectives, priorities and the goal of a coherent safety plan for tunnels. The measures described in the UIC and UNECE recommendations reflect best practice and can be used, in spite of their non-mandatory nature, as guidelines for new and existing tunnels. *The following presentation reflects the author's views and does not commit the EU Commission or other organisations.*

1. INTRODUCTION

The Reasons for creating three international guidelines for railway tunnel safety:
Railway tunnels are relatively safe places. The risks for passengers and train crews are lower in tunnels than on the rest of the railway network because many of the causes of accidents, such as collisions at level crossings, collisions with obstacles on the track (cars, trees, etc.) or with shunting trains, and derailments owing to natural phenomena (e.g. flooding, avalanches) are non-existent. Basically, three types of accidents take place in tunnels: derailments, train collisions and fires. For the above-mentioned reasons and because operating is simpler, accidents occur less frequently per train-kilometre in tunnels than on open line. However, evacuation and rescue are more difficult in tunnels. And the most relevant difference by comparison with open line is the confined space of a tunnel, in which a fire that would be a manageable incident elsewhere can prove to be catastrophic. Consequently, many tunnel-specific safety measures are aimed at mitigating the impact of fire.
Within their umbrella organisation, UIC (International Union of Railways), railway infrastructure managers and operators have compared their safety practices and described the state of the art in UIC Leaflet 779-9 R "Safety in railway tunnels" in 2003.
Alerted by the road tunnel fires in the Mont Blanc and the Tauern tunnels (1999), national authorities have assessed their safety regulations in road as well as in rail tunnels. They have joined forces to create an international set of recommendations within UNECE (United Nations Economic Commission for Europe, Geneva). Their road tunnel recommendations were published in 2001 and the rail tunnel recommendations will follow in 2004.

The EU Commission has drawn up a directive for safety in road tunnels and has commissioned a technical specification for interoperability (TSI) on safety in rail tunnels by 2005.
Thus, three international regulations on safety in rail tunnels have been or are about to be produced at short intervals by different bodies with different objectives; starting, so to speak, bottom up with a compendium of best practice by railway professionals, developed further by government experts to become recommendations for 55 European governments, the series will hopefully be achieved in 2005 with a binding regulation for EU countries. Fire is obviously the most terrifying threat in tunnels. It is considered as the main and specific risk in tunnels in all three regulations.

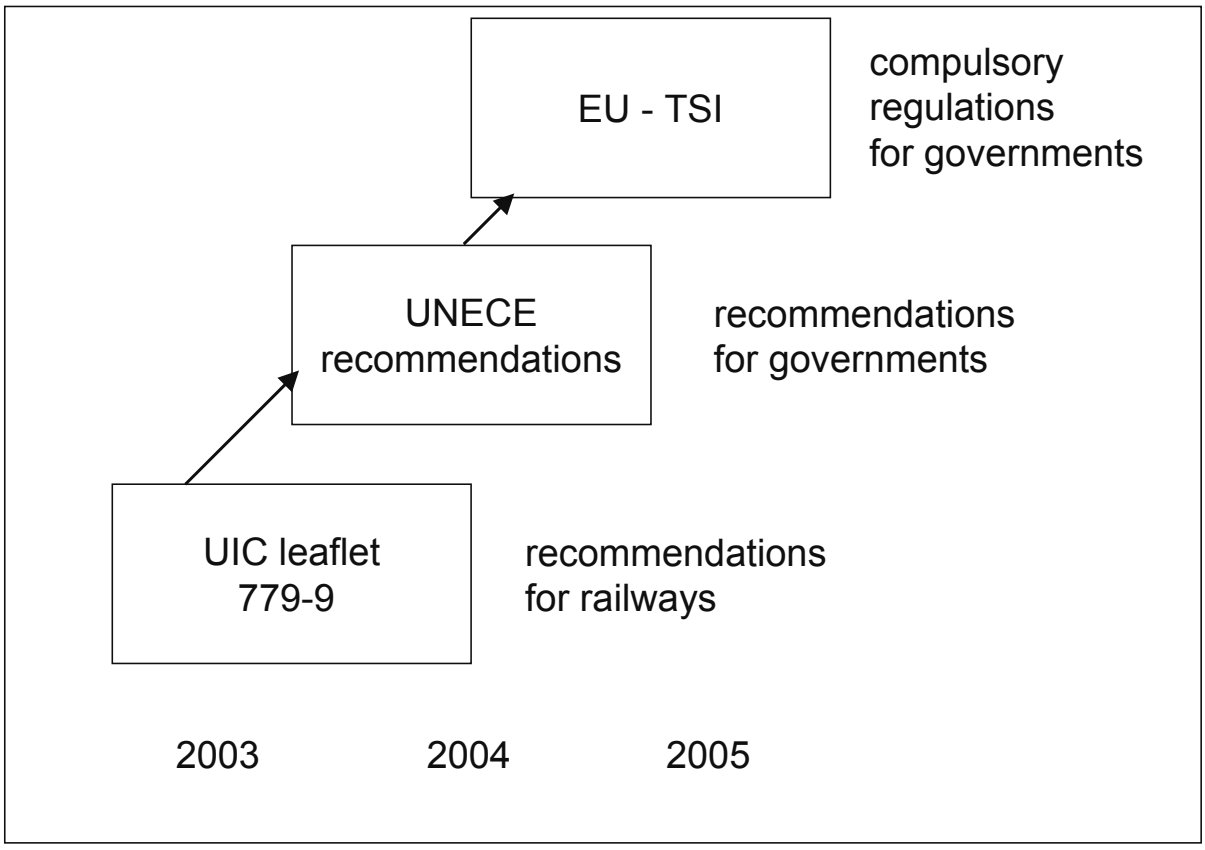

Figure 1 Three European guidelines on railway tunnel safety in three years

2. THE UIC-LEAFLET 779-9 R "SAFETY IN RAILWAY TUNNELS" (2003)

2.1 About UIC

The Paris-based UIC (Union Internationale des Chemins de fer, International Union of Railways) is the umbrella organisation of railways worldwide, an 80-year old, non governmental and non-profit organization. Railway experts from all countries meet there and lay down the state of the art in railway technology. The resulting UIC leaflet collection, totalling roughly 30,000 pages, is an encyclopaedia of railway know how; it has no legal standing, since governments, not railways, edict regulations and oversee their application, but UIC leaflets often are taken as a basis for national and international rules.

2.2 Over 50 safety measures for rail tunnels described and commented

In 2001-02, a working party made up of 14 railway infrastructure managers and operators, combining the experience of the owners and operators of most European railway tunnels, produced a new leaflet on tunnel safety. It is a compendium of possible measures to increase safety in tunnels, reflecting current best practice and covering the field of infrastructure, rolling stock and operations. Each measure is described in terms of its cost-effectiveness and accompanied by a recommendation.
An example of a safety measure, its description and assessment is presented in Table 1. The full list of measures is shown in Table 2.

R-11	**a) Emergency brake neutralisation** **b) Maintaining the movement capability**
General description and goal a) Neutralisation of emergency brakes in tunnels (or similar system). b) Vehicle design to allow running in the event of fire for as long as possible (at least 15 minutes): it includes adequate vehicle body design and materials in order retain stability, shape, vehicle design and to reduce sensitivity of electrical wiring for train control (optimal location, fire resistance).	
Relevant aspects • General concept in the event of train fire: leave the tunnel whenever possible (except in very long tunnels). • There are different technical systems for neutralisation of emergency brakes (by-pass braking or alarm system notifying the train driver). • International traffic. • Compatibility requirements for electrical wiring. • Agreement and definition of conditions (e.g. tunnel length) neutralisation of the emergency brake is necessary. • Agreement necessary about the system to use for international traffic in future. • Special procedures for passing red lights in tunnels (in the event of fire, a train should be able to leave a tunnel even if the signal display is a red light).	
Specifications • There are different technical systems for emergency braking: - Braking is activated and the driver has to deactivate it. - Activation of the brakes triggers a signal in the cab and the driver has to decide whether to brake or not.	
Impact on safety + Increases the likelihood that, in the event of fire, a passenger train will be able to leave the tunnel. + Rescue possibilities are better in the open. – In the event of sudden running gear failure, derailment, or other emergency, the train cannot be stopped by emergency braking in the tunnel. – No impact on fire in the traction unit. – If braking is activated immediately, the train may stop even if the driver deactivates braking immediately (e.g. if the train is running at low speed). Risk mitigation: medium	
Further effects • If only parts of rolling stock is equipped: need for a stringent management composing/operating the trains.	
Cost-effectiveness Good cost-effectiveness can be assumed.	
Assessment **New and existing tunnels** General strategy/priorities: a) Minimum standard: Sign near emergency brake ("do not use the emergency brake in the event of fire ..."). b) Introduction of an emergency brake neutralisation system is recommended.	

Table 1 Example of a safety measure – emergency brake override and maintaining the movement capability - in the UIC leaflet

Infrastructure (I)		**NT**	**ET**
Prevention of incidents	I-1 Speed monitoring / signalling system	0	0
	I-2 Train radio: operations centre – train crew – passengers	+	0
	I-3 Train detection (axle counter, track circuit)	+	0
	I-4 Train control equipment (blocked brake, hot boxes)	+	+
	I-5 Arrangement of switches	+	+
	I-6 Track inspection	+	+
	I-7 Access control (security)	0	0
	I-8 Inspection of tunnel condition	+	+
Reduction of effects	I-20 Double-bore single-track tunnels	0	-
	I-21 Cross section of double-track tubes	0	-
	I-22 Fire protection requirements for structures	+	0
	I-23 Fire, smoke and gas detection in tunnels	0	0
	I-24 Fire extinguishing systems (sprinkler or similar installations)	0	0
	I-25 Smoke extraction systems/ventilation system	0	-
	I-26 Track drainage system (drainage and retaining basin)	+	-
Facilitation of escape	I-40 Escape routes (routes, handrails, marking)	+	+
	I-41 Emergency tunnel lighting	+	+
	I-42 Emergency telephones/communication means	+	+
	I-43 Escape distances	0	0
	I-44 Vertical exits/access	0	0
	I-45 Lateral exits/access	0	0
	I-46 Cross passages	0	0
	I-47 Parallel service and safety tunnel	0	0
Facilitation of rescue	I-60 Earthing device	+	+
	I-61 Access to tunnel entrance and tunnel exits	+	+
	I-62 Track accessible for road vehicles	-	-
	I-63 Rescue areas at tunnel entrance or exits	+	0
	I-64 Water supply (at access, in tunnel)	+	0
	I-65 Electrical supply for rescue services	+	+
	I-66 Radio installation for rescue services	+	+
	I-67 Reliability of electrical installations (fire resistance, autonomy)	+	0
	I-68 Control system	0	-
	I-69 Rail vehicles for rescue (tunnel rescue train)	0	0
	I-70 Road/Rail vehicles for rescue	0	0

Rolling stock (R)		**NT**	**ET**
Prevention of incidents	R-1 Fire protecting measures (fire load, prevent fire spreading)	+	+
	R-2 Onboard fire detection (traction units and/or coaches)	0	0
Reduction of effects	R-10 Derailment indicators on train	0	0
	R-11 a) Emergency brake neutralisation	+	+
	b) Maintaining the movement capability	+	+
	R-12 Onboard fire extinguishing equipment (traction units and/or coaches)	+	+
	R-13 Central control of air conditioning	+	+
	R-14 Ability to split trains	-	-
	R-15 First aid equipment on board	+	+
Facilitation of escape	R-20 Escape equipment and design of coaches (incl. access for rescue services)	+	+
Operation (O)		**NT**	**ET**
Prevention of incidents	O-1 Regulations for operations (especially passenger/freight train)	0	0
	O-2 Regulations for carriage of dangerous goods	0	0
Reduction of effects	O-10 Stop following or oncoming trains (outside the tunnel) in the event of an incident	+	+

Facilitation of escape	O-20	Emergency information for passengers (preparation for emergencies)	+	+
	O-21	Competence of train crew	+	+
Facilitation of rescue	O-30	Emergency and rescue plans	+	+
	O-31	Exercises with rescue services (railway/rescue services communication and co-ordination)	+	+
	O-32	Information on carriage of dangerous goods	+	+
	O-33	Provision of rescue equipment	+	+

Table 2 Table Safety measures recommended by the UIC leaflet

2.3 Priorities and principles governing the UIC leaflet

Railways agreed on the following priorities (see Figure 2): 1.Prevention 2.Mitigation 3.Escape and 4.Rescue. This order reflects a decreasing order of effectiveness, especially in the event of a fire.

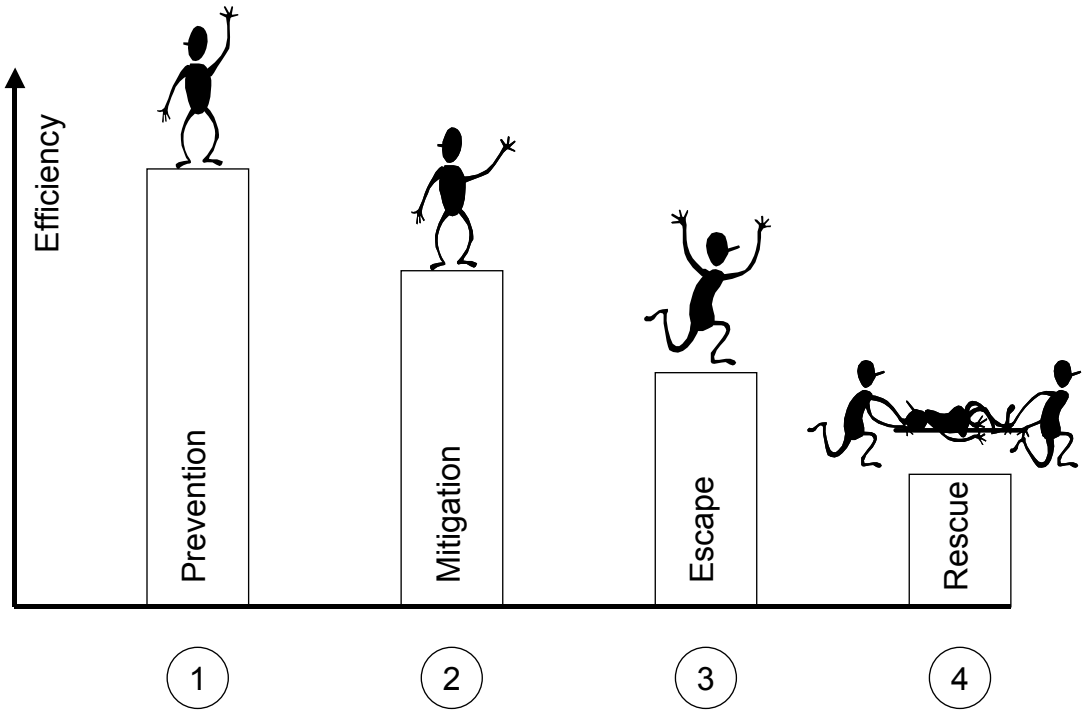

Figure 2 Priorities in safety measures

Prevention is better than cure: the strength of the railway is prevention. Trains are guided by rails. Train intervals are controlled by the signalling system in order to prevent collisions. Modern rolling stock is fire-hardened. Train drivers and train crews are trained to ensure the safety of their trains and to lead the evacuation of a train in an incident**.** These and other features can explain the low risk of an accident in rail tunnels.
Give a fair chance to escape: if safety measures were selected on the basis of a strict cost-effectiveness criterion only, they would concentrate on preventive and mitigating measures and leave little money for escape and rescue. However, it is railway policy that a train passenger should be given a fair chance to escape, even from a serious accident. Escape routes therefore are an irrevocable part of every tunnel safety plan, similarly to rescue exercises with fire brigades.
Optimal safety is the result of an optimal combination of measures in all domains: infrastructure, rolling stock, operations. The measures applied in a specific tunnel should be carefully selected out of the list proposed in the UIC leaflet; implementing all of them in a cook-book-like manner would be a waste of money. This becomes obvious when considering existing tunnels, where structural changes are often impossible at reasonable costs; safety can best be improved there through rolling stock and operational measures.
National regulations have, of course, priority over the recommendations of the UIC leaflet.

3. UNECE-RECOMMENDATIONS

3.1 Starting with a survey

The UNECE (United Nations Economic Commission for Europe) Inland Transport Committee created an ad hoc multidisciplinary group of experts on safety in tunnels to report on the safety issues, in the first place those pertinent to road tunnels. Their work was finalised in 2001. A further group was invited to consider safety in railway tunnels. In December 2003, this group completed the draft report, “Recommendations of the multidisciplinary group of experts on safety in tunnels (rail)”, to be submitted for approval to the Inland Transport Committee in February 2004. The group began with an inventory of long (>1 km) rail tunnels in the UNECE region. In addition, the group collected existing tunnel safety documentation from the member governments, the European Union and relevant international organisations. Note was taken in particular of the work already done by the UIC for its leaflet.

3.2 General principles

The UNECE-recommendations are based on the same priorities as the UIC leaflet, namely:
1.Prevention of accidents
2.Mitigation of the consequence of accidents
3.Facilitation of escape and
4.Facilitation of rescue.
They also state that cost-effective safety is the result of an optimal combination of infrastructure, rolling stock and operational measures.
The UNECE group recommends that infrastructure owners and train operators should have a comprehensive safety concept for all tunnels, new and existing, containing the emergency plans of the operator and the plans of those public services ensuring co-operation in an emergency. The safety concept should demonstrate that the current safety level for all persons (passengers, staff and contractors) meets the requirements set by state authorities.

3.3 Safety measures for new tunnels

The UNECE recommendations describe and comment over 50 safety measures for new tunnels, divided into infrastructure, rolling stock and operations measures following the above-mentioned priorities and within these categories (Table 3).

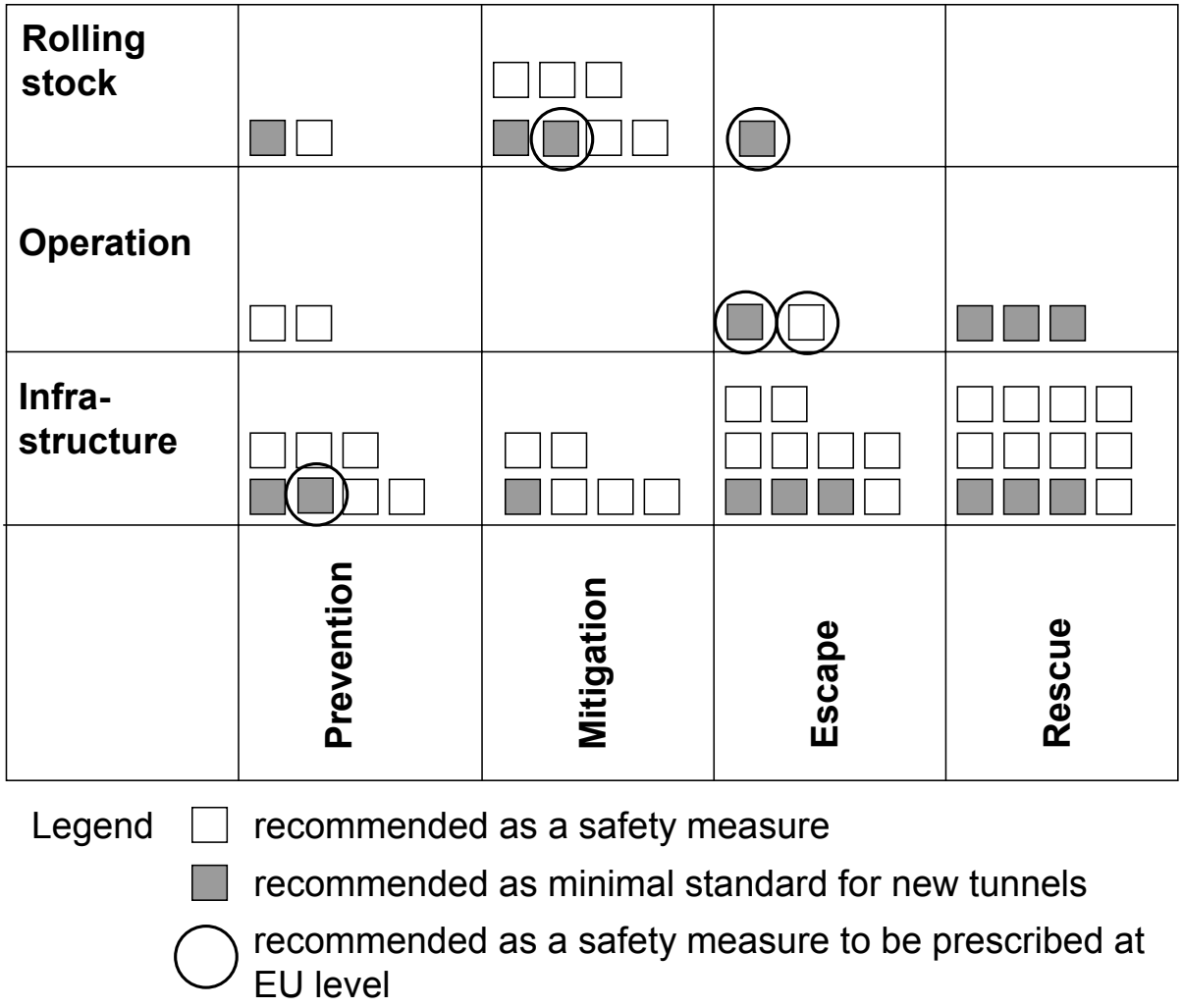

Table 3 Safety measures recommended by UNECE, divided into categories

The group proposes that the following 19 measures selected in the complete list should be considered as *minimal safety standards for new tunnels* in order to ensure a harmonised minimal safety level in rail tunnels across Europe:

- Speed monitoring and signalling system
- Regular inspection of tunnel condition
- Fire protection measures for rolling stock
- Fire protection requirements for structures
- Train radio
- Emergency brake override and maintaining movement
- First aid equipment on board
- Take the train out of the tunnel (operations rule)
- Stop following or passing trains in the event of an incident

- Escape walkway
- Tunnel markings
- Emergency tunnel lighting
- Training of railway staff
- Water supply for fire-fighting and rescue services
- Radio installation for rescue services
- Reliability of electrical installations
- Emergency and rescue plans
- Exercises with rescue services
- Information on transport of dangerous goods

In order to reach the desired safety level of a tunnel, the minimum standards should be supplemented by other measures; the complete set of measures selected for a specific tunnel is to be recorded and justified in the safety concept. If one of the minimal standards can not be applied at reasonable cost, it could be replaced by other measures providing the same level of safety.
The group suggests that a number of measures important for interoperability be specified in the form of *binding rules by the EU*; these are:

- Speed monitoring and signalling system
- Emergency brake override and maintaining movement
- Escape equipment and design of coaches
- Emergency information for passengers
- Training of railway staff

It is interesting to note in Table 3 that the UNECE group has concentrated on measures in the escape/rescue categories and in the field of infrastructure (whereas railways, for efficiency reasons, instead promote preventive/mitigating measures in the fields of rolling stock and operation). This accumulation reflects the tasks of governments, engaged in defining a safe infrastructure and setting up arrangements with fire brigades and rescue forces. The regulation for rolling stock and operations is likely to be entrusted to other bodies.

3.4 Recommended safety measures for existing tunnels

The UNECE group states that 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 using any tunnel covered by the recommendations. 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.
With regard to the diversity of existing tunnels and to the financial constraints, the group has not defined any minimal safety standard for existing tunnels. However, it lists some infrastructure measures that could be applied at reasonable cost also in existing tunnels:

- Speed monitoring and signalling system
- Tracking the status of the train before entering tunnels
- Regular inspection of tunnels
- Tunnel markings
- Emergency tunnel lighting
- Disconnection and earthing of traction current
- Provision of rescue equipment

4. TECHNICAL SPECIFICATIONS FOR INTEROPERABILITY (EU)

4.1 The mandate given to AEIF

AEIF (European Association for Railway Interoperability) is the joint representative body mandated by the EU Commission to draw up the TSIs. It brings together representatives of infrastructure managers, railway companies and industry.
AEIF has been mandated to submit a draft TSI on "Safety in railway tunnels" by 2005. It was considered important that specifications be governed by a coherent view of the safety concept in railway tunnels, but it was left open, for the moment, as to whether the specifications would be grouped together in a specific TSI for railway tunnels or spread out in the other TSIs on the infrastructure, rolling stock and operations sub-systems, and perhaps others.

4.2 Some key issues

A working party of more than 30 experts from most European countries began to draft the TSI on "Safety in railway tunnels" in May 2003. It has the delicate task of selecting among the best practice measures described in the UIC, UNECE and other recommendations those which will become mandatory in EU member states. The EU objective is to promote interoperable trainsets to be worked on interoperable railway lines all over Europe under harmonised safety conditions. Safety has to be maintained generally and, where reasonably practicable, continuously improved. Safety must not serve as a pretext to hinder open access.
The expert group has defined the relevant accident scenarios and the categories of measures to be specified. Examples of *key issues* it has to deal with are:

Prescriptive or objective-based TSI?
Basically, the nature of a TSI is a prescriptive one. An interoperability constituent complying with the specifications is assumed to comply with the essential requirements and must be admitted on the Trans-European Network (TEN). Verification of conformity is entrusted to a notified body. However, the experts agree that adequate safety of a tunnel depends also on local circumstances, that rigid application of rules might lead to inefficient or incomplete solutions. A possible way could be to define a standard set of measures containing, in particular, the safety-relevant properties of interoperable trainets that will ensure an adequate safety level for the majority of tunnels. For specific cases, such as very long tunnels, additional infrastructure or operational measures might be needed; a safety plan will have to demonstrate that the required safety level has been reached. A specific safety plan is also requested if certain specifications cannot be met and must be replaced by others.

Existing tunnels:
Most railway tunnels are old, their age averages 70 years in Europe. State authorities have tended to concentrate, in the past, on the implementation of safety measures in new tunnels. Governments have only recently supported plans to enhance the safety of existing tunnels, thus contributing to rebalance the risk profile. The TSI also apply primarily to new tunnels. They apply to upgraded tunnels only if the upgrading operation requires a new authorisation for re-opening the tunnel for rail services, a decision that lies in the hands of the national authority. Considering the longevity of rail tunnels, how long will it take until all tunnels comply with the TSI design rules? This does not mean that the safety level of old tunnels remains unacceptably low. The railway benefits from the fact that the most effective safety measures are of a preventive/mitigating nature, that they do not depend on structural changes and that they apply to all tunnels, new and existing ones.

The safety level of existing tunnels can therefore be raised, step by step, through introduction of interoperable rolling stock, operations measures, training of train crews for emergencies and rescue plans.

Taylor-made solutions?
Cost-effective safety in a tunnel is the result of an optimal combination of measures in different fields (infrastructure, rolling stock, operation). In existing tunnels, one would probably prefer non-structural measures, in all tunnels, cost-consciousness could lead to a specific combination of measures selected for a specific tunnel. How much freedom can be left in a TSI for such taylor-made solutions?

5. CONCLUSIONS

The three international guidelines presented have been drawn up by different organisations and for a different audience. They differ also with regard to the level of obligation of their recommendations. They have in common that
Fire is considered as the main and specific risk in tunnels. Although tunnels are statistically safer than the rest of the railway network, the public aversion against fire accidents in tunnels can justify more extensive safety measures than would be required on the basis of the estimated number of fatalities alone.
The priority shall be:
1.Prevention
2.Mitigation
3.Escape and
4.Rescue, for efficiency reasons.
Escape and rescue provisions have to be part of every safety plan in tunnels in order to give passengers a fair chance, even in the event of a serious accident.
Cost-effective safety in tunnels is the result of an optimal combination of safety measures in the fields of infrastructure, rolling stock and operations
The price of safety did not come out of the first two guidelines. Cost figures have been used to compare the efficiency of different measures only. There is no indication yet of the total costs on the TEN network.
The measures described in the UIC and UNECE recommendations reflect best practice and can be used, in spite of their non-mandatory nature, as guidelines for new and existing tunnels.

6. REFERENCES

www.uic.asso.fr
www.unece.org
www.aeif.org