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Ad hoc Multidisciplinary Group of Experts on
Safety in Tunnels (rail)

REPORT OF THE AD HOC MULTIDISCIPLINARY GROUP OF EXPERTS ON SAFETY IN TUNNELS (rail) ON ITS FIRST SESSION (27-28 June 2002)

Addendum 1

Annex 4

Report on Safety in Railway Tunnels
(as transmitted by the International Union of Railways (UIC))

Note: In view of the importance of the report "Safety in Railway Tunnels" by the International Union of Railways (UIC) for all member countries, the Ad hoc Multidisciplinary Group of Experts on Safety in Tunnels (rail) at its first session requested the secretariat to make it also available in the Russian language.

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International Union of Railway (UIC)

Safety in Railway Tunnels
Recommendations for Safety Measures

Final Report, February 2002

Ernst **Basler** + **Partners** Ltd.

Summary

In 1991, the UIC published the report IF4/91 "Measures to limit and reduce the risk of accidents in underground railway installations with particular reference to the risk of fire and the transport of dangerous goods". In 2001, the UIC project group "Safety in Railway Tunnels" started a project to revise this report and to compile a new leaflet concerning the safety in railway tunnels. The present report is the result the first discussion in the project group and serves as a basis for the planned leaflet.
The scope of the present report is defined as follows:

- The report emphasises the aspect of infrastructure measures. It also deals with operation and rolling stock, as far as it is necessary to define infrastructure measures in a comprehensive way.
- Concentration on safety measures for tunnels only: General rules and standards which have also an effect on tunnel safety are not evaluated.
- Railway tunnels: Underground platforms and underground railways / subways in city areas are not covered in the report.
- Tunnel length: Tunnels from *about* 1 to 15 km. For longer tunnels the recommended safety measures can be used as a basis but special/additional safety measures may be required.

The report consists of an introductory text with a summary of the recommendations and conclusions on a recommended set of safety measures. The main information and the detailed recommendations for each safety measure are compiled in tables in the following appendices:

- A2 Infrastructure
- A3 Rolling stock
- A4 Operation

The recommendations are to be seen as guidelines but not strict rules.

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General remarks

In 1991, the UIC published the report IF4/91 "Measures to limit and reduce the risk of accidents in underground railway installations with particular reference to the risk of fire and the transport of dangerous goods". In 2001, the UIC project group "Safety in Railway Tunnels" started a project to revise this report and to compile a new leaflet concerning the safety in railway tunnels. The project was divided into two phases:

- **Phase 1: Evaluation of relevant regulations (literature study)**
  Existing European governmental or corporate regulations relating to safety in railway tunnels have been evaluated. Based on a comparison of these documents, conclusions with regard to common practice or obvious differences were drawn for a defined set of safety measures.
- **Phase 2: Assessment of measures and proposal for leaflet (final phase)**
  The measures evaluated in phase 1 have been assessed in more detail. Based on this assessment a recommendation is made, under which circumstances and for which type of tunnel a safety measure is adequate or not. The main information and the recommendations for each safety measure are compiled in the tables in the appendices A2 to A4. The present report summarizes the result of the assessment and serves as a basis for the planned leaflet.

The evaluation and comparison of a large number of rules and standards on tunnel safety in different countries showed a broad range of solutions and requirements for safety measures. The main points of the literature study can be summarized as follows:

- The evaluated documents concentrate on safety in tunnels. Besides that, there are a lot of other standards and regulations about safety, which not specifically refer to tunnels. Nevertheless they have a strong influence on safety in tunnels (e.g. fire standards for rolling stock, interoperability standards). Therefore several of the evaluated documents seem to be incomplete, because some measures are treated in other standards and regulations.
- The evaluated documents are placed on different levels concerning the liability (general concepts or guidelines of an authority). Firm requirements of an authority (e.g. Germany) are included as well as conceptual studies with recommendations (e.g. Switzerland, Sweden).
- The level of detail and the scope of the documents is different. There are overall concepts (e.g. UIC or Switzerland) as well as indications for single safety measures. Some documents focus on objectives (e.g. UK), others define detailed specifications for certain safety measures. As most of the documents deal with infrastructure, there are only few indications on rolling stock and operational measures (cf. first remark).
- The documents also reflect different approaches to tunnel safety. The Swedish and Swiss approach base explicitly on a risk assessment. Other documents define safety measures independently of a tunnel specific risk assessment (e.g. Austria and Germany).
- Most of the regulations refer to new / planned tunnels. If there are indications to existing tunnels, they point out, that local circumstances must be considered as far as reasonably practicable (cost-effectiveness).

Considering all these points it is not surprising, that there are differences in the design and the implementation of safety measures in tunnels in the different countries.

Scope

Safety in tunnels is the result of a combination of infrastructural, operational and rolling stock measures. The present report is focused on infrastructure, whereas operation and rolling stock measures are treated as far as it is necessary to define infrastructure measures (in lesser detail). In the present context, the term "infrastructure" includes constructive work as well as fixed installations. The terms are defined from the point of view of the safety measure and do not reflect the responsibility for the safety measure[1)]. The scope of the report is defined as follows:

- Safety measures for tunnels only: General rules and standards which have also an effect on tunnel safety are not dealt with.
- Railway tunnels: It does not include underground platforms and underground railways/ subways in city areas.
- Tunnel length: tunnels from about 1 km to *about* 15 km. For longer tunnels the proposed safety concept can be used as a basis but special/additional safety measures may be required[2)].
- Focus on standard gauge.
- Electrified and non-electrified railway tunnels are included.

The risk in a tunnel is not only influenced by its length but also by aspects such as the operational concept (e.g. traffic types and restrictions, train frequency, speed) or the existing incident management strategy. They are important factors to be taken into account when deciding about the safety measures for a tunnel. In order to consider all these risk influencing factors adequately, a tunnel specific risk analysis may be necessary.
Another important factor is the age of a tunnel. While a planned tunnel offers the most possibilities to realize safety measures, the scope in existing tunnels is often restricted due to physical properties (dimensions, cover, construction, geology etc.). The assessment and recommendations in the present report are primary formulated for new tunnels. Recommendations for existing tunnels then are derived.
Additionally the recommendations are based on the following assumptions and conditions:

- The tunnel is part of a railway network (system view).
- Mixed traffic (passenger trains as well as freight trains, including also combined traffic).
- Average operation data (e.g. mean value of about 100 trains per day and direction).
- High rock/ground cover.

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1) Even if an infrastructure company is responsible for an operational measure, it is still classified as an operational measure and not as an infrastructural measure.
2) Corresponding remarks on very long tunnels are given in the report. It is planned to deal with very long tunnels in a separate work.

If a specific tunnel differs from these conditions it might be appropriate to adjust the recommendations by taking into account the local situation.
Additional safety measures may be adequate, if the following conditions are fulfilled:

- Undersea tunnel (U-shaped).
- Lorry transport on shuttles (e.g. system of the Channel Tunnel).

3 Definitions

The following table defines some important and frequently used terms.

Term	Definition
Existing tunnels	Tunnels which are under operation.
Reopened tunnels	Existing tunnels, which shall be reopened after a closure of several years.
New / planned tunnels	Tunnels in a planning phase or partially already under construction. Relevant safety decisions can still be made.
Safety	Includes all accidental events caused by technical failures, human errors, natural hazards, etc.
Security	Includes all malicious interventions in order to damage people or property.
Safe place	Examples of safe places are: • Tunnel entrances. • Emergency exits, parallel safety tunnel or parallel tube, if smoke transgression from the main tunnel is prevented. • Areas inside a tunnel if they are kept free of smoke, are ventilated and protected from heat. • Section of a main tunnel which is kept free of smoke
Self rescue	All actions which are started after an accident by the train staff and passengers to leave the accident place (including first aid).
Rescue services	Services of railways, public fire fighting organizations, police, sanitary organizations.
risk	In general: possibility for a loss. Technical definition: function of frequency and consequence of events
cost-effectiveness	Ratio between the costs of a safety measure and the expected risk reduction

Table 1: Definitions

4 Summary of the recommendations

The results of the assessment are summarized in the following tables. Three types of recommendations have been distinguished:

Symbol	Recommendation
+	The measure is generally recommended as safety measure
0	The measure is recommended under certain conditions (depending on local situation or regarding the feasibility in existing tunnels etc.)
-	The measure is not recommended as safety measure

Table 2: Types of recommendations

For the recommendations, aspects like effect on safety, costs (investment, maintenance, operation), implications on operation, etc. were taken into consideration. If a safety measure is not recommended, it does not mean that it has no effect on safety. Even if the risk reduction is high, the measure may not be recommended if due to very high costs, the cost-effectiveness is poor. The recommendations are to be seen as guidelines but not as strict rules.

The following tables with the rating intends to give an overview and is therefore fairly rough. For the detailed definition of the measures and the recommendations see appendices A2 to A4. The recommendations are made for new tunnels (NT) and existing tunnels (ET) separately. The recommendations are to be seen as guidelines but not as strict rules. For specific situations (e.g. short tunnels), deviations might be appropriate.

Table 3: Infrastructure measures

Infrastructure (I)		**NT**	**ET**
Prevention of incidents	I-1 Speed monitoring / signalling system	0	0
	I-2 Train radio: operation centre – train crew – passengers[3)]	+	0
	I-3 Train detection (axle counter, track circuit)	+	0
	I-4 Train control equipment (blocked brake, hot boxes)	+	+
	I-5 Wheel flat detector	0	0
	I-6 Load control (wheel load measurement, profile envelope)	0	0
	I-7 Derailment indicator (trackside)	-	-
	I-8 Arrangement of switches	+	+
	I-9 Track inspection	+	+
	I-10 Access control (security)	0	0
	I-11 Inspection of tunnel condition	+	+
Reduction of effects	I-20 Inclination of tunnel axis	-	-
	I-21 Two single track tubes	0	-
	I-22 Cross section of double track tubes	0	-
	I-23 Fire protection requirements for structures	+	0
	I-24 Fire, smoke and gas detection in tunnels	0	0
	I-25 Fire extinguishing systems (sprinkler or similar installations)	0	0
	I-26 Smoke extraction systems / ventilation system	0	-
	I-27 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 phones / communication means	+	+
	I-43 Loudspeaker system in tunnel	-	-

3) Inclusive equipment of rolling stock

Infrastructure (I)		NT	ET
	I-44 Escape distances	0	0
	I-45 Vertical exits / access	0	0
	I-46 Lateral exits / access	0	0
	I-47 Cross passages	0	0
	I-48 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 TV monitoring (portals and tunnel)	-	-
	I-69 Provision of rescue equipment	+	+
	I-70 Control system	0	-
	I-71 Rail vehicles for rescue (tunnel rescue train)	0	0
	I-72 Rail/Road vehicles for rescue	0	0

Table 4: Rolling stock measures

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)	+	+

Table 5: Operational measures

Operation (O)		NT	ET
Prevention of incidents	O-1 Regulations for operation (especially passenger / freight train)	0	0
	O-2 Regulations for transportation of dangerous goods	0	0
Reduction of effects	O-10 Stop following or encountering trains (out of the tunnel) in case of incident	+	+
Facilitation of escape	O-20 Emergency information for passengers (preparation for emergencies)	+	+
	O-21 Training of train crew	+	+

Operation (O)			NT	ET
Facilitation of rescue	O-30	Emergency and rescue plans	+	+
	O-31	Exercises with rescue services (communication and co-ordination railway / rescue services)	+	+
	O-32	Information on the transport of dangerous goods[4)]	+	+

5 Conclusions

5.1 General aspects of safety in tunnels

A general principle, which all railways have in common, is firstly to prevent accidents and secondly to reduce their effects (reducing the consequences by facilitating escape and rescue). That rule also applies for railway tunnels. Based on this principle, railways have achieved a high safety standard by applying safety measures such as:

- High reliability and systematic control of infrastructure and rolling stock.
- Visual control of trains at stations.
- Signaling system to control running of trains.
- Professional education of employees.

Most of the accident preventing measures are not specific to tunnels, but have an effect in the whole railway system. Hence they are described in various rules and standards and not specifically in those for tunnels.

In tunnels, three main accident types can be distinguished: derailment, collision and fire. Other accidents typical for open lines such as collisions at railway crossings, with obstacles on track (cars, trees etc.) and with shunting trains or derailment due to natural hazards (e.g. flooding, avalanche) are mostly not possible in tunnels. Due to this fact and due to simpler operational conditions, the frequency of accidents in tunnels per train-kilometre is lower than on open track or in the area of railway stations.

Contrary to the open track, accidents with fires are of major concern. Due to the enclosure in a tunnel, these accidents have the potential of catastrophic consequences. Smoke and heat can spread out in the tunnel and lead to conditions in part of the tunnel or in the whole construction which are lethal to people. This not only complicates the self-rescue but impedes also the access for rescue services. Therefore, a lot of tunnel specific safety measures deal with consequence reducing measures in case of fire.

Due to it's potential for catastrophic consequences, risks in tunnel are perceived stronger in public than high frequency/low-consequence events such as accidents at level crossings. This effect is called risk aversion. It is important to take this risk aversion into account when assessing safety measures. Therefore it is justified to implement more

4) Reasonable as general safety measure, but not only for tunnel safety reason.

safety measures than it would be necessary when just considering the expected number of fatalities[5)].

5.2 Recommended set of safety measures for new tunnels

Based on these recommendations, a general set of safety measures can be defined. It is a combination of infrastructural, operational and rolling stock measures and contains preventive measures as well as measures to reduce the effects and to facilitate the escape and rescue. As fire in passenger trains are a major and specific risk for tunnels, the set of measures focuses on this accident type.

5.2.1 Prevention of incidents

Infrastructural measures:
Railways have always focused their efforts on the prevention of accidents. Most of the accident preventing measures are not specific to tunnels, but have a safety effect on the whole railway system such as a speed monitoring and signalling system (I-1) or train radio (I-2). Also the systematic maintenance of track and tunnel (I-9/I-11) and the optimisation of the location of switches or other track discontinuities (I-8) help to prevent incidents and are therefore recommended.

Prevention of fires on rolling stock:
Fire protecting measures such as constructive measures and vehicle design to prevent outbreak and spread of fire or the use of materials which don't produce toxic substances or large amount of smoke in case of fire (R-1) are recommended. Theses aspects should be integrated consistently in the specifications for new rolling stock as well as in the specifications for the renewal of existing coaches.

Operational measures:
Operational measures such as regulations for mixed operation (O-1) or regulations for the transportation of dangerous good (O-2): When optimising operational conditions, the encounter between freight trains (especially hazardous goods trains) with passenger trains should be avoided as far as reasonably practicable.

5.2.2 Reduction of effects

If despite all the preventive measures a fire in the train is developing, there should be minimal onboard fire extinguishing equipment to deal with the fire (R-12). At the same time, a reliable communication line to the operation centre should be available (I-2). On the operational side, measures should allow to prevent other trains entering the tunnel (O-10).

In the event of fire, the general strategy for tunnels with a length up to about 15 km is to get the train out of the tunnel in order to reduce the consequences of the fire[6)]. The

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5) The concept of considering risk aversion in decision making is treated very differently in different countries (whether to consider or not, how strong to consider).
6) For longer tunnels, other strategies may be more adequate.

neutralisation of the emergency brake and maintaining the movement capability (R-11) are the crucial demands in this phase of the accident. The train has to run for as long as possible under fire conditions (at least 15 minutes). This has to be achieved by adequate vehicle design and by using appropriate materials.

5.2.3 Facilitation of escape

If despite the mentioned rolling stock measures, the train comes to a standstill inside the tunnel, it is crucial that the people can leave the train as quick as possible and move to a save place (concept of

self rescue). Therefore, the design of the coaches should support the escape out of the coach by providing escape equipment and appropriate design (R-20). Because in the first phase of an accident, the rescue services are not yet at the scene of the accident, the escape of the people can only be supported by the train crew. Therefore, appropriate emergency information of the passengers (O-20) and adequate training of the train crew is decisive (O-21). In order to enable a fast alert of the operation centre and a quick response by rescue services, reliable communication means (I-42) are necessary.

To reach a safe place in case of a fire is a central aspect of all tunnel safety concepts. To meet this requirement, it is necessary that the tunnel provides walkways with handrails and indication of the escape direction and distances (I-40) and has a sufficient and reliable emergency lighting (I-41). The distance between two safe places is proposed to be not over 1000 m (I-44). In existing tunnels, it generally won't be possible to meet this requirement. In this situation, two strategies have to be examined:

- To improve conditions to walk/escape in the tunnel and to shorten the escape distance by constructing emergency exits or safe places such as vertical exits or similar possibilities, if there are good opportunities (safety concept focused on escape).
- To provide rescue/transportation means for the evacuation of people (rail or road vehicles for rescue, I-71/72), where the escape distance can't be shortened (safety concept focused on rescue).

5.2.4 Facilitation of rescue

In the second phase of an accident, the rescue services have reached the scene of the accident through the tunnel entrances and/or through emergency access (I-61). They support the escape and rescue of people in the tunnel. Due to tunnel events in the last few years, the demand of the public and the rescue services for effective rescue measures has risen considerably. In order to enable a quick and effective rescue, a set of measures is necessary and therefore recommended:

- Provision of rescue equipment (I-69) and earthing device (I-60).
- Good access to tunnel entrance and – if applicable – tunnel exits (I-61) with rescue areas (I-63).

- Reliable communication means as well as electrical and water supply inside the tunnel (different concepts possible, mobile and fixed supply; I-65 - 68).

The rescue services have to rely on the emergency and rescue plans (O-30) specifically prepared for the tunnel. In order to ensure maximum effectiveness of the rescue services, regular exercises in tunnels (O-31) are very important.

5.3 Implementation in existing/reopened tunnels

The above recommended set of safety measures would require an upgrade of existing tunnels. Such an upgrade is best integrated in the normal maintenance and renewal cycle of a tunnel. Because of the often restricted possibilities in existing tunnels, this upgrade is very much an optimization task.
A decision about an upgrade shall consider the local situation, that means: specific risk situation of a tunnel and the possibility for additional safety measures. The implemented package shall be the result of a sound evaluation.

A1 Preliminary Remarks

Information on the following tables

The information needed for the assessment and recommendation of the safety measures is recorded in tables (appendices A2 to A4). They contain the following information:

- General description and goals:
  Short definition of measure and it's goal.
- Relevant aspects:
  Factors to be considered when assessing the measure such as general technical and operational requirements or relevance and connection to existing safety concept.
- Specifications:
  Technical specifications found in the evaluated standards and regulations with additions where necessary and reasonable. If documents differ, the specifications are defined by consensus.
- Effects on safety:
  List of effects on safety (positive and – if relevant – negative). Where possible, a *very rough* rating of the overall risk reduction was made. This rating is based on expert judgment and existing studies. Three classes were distinguished:
  - Low: Risk reduction up to 5%
  - Medium: Risk reduction between 5 and 25%
  - High: Risk reduction higher than 25%

Remark: The risk reduction refers to an average situation/tunnel as defined in chapter 2. It defines a basic risk level without the safety measure on which the effect of the additional safety measure is assessed.

- Further effects (not safety related):
  Further effects to be considered when assessing the measure such as link to other measures (combinations), technical feasibility, effects on operation and maintenance, comfort or environment. The measure costs (investment, running, maintenance) are not mentioned specifically unless they exceed an expected average.

- Cost-effectiveness[7]:
  Where possible, a *very rough* rating of the ratio of costs to risk reduction was made. This rating is based on expert judgment and existing studies. Three classes were distinguished:

  - Good: The safety benefit (risk reduction expressed in terms of monetary risk[8]) is usually higher than the costs involved with the measure.

  - Medium: The costs of the measure and it's safety benefit are about equal.

  - Poor: The costs of the measure are usually higher than the achieved risk reduction.

- Conclusion from phase 1:
  Summary of the main common aspects or differences as found in the literature study.

- Recommendation:
  Recommendation for new and existing[9] tunnels. The recommendations are the result of an assessment of *all* the abovementioned aspects and discussion within the working group. If a measure is regarded to be reasonable in the whole context, it will be recommended as safety measure.

A2 Infrastructure

I-1	Speed monitoring/signalling system
General description and goal Monitoring of speed can be effected on the locomotive, on speed checking sections by means of automatic train control at fixed points (ATCS), by means of radar or ahead of signals, using signal-based safety controls.	
Relevant aspects • Dependent on existing train control and signalling system in the railway net/on the specific route. • Operational characteristics: train density, speed (e.g. > 160 km/h). • Under continuous automatic train-running control, speeds are monitored continuously. • Possibility to upgrade an existing system with additional safety functions	

7) Under consideration of risk aversion towards very large consequences. Otherwise, most of tunnel safety measures would have a poor cost-effectiveness.
8) Based on concept of marginal costs: The applied willingness-to-pay to save one live is about 10 Mio. Euro. That value is far above amounts used in road traffic and reflects the high safety requirements for a public transport mean.
9) Also applicable for reopened tunnels.

I-1	Speed monitoring/signalling system
Specifications The system should be able to prevent trains from overrunning a stop signal and from exceeding the maximum speed with a high reliability.	
Effects on safety + Prevention of collisions caused by drivers errors (overrun of a stop signal). + Prevention of derailments caused by exceeding speed limit (e.g. on a switch). + May be suitable also for temporary speed restrictions caused e.g. by tunnel works. Risk-reduction: high	
Further effects • Operational advantages: higher train density	
Cost-effectiveness New Tunnels: in general good, depending on system Existing Tunnels: medium; depends on the existing signalling system and the possibilities of an upgrade with additional safety functions (if necessary)	
Conclusion from phase 1 Speed monitoring and signalling systems are not a safety measure specifically for tunnels	
Recommendation **New Tunnels** Speed monitoring recommended, if equipment on the specific route is planned. **Existing Tunnels** If an upgrade of an existing system for speed monitoring is possible, then tunnels should have high priority for the upgrade.	

I-2	Train Radio (operation centre – train crew – passengers)

General description and goal

Train radio permits communication between the train crew and operation centre and to passengers in the coaches. It includes fixed installations in the tunnel and the equipment of the trains (including coaches).

Relevant aspects

- Train radio is primary used for operating purposes (main aspect).
- Important information can be conveyed quickly and reliably (e.g. instructions between the train crew and operation centre and to passengers in the coaches in case of an emergency stop).
- Tunnels are part of a rail net and therefore part of a general equipment strategy for this net.

Specifications

- Equipment according to the standard of a line where tunnels are part of.
- Connection between train, operation centre and passengers.
- Possibility to disseminate information within the train.
- Reliability has high importance (see I-67)

Effects on safety

+ In case of an accident, the train staff is able to call the operation centre rapidly: to alarm rescue services, to stop other trains.
+ Trains which aren't involved in an accident can be stopped by means of train radio.
+ The operation centre can inform or give advice to the train crew and passengers.
+ The train crew can give advice to the passengers in the train (e.g. to start self-rescue).
– In case of fire, a failure is possible (problem of heat, failure of not sufficiently protected cables).

Risk-reduction: medium

Further effects

-

Cost-effectiveness

For new and existing tunnels good cost-effectiveness can be assumed (especially if the main purpose is operation).

Exceptions are: if for operation purpose there is no need for train radio and it would be introduced for safety reasons only (→ unfavourable cost-effectiveness)

Conclusion from phase 1

Train radio is generally recommended in tunnels and is already broadly introduced (not only for safety reasons)

Recommendation

New Tunnels

Recommended as a standard measure for new tunnels (including the possibility to transfer messages in all coaches of a train).

Existing Tunnels

Recommended also for existing tunnels.

a) if a tunnel is part of a line which is equipped with train radio, the tunnel shall be equipped too.
b) if a line is not yet equipped, tunnels shall be a relevant argument when setting priorities.

A tunnel may not be equipped if it is part of a line with low traffic/reduced standard

I-3	Train detection (axle counter, track circuit)

General description and goal

Checking that a track section has been completely cleared and trains are complete.

Relevant aspects

- Train detection is effected by means of axle counters or track circuits. The information on the position of a train in the tunnel should be also available to the control centre.
- Basic element of train protection/signalling system.
- Depending also on operation conditions: e.g. very low traffic.
- To combine with an adequate train protection/signalling system.
- Is not a tunnel specific safety measure: if decided to equip, it means equipping a whole line.

Specifications

-

Effects on safety

+ Prevention of movements into occupied track sections, prevention of collisions.
+ Localisation of stranded train by traffic control centre (in order to stop other trains, e.g. on the opposite track, and to prepare optimal rescue actions).
– For rescue purposes, the localisation with track circuit/axle counters might not be precise enough.

Risk-reduction: medium-high

Further effects

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Cost-effectiveness

If the measure is motivated by tunnel safety only, cost-effectiveness ratio may be unfavourable. If it is part of a whole concept including open stretch combining with an adequate train protection system, a good cost-effectiveness can be assumed.

Conclusion from phase 1

Two main goals can be derived from the documents: a) preventing collisions, b) knowing the location of a stranded train in case of an emergency/evacuation. b) is a tunnel-specific requirement and may be not solved precise enough with a "classical" axle counter or track circuit.

Recommendation

New tunnels

Recommended as standard measure.

Existing tunnels

Recommended as standard (exceptions: e.g. for lines with very low traffic and simple operational conditions)

I-4	Train control equipment (blocked brake, hot boxes)

General description and goal

Lineside fixed temperature sensors for the detection of hot axles and wheels, so that trains can be stopped in a safe place before entering the tunnel.

Relevant aspects

- Hot axles may arise anywhere in the railway net at any time whereas hot wheels as result of blocked brakes concentrate more on long declines (→ concept for position of control equipment necessary).
- Hot wheels as consequence of blocked brakes weaken a wheel. A wheel may roll hundreds or thousands of kilometres until it breaks (→ such a weakened wheel cannot be detected in the approach of a tunnel).
- Hot axles can occur very quickly within a short distance (→ detectable in the approach of a tunnel).
- In addition to the installation, rules and procedures are necessary to check a train after an alarm (→ place and personal to check a train and to take a wagon out of a train).
- The importance of technical detection equipment increases because railway staff along the line, which could control the passing trains visually, is more and more reduced.

Specifications

- Appropriate distance between two installations: Depending on the netwide concept for installations (typical range in between 25 and 100 km).
- Depending on the operation mode for double track lines: one or both tracks are equipped.
- Rules and procedures to check a train

Effects on safety

+ Prevention of derailments caused by broken wheels and axles.
+ Prevention of fires caused by overheating.
+ As the installations are integrated in a network, they have an effect not only on tunnels (main effect on open stretch).
– Wheels may be overheated and woken long before approaching a tunnel: limited effectiveness of installation in the case of blocked brakes/overheated wheels as cause for a derailment.

Risk-reduction: medium

Further effects

- False alarms (alarm with too low temperature). Problem to set an optimal temperature for alarm.
- Reliability of checking procedures by railway staff after a alarm.
- Lineside fixed temperature sensors complicate the maintenance of the track

Cost-effectiveness

New and existing Tunnels: good cost-effectiveness when assuming, that network of installations has been optimised (e.g. optimal distances).

Conclusion from phase 1

Recommended where trains are not observed by operating staff on the approach to sections with many tunnels, or on the approach to tunnels more than approx. 5 km in length.

Recommendation

New and existing tunnels

Recommended on the approach to sections with many tunnels. Isolated tunnels shall be covered by the ordinary network of installations.

I-5	Wheel flat detector

General description and goal

Detection of irregularities in the curvature of the wheel tread by principle of rail-wheel circuit or impact measurement to detect a potential hazard in an early stage especially to avoid broken rails or derailments.

Relevant aspects

- Flat wheels weaken the rail and the wheel (but the chain from cause to failure is not as stringent as e.g. for hot axles).
- Optimally to combine with other trackside detection systems (→ combine also rules, procedures and places to check a train after an alarm, cf. I-4).
- Located at strategic points in the network.
- Not a tunnel specific safety measure.

The following aspects are the same as for I-4:

- In addition to the installation, rules and procedures are necessary to check a train after an alarm (→ place and personal to check a train and to take a wagon out of a train).
- The importance of technical detection equipment increases because railway staff along the line, which could control the passing trains, is more and more reduced.

Specifications

- Criteria for optimal location and distance between two installations same as I-4 (if combined).
- Depending on the operation mode for double track lines: one or both tracks are equipped.
- Rules and procedures to check a train

Effects on safety

+ Prevention of derailments caused by broken rails, especially at low temperatures.
+ Has an effect not only in tunnels but also on open stretches.

Risk-reduction: low (if not combined)

Further effects

- False alarms are easily possible.
- Wheel flat detector enhance the maintenance of the track

Cost-effectiveness

New and existing Tunnels: poor cost-effectiveness if realised for tunnels only (to little risk reduction, if not combined with other train control equipment)

Conclusion from phase 1

Generally not treated. To be discussed to what extent it is a relevant and tunnel-specific safety measure.

Recommendation

New and existing tunnels

Not a tunnel specific safety measure. If installations are positioned optimally in the network, also tunnels are covered. Not recommended as standard measure specifically for tunnels.

I-6	Load control (wheel load measurement, profile envelope)

General description and goal

Two main types can be differentiated:

a) Optical detection of loads which foul the gauge. Displaced loads can lead to collisions or lost load due to interfering with other trains.

b) Electronic weighing in order to detect an unbalanced load.

Relevant aspects

- In principle, not a tunnel-specific safety measure, but can be focused on the approach to tunnels.
- Of primary interest for double track tunnels (interactions are possible) with mixed traffic (freight trains ↔ passenger trains, freight ↔ freight trains).
- Located at strategic points in the network (e.g. exits of large marshalling yards).
- Not a tunnel specific safety measure.

The following aspects are the same as for I-4:

- In addition to the installation, rules and procedures are necessary to check a train after an alarm (→ place and personal to check a train and to take a wagon out of a train).
- The importance of technical detection equipment increases because railway staff along the line, which could control the passing trains, is more and more reduced.

Specifications

- Criteria for optimal location and distance between two installations: dependent on desired risk reduction.
- Depending on the operation mode for double track lines: one or both tracks are equipped.
- Rules and procedures to check a train.

Effects on safety

+ Preventing collisions during encountering of two trains, caused by loads which foul the gauge.
+ Preventing collisions with lost load, e.g. due to aerodynamic impact on a displaced (not sufficient fixed) load at the encountering of two trains.
– Not effective for very quick load displacement.

Risk-reduction: small

Further effects

- False alarms are possible: e.g. a slightly fluttering awning, which has not yet an implication on safety.
- These detection systems are sensitive (→ maintenance, reliability) and complicate the maintenance of the track.

Cost-effectiveness

New and existing Tunnels: poor cost-effectiveness if realised for tunnels only.

Conclusion from phase 1

Generally not treated. To be discussed to what extent it is a relevant and tunnel specific safety measure (in the context of double track tunnels, interactions of trains are an issue).

Recommendation

New and existing tunnels

Not a tunnel specific safety measure. If installations are positioned optimally in the network, also tunnels are covered. To be evaluated on sections with double track and several tunnels in a chain or long tunnels.

I-7	Derailment indicator (trackside)

General description and goal

Equipment to monitor derailed wheels before entering a tunnel, also inside tunnel in front of switches/crossovers and in connection with other main signals inside tunnel.

Relevant aspects

- Are to be fitted on each track in connection with main entrance signal.
- A derailed train needs to be stopped immediately. Therefore a procedure similar to the other detection systems (I-4, I-5) is not adequate (too slow).
- The main effect will be for freight trains, where a derailed axle often is pulled on over kilometres, before it is detected. In passenger trains, the detection of a derailed axle is usually quicker.

Specifications

- The installation must be as close as possible to the tunnel entrance (resp. crossovers), but still enough far away, that a train can stop before entering the tunnel.
- The train has to be stopped automatically by the signalling system

Effects on safety

+ Prevents a derailed train from entering a tunnel or passing a switch (→ reduces the consequences).

– As the installation detects only a train/axle which is derailed short before a tunnel, the effect concentrates on a very small section of a line (at the maximum a few kilometres, which a derailed axle can be pulled on). It reduces the reliability of a detection: if the axle derails some meters afterwards, it is not detected.

Risk-reduction: small

Further effects

- See I-4 to I-6

Cost-effectiveness

New and existing Tunnels: poor cost-effectiveness, as the effect concentrates on a very small section of a line.

Conclusion from phase 1

Is an issue in Sweden, Norway and Denmark. No recommendations in other countries. To be traded off with equipment of rolling stock to detect derailed wheels.

Recommendation

New and existing tunnels

Not recommended as general safety measure. Exceptions may be: tunnels where a derailed train can cause hazardous event chains (e.g. underground areas with multiple tracks and high traffic density).

I-8	Arrangements of switches

General description and goal

In tunnels and on the approach to tunnel entrances the installation of switches or other track discontinuities should be avoided (completely remove or shift the location). Accidents caused or influenced unfavourably by switches will then not occur in tunnels.

Relevant aspects

- Operational requirements
- Possibility for alternative locations for switches

Specifications

- Minimal distance between switches and tunnel entrance: a few hundred metres (depending on line speed)

Effects on safety

+ Accidents in tunnels, where switches are the cause, are reduced (derailments, collisions).
+ Consequences of accidents in tunnels, where switches are a relevant circumstance, are reduced, e.g. a derailed wheel is pulled over a switch and leads to the complete derailment of a car/train.
– If switches are placed out of tunnels at another location, risks are not eliminated but shifted to a more "favourable" place.

Risk-reduction: medium

Further effects

- Operational requirements: switches are necessary to keep the capacity of a line, especially under maintenance conditions.
- Reduced maintenance and cost if switches are completely eliminated

Cost-effectiveness

New and existing tunnels: good, if operational needs can be fulfilled

Conclusion from phase I

The arrangement of switches is an issue of discussion in several countries but has not yet led to concrete recommendations.

Recommendation

New and existing tunnels

The arrangement of switches is an optimisation task, where safety considerations shall have high priority. From this point of view the following recommendations are made:

Switches or other track discontinuities should be reduced to the operational minimum in tunnels. If not possible, movable-point-frog switches should be considered (depending on speed, axle load and operational requirements.

I-9	Track inspection

General description and goal

Systematic monitoring of track condition in tunnels: track geometry, height of track, track material (also wear and tear) and track stability (UIC-Leaflet 720)

Relevant aspects

- A sound track forms the basis of safe movement and reliable operation.
- Systematic inspection includes also consequent maintenance work after detecting irregularities.
- Conditions in tunnels usually are more favourable than on open stretches: constant conditions, less influences from the environment (→ no reason for intensified inspection in tunnels).
- Track inspection is part of the general maintenance concept (→ integrated in maintenance concept for a tunnel)

Specifications

-

Effects on safety

+ Reducing track defects as cause for accidents (e.g. derailment).
+ During inspection other irregularities around the track may also be detected (not systematically).
+ Avoid that vehicles or loads strike the tunnel walls (under extreme conditions).
– Workplace risks, if inspection is done under operation.

Risk-reduction: small-medium

Further effects

- A low number of track defects is necessary for reliable operation too (no restrictions).
- A detailed inspection needs time: can reduce the capacity of the tunnel.
- To combine with I-11 (Inspection of tunnel condition)

Cost-effectiveness

New and existing tunnels: good cost-effectiveness.

Conclusion from phase 1

Even if only few documents refer to, it can be assumed, that track inspection is a standard measure (as part of a general maintenance strategy).

Recommendation

New and existing tunnels

A systematic track inspection is recommended as basis for any safe operation.

I-10	Access control (security)

General description and goal

Measures to prevent unauthorised access to the tunnel portals or exits: signs, fencing, secure locks, remote or local surveillance.

Relevant aspects

- Unauthorised access may also mean railway staff entering into the tunnel if it is in service.
- Possible objects to secure: tunnel entrances, emergency exits, technical buildings at entrances, rescue area and access roads.
- Security risks depend strongly on the location and attraction of a tunnel (exposure): e.g. mountain area ↔ city area (frequency of people trying to enter into the tunnel is completely different). Attraction of an object as target to get high effect/attention in the public.
- Special attraction to enter into a tunnel: lighted tunnel; tunnel as shortest connection between A and B for walking; niches as "protected" place to stay and sleep; graffiti.
- Combinations of different measures, depending on the exposure/hazard scenarios for a tunnel are possible.
- Can be combined with a fencing of the open track.
- Access control shall not influence safety functions, e.g. at emergency exits (access from outside shall be possible at any time)

Specifications

- Signs: warning and entry prohibited at tunnel entrances.
- Emergency exits: locked doors, possible to open from inside by anyone and outside by railway/rescue services (remote or on place).
- Fences: depending on the exposure and possible security hazard scenarios for portal area and emergency exits. Large doors for emergency access.
- TV-monitoring of sensitive areas like tunnel entrances (see also I-68): depending on the exposure and possible security hazard scenarios. Remote monitoring by a control/operation centre for the tunnel.

Effects on safety

+ Avoids sabotage or vandalism in the tunnel (near portals) and especially at buildings outside like emergency exits.
+ Reduces accidents with people entering/walking through the tunnel.

Risk-reduction: small-medium (depending on the exposure of an object)

Further effects

- Reduces graffiti damages/costs

Cost-effectiveness

New and existing tunnels: poor to medium.

Strongly depending on exposure and chosen measures. "Passive" measures like signs, locking of doors and fencing are cost-effective. "Active" measures like TV-monitoring only if high security risks are expected.

Conclusion from phase 1

The focus lies on access through emergency exits (closed doors, fences), less through tunnel entrances. No active monitoring is recommended.

I-10	Access control (security)

Recommendation

New and existing tunnels

- Security measures shall be taken on the basis of a risk assessment including the localisation/exposure, accessibility of tunnel objects, attraction as object for vandalism or sabotage and the local experience/tendency with vandalism and sabotage.
- For new tunnel it is recommended as standard measure to put signs and fences at tunnel entrances and to lock all exits. Further measures are only recommended, if an assessment of security risks shows high risks.
- Existing tunnel are recommended to upgrade (optimisation), if the local situation (in general city areas) makes it reasonable.

I-11	Inspection of tunnel condition

General description and goal

Inspection of tunnel condition (UIC-Leaflet 779.10 R) using special tunnel inspection vehicles in order to avoid accidents caused by the condition of the structure or of the surrounding rock.

Relevant aspects

- Tunnel inspection is necessary independent of all other safety measures.
- Influence factors: tunnel age, geology (e.g. hard rock, loose rocks), groundwater situation.
- Surroundings: under built area, underwater.
- Tunnel construction.
- Installations and their fixation.
- Inspection of tunnel condition is a part of the general maintenance.
- Systematic inspection includes also consequential maintenance work after detecting irregularities

Specifications

-

Effects on safety

+ Avoid accidents from conditions in the tunnel: water, fallen installations, fallen pieces from tunnel wall.
– Workplace risks if inspections are under operation.

Risk-reduction: small

Further effects

- Optimise the tunnel condition and maintenance work in a long term view (optimise maintenance costs and operational reliability)

Cost-effectiveness

New and existing tunnels: good if adequately done.

Conclusion from phase 1

Even if only few documents refer to, it can be assumed, that tunnel inspection is a standard measure (as part of a general maintenance strategy).

Recommendation

New and existing tunnels

A systematic inspection is recommended as a basis for any safe operation and optimised maintenance in a long term view.

I-20	Inclination of tunnel axis

General description and goal

Inclination with a clear direction shall enable trains to roll out of the tunnel even without electric power and to form a clear direction of air flow to support evacuation of smoke.

Relevant aspects

- Topography
- Track parameters like curvature and inclination.
- Track drainage system: drainage to only one tunnel portal (→ e.g. construction of only one retension basin if necessary).

Specifications

-

Effects on safety

+ Enables to roll out after a break down without traction power (in one direction only).
+ If a defined and sufficient airflow exists, it allows an evacuation or intervention from a smoke free side.
– Airflow depends on several other parameters and may turn even if there is a clear inclination.
– A rolling out of the tunnel may not be possible if trains are driving upwards.
– Even if the inclination would enable a train to roll out, it often fails because e.g. brakes are blocked.

Risk-reduction: small

Further effects

-

Cost-effectiveness

(not assessed)

Conclusion from phase 1

In general the inclination of tunnel axis is forced by the environment and hardly a parameter to choose by safety reasons (therefore the recommendations are rather formulated softly).

Recommendation

New Tunnels

- In general the inclination is not a free parameter to choose. A clear inclination or a roof profile are seen as equal. For U-shaped tunnels, additional considerations are necessary (e.g. evacuation in case of a stop).

Existing Tunnels

- Inclination is given

I-21	Two single track tubes

General description and goal

Two single track tubes instead of double track tunnel for avoidance of accidents caused by two crossing trains and better rescue conditions in case of an accident, especially in case of fire.

Relevant aspects

- Two single track tubes need more space in the portal area .
- If a bridge is necessary to continue, it sometimes needs two parallel bridges (factor of costs and available space).
- Depending on the local situation, construction costs may vary compared to a double track tunnel.
- The definition of the tunnel system – double track or two single track – is a multicriteria decision: construction costs, construction time and risks, operation (maintenance concept, crossovers), topography (including space at the portals), aerodynamic aspects and safety.
- Safety is influenced by: traffic density and type (e.g. mixed traffic), possibilities to realise a rescue concept with reasonable escape distances, tunnel length, etc.
- For new projects a tendency is visible to define minimal escape distances and requirements/precautions for mixed traffic by the authorities. If these requirements cannot be fulfilled with double track tunnels and escape facilities, two single track tunnels may be the solution.
- The decision on a tunnel system should be the result of a thorough evaluation of all these parameters.

Specifications

- -

Effects on safety

+ No interactions between encountering trains (especially if mixed traffic).
+ Reduces the probability of accidents where several trains are involved (collision after derailment, second train in smoke spread).
+ The effect of a two single track tunnel is optimal, if there is no cross over in the tunnel.
+ Possibility to provide short escape distances (second tube as safe place).
+ Second tunnel as access for rescue services in case of an accident.
– If there are crossovers, many of the advantages are lost (smoke spread into the second tunnel). It may be necessary to prevent a smoke transfer by e.g. gates.
– Rescue procedures through cross passages into the neighbouring tunnel need stringent rules and procedures, otherwise the risk of accidents with escaping people is high.
– The smaller cross section will be filled with smoke a little bit quicker (also depending on the shape of the cross section).

Risk-reduction: high

Further effects

- Advantages for maintenance works.

Cost-effectiveness

New tunnels: good to unfavourable, strongly dependent on local situation.

Conclusion from phase 1

The evaluated documents are applied for tunnels up to max. 25 km. For this range the basic message in the documents is, that the choice of the optimal system has to be done knowing the specific situation. There is no regulation, which describes definitively a two single track tunnel.

I-21	Two single track tubes

Recommendation

New Tunnels

The optimal system shall be the result of an evaluation of all relevant parameters. Under the condition, that required escape distances and operating restrictions (e.g. mixed traffic) can be observed the more cost-effective system shall be chosen.

Existing Tunnels

Not applicable

I-22	Cross section of double track tubes

General description and goal

Tunnel diameter should be sufficiently large that hazardous pressure transients do not occur (when two trains are passing).

Relevant aspects

Cross sections have to be defined considering different needs, as for example:

- Geology / construction method
- Train speed / aerodynamic aspects
- Safety / Space for escape routes
- Construction costs (the larger the section the higher the costs)

Specifications

Safety reasons may influence the cross section only in exceptional situations.

Effects on safety

The following advantages are relied to a large cross section:

+ Reduces possible interactions related to aerodynamic effects.
+ Enables larger walkways.
+ Enables a larger distance between the track axes (reduces the probability of a collision in case of a derailment) .
+ Reduces probability of collisions due to shifted load.
+ More favourable under the point of view of smoke spread.

Risk-reduction: medium

Further effects

- The cross section of double track tunnels will mainly be influenced by factors other than safety

Cost-effectiveness

New tunnels: poor; if a large cross section would be defined only for safety reasons (see advantages above), the cost effectiveness would be unfavourable.

Existing tunnels: not applicable

Conclusion from phase 1

The cross section (e.g. large diameters) is not a primary safety parameter (as far as other requirements like space for escape route or aerodynamic aspects are solved).

Recommendation

New Tunnels

Recommendation: If all safety requirements like width of escape routes etc. can be fulfilled, there are no further requirements to the cross section from the point of view of safety.

Existing Tunnels

Not applicable

I-23	Fire protection requirements for structures

General description and goal

The tunnel structure should be designed so that it is not rendered unsafe by loss of load carrying capacity during a fire. Materials and equipment should have defined smoke emission and flammability characteristics.

Relevant aspects

- Under the point of view of safety for passengers, defined smoke emission and flammability characteristics are more important than protection of structures.
- Fire protection requirements may follow several goals:
  - keep resistance of the structure to protect rescue services and construction workers during and after a fire.
  - keep resistance of the structure, if the tunnel passes close under built area, lies in groundwater or goes under surface water → higher requirements.
  - minimise the damage and time until reopening a tunnel.
- Importance of a line, e.g. a vital connection between A and B → higher requirements.
- Transportation of dangerous goods.
- Passive (constructive) and active (installations like sprinklers or similar systems) methods of fire protection, possibilities of rescue services .
- Today different specifications for constructive protection are used (different national standards, which have to be respected)

Specifications

- Resistance to fire: e.g. ISO 834, conditions of fire according to Eurocode 1, part 2.2 and the hydrocarbon curve.
- Materials: non flammable/defined materials concerning smoke emissions.

Effects on safety

+ + Reduce toxic gases caused by burning cables and installations (important during self rescue) .
+ + Protect rescue services and construction workers during and after a fire.
+ Prevent damages on buildings on the surface close to the tunnel.
+ Prevent entering of water (after a collapse).

Risk-reduction: Strongly dependent on the local situation.

Further effects

- Minimise the damage and time until reopening a tunnel (renewal costs and operation losses).

Cost-effectiveness

New tunnels: good; using a standard temperature curve can be assumed as cost-effective, further requirements are adequate, if higher risks are expected.

Existing tunnels: good; optimising in case of renewal can be assumed as cost-effective.

Conclusion from phase 1

Temperature curves are specified, but there is not a clearly preferred curve.

I-23	Fire protection requirements for structures

Recommendation

New tunnels

- The use of a clearly defined and broadly accepted temperature curve is recommended (e.g. ISO 834, conditions of fire according to Eurocode 1, part 2.2 and the hydrocarbon curve).
- Additional requirements are recommended for underwater sections or sections close under built areas.
- Lower requirements are reasonable under the following conditions:
  - Construction with secondary function
  - If damage poses no primary safety problem and higher damage and longer closure of a tunnel is accepted
  - If alternative solutions are chosen (e.g. active measures such as fire extinguishing systems, I-25)
- For all installations, it is recommended to use non flammable / defined materials concerning smoke emissions (see also I-67).

Existing Tunnels

In case of a renewal, recommendations for new tunnels shall be applied as far as reasonably possible. For all installations, it is recommended to use non flammable/defined materials concerning smoke emissions (see also I-67).

I-24	Fire, smoke and gas detection in tunnels

General description and goal

Installation of fire, smoke and gas detectors in tunnels, enabling rapid location of a fire in ignition phase:

a) In main tunnel
b) In technical rooms

Relevant aspects

- Type of traffic is important: passenger, freight, combined traffic/lorries
- Detecting: fire/heat, smoke, gas (preferably explosive gases)
- Detecting fire in fixed installations or in running trains
- Different type of gases: heavy gas (collecting at a low point in the tunnel) or light gas (collecting at the ceiling) -> position of gas detectors
- Gas detectors generally detect only one specific gas, so that a whole series of gas detectors would be needed
- Fire, smoke and gas detectors are intensive for maintenance

Specifications

- To be distinguished between main tunnel and technical rooms
- Different systems are available: punctually, linear, based on different detecting concepts

Effects on safety

a) Main tunnel

+ More rapid alarm in a control/operation centre (especially trains transporting lorries) → possibility to take optimal actions: alarm rescue services, stop or drive out a train
+ Detect a fire in an early stage → reduce damage and potential for escalation
  – A fire on a train can only be detected if it is already in an advanced stage: smoke and flames come out of the coach
  – False alarm can also cause additional risks

b) Technical rooms

+ Precise location of a fire → quick and precise fire fighting action

Risk-reduction: small

I-24	Fire, smoke and gas detection in tunnels

Further effects

- False alarms cannot be excluded, e.g. during work in the tunnel (e.g. welding and rail grinding) → operational disturbances.

Cost-effectiveness

New and existing tunnels: poor to medium

A fully equipping of the complete tunnel can be assumed as not cost-effective; punctually equipping of sensitive installations may be cost-effective.

Conclusion from phase 1

Generally recommended for technical rooms but not for the whole tunnel (is also a matter of several discussions in the public as consequence of the recent large fires in tunnels).

Recommendation

New Tunnels

a) Main tunnel

- Not recommended as standard
- Gas detectors recommended for tunnels with a low point in the tunnel (u-shaped) and if gas could enter the tunnel from the surroundings.

b) Technical rooms

- Fire and/or smoke detectors are recommended for technical installations concentrated in separate rooms in the tunnel.

Existing Tunnels

- In the course of a renewal/general upgrade the recommendations for new tunnel should be followed as far as reasonable.

I-25	Fire extinguishing systems (sprinkler or similar installations)

General description and goal

Automatic or manually started fire extinguishing systems in order to fight the fire in a early stage.

a) Systems in the main tunnel

b) Systems in technical rooms

Relevant aspects

- With sprinkler systems in the main tunnel it is necessary to solve the problem of the catenary (technical feasibility and operational rules and procedures)
- Large water consumption considering the dimensions of a train fire → water supply and also adequate drainage system is necessary
- Water may not be the right mean for technical installations
- Special aspect: rescue stations in very long tunnels → different situation

Specifications

a) Main tunnel: Not specified, see recommendation.

b) Technical rooms with highly sensitive installations: provision of smoke/fire detection with automatic extinguishing system and/or manual fire extinguishers To define the efficiency is part of a specific project.

Effects on safety

a) Main tunnel

+ Rapid cooling: reduces damages to structures and may prevent a spread out of the fire
– Sprinklers will operate only when the train has stopped (but then the fire probably has developed)
– Traditional sprinkler systems are hardly able to fight a fire in progress (e.g. full fire of a coach after stopping)
– A sprinkler system does not reach a starting fire in a running coach
– High temperature: problem of scalds, if still people are close the fire
– With automatic sprinkling: contact with certain chemical substances may lead to uncontrolled reactions
– Installations in the main tunnel may increase workplace risks if maintenance is done during operation

b) Technical rooms

+ Very good extinguishing effectiveness at an early stage, if fire fighting installations are close to the source

Risk-reduction: small-medium

Further effects

- Damages due to false alarm
- Sprinkler systems need high maintenance to get high reliability

Cost-effectiveness

New and existing tunnels: poor to medium

A fully equipping of the complete tunnel can be assumed as not cost-effective; punctually equipping of sensitive installations/technical rooms may be cost-effective.

Conclusion from phase 1

If guidelines recommend it, then only for technical installations.

I-25	Fire extinguishing systems (sprinkler or similar installations)

Recommendation

New and existing tunnels

a) Main tunnel: no extinguishing systems are recommended.
b) Automatic extinguishing systems are only recommended for rooms with highly sensitive technical installations. Fire extinguishers are recommended to place at rooms/compartments with technical installations.

I-26	Smoke extraction systems/ventilation system

General description and goal

Three main situations are to be distinguished:

a) Main tunnel: mechanical smoke extraction system in the main tunnel in order to pull out smoke or to install a defined air stream in order to get a smoke free side for rescue.
b) Smoke extraction if a double track tunnel enters into two single track tubes or at passages between two single track tubes (to keep the parallel tubes free of smoke, to prevent air circuits)
c) Safe places: ventilation systems to keep emergency exits, cross passages or a parallel safety tunnel free of smoke (produce overpressure)

Relevant aspects

- For normal operation a ventilation system in general is not necessary (exception on non electrified lines are possible). This is a clear difference to road tunnels.
- Clear distinction between fans, which have to install a longitudinal airflow only and extraction systems to pull out smoke locally.
- To move an air column in a tunnel needs a high performance system. Running trains are mostly much more efficient, so that a ventilation system can only work well, if running trains have left the tunnel or stopped.
- In special situations, alternative measures like doors can be suitable
- Situations which have to be treated specially:
- Combination of tunnel and underground stations → different situation
- Smoke extraction in a rescue station of a very long tunnel → different situation

Specifications

a) No specification for the main tunnel (see also recommendation)
b) Combination of double track/single track tunnel or at passages between two single track tubes: the ventilation/smoke extraction system has to be designed, that smoke transfer from one tube in the other at the passage is reduced to a minimum. A detailed concept and sufficient dimensioning of the system is necessary.
c) Safe places: The ventilation system has to be designed that smoke transfer into the safe place is reduced to the minimum when opening doors to the main tunnel (see also I-44, I-45, I-46 and I-47). If there are alternatives to an active ventilation, which fulfils that requirement, it is acceptable as well (e.g. doors).

- Reliability: see I-67
- Fans for a longitudinal airflow need space. For existing tunnels it poses severe problems.

I-26	Smoke extraction systems/ventilation system

Effects on safety

a) Longitudinal airflow in the main tunnel

+ If the airflow is strong enough, it guarantees one smoke free side, where people are safe and rescue actions can take place
– The decision about an optimal airflow/direction is a difficult one. There are always people on the wrong side. If decisions are wrong, e.g. by lack of adequate information, the situation might become even worse
– To start and accelerate the airflow needs time, even more, if an existing direction should be changed
– An intensified airflow mixes up the air and reduces clear/sharp smoke layers
– Remark: for railway application the positive effect of longitudinal ventilation is a matter of controversial discussions. It cannot be compared with road tunnels, where different ventilation systems, e.g. a transversal ventilation, can easily be installed.

b) Smoke extraction in the main tunnel at specific places (double track/two single track; passages between two single track tubes):

+ Prevent smoke spread into tunnel sections which are defined as safe parts
+ Reduce the probability that further trains are involved in smoke
– Smoke extraction imposes an airflow in the tunnel which may be unfavourable for self rescue and actions of rescue services
– See also longitudinal airflow

c) To keep safe places free of smoke

Risk-reduction: not assessed

Further effects

- Ventilation/smoke extraction systems need high maintenance to keep reliable
- Extraction systems need a chimney: depending on the location it can pose some problem (e.g. in densely populated area).

Cost-effectiveness

New tunnels:

a) Smoke extraction as general measure: poor cost-effectiveness, considering the unclear effectiveness and expected high investment and maintenance cost.

b) and c): Medium to poor because of presumably high costs

Existing tunnels: Not reasonably applicable

Conclusion from phase 1

Documents show the controversial discussion on ventilation/smoke extraction systems. The range reaches from “not recommended” to “required” (under defined conditions). It is a safety measure often demanded by rescue services.

Recommendation

New Tunnels

a) Smoke extraction in the main tunnel: not recommended as standard measure to control smoke spread.

b) and c) Recommended for specific situations, where safe areas shall be kept free of smoke (e.g. parallel tubes, emergency exits). In order to reach this goal, alternative measures like doors or locks may also be adequate.

Existing Tunnels

Not reasonably feasible for existing tunnels.

I-27	Track drainage system (drainage and retaining basin)

General description and goal

The track drainage systems removes water from the tunnel.

Relevant aspects

- Construction of the tunnel as tight tube: only fluids from inside have to be transported
- If there is also water from outside the tunnel tube: decision between mixed system (fluids from the track and water from the mountain are mixed) and separated system (fluids from track are removed separate to water from mountain)
- Such fluids inside the tunnelcan be: Snow or rain water brought into the tunnel by trains, spills, water from fire fighting
- Water treatment at the portals: retention basin, depending on the sensitivity of the environment
- Tunnels with a low point: need of an adequate retention basin (pump sump) and pump installation.
- Protection from explosion: prevent fire/explosion spread in closed pipes and in basins/pump sumps.

Specifications

- Minimal longitudinal and transversal inclination to ensure an efficient removal of fluids
- Protection from fire/explosion spread in the drainage system (separated sections)
- Dimensioning of drainage system: expected water from the mountain, capacity of water mains (if installed) or other fire fighting means, leaking wagons (at least 80 m3)
- Design should especially consider maintenance aspects
- The track drainage system includes retaining basins - if there is transportation of dangerous goods- to retain polluted extinguish water or run out dangerous goods.
- Dimensioning of retention basin: leaking wagons plus water mains for a defined time period
- If a tunnel passes beneath a river, or water has to be pumped out for other reasons, then the pump sump should be dimensioned to contain:

- Seepage for a defined period
- The contents of water mains or hydrants for fire fighting if these are damaged at their lower end
- The contents of 3 tank wagons
- The water necessary to operate a fire fighting line for one hour

Effects on safety

+ An appropriate dimensioned drainage system reduces the possibility of escalation (e.g. explosion after a release of dangerous goods)
+ Reduction of environmental damage at portals
+ Reliable drainage of water from the tunnel (risk of flooding decreases)
– In case of a release of explosive dangerous goods retaining basins or pump sump have a higher risk of explosion

Risk-reduction: small

Further effects

- Need for high maintenance to get high reliability (problem of chalk, aggressive water, substances)
- If there is a lot of water from the mountain: possibility to use it for water supply in case of fire (cf. I-64).

Cost-effectiveness

New tunnels: good (considering safety aspects if designing the drainage system)

Existing tunnels: not applicable

Conclusion from phase 1

Generally formulated recommendations, no fixed requirements e.g. for a certain drainage system.

I-27	Track drainage system (drainage and retaining basin)
Recommendation **New Tunnels** If designing the drainage system it is recommended to consider safety aspects as specified. **Existing Tunnels** Not feasible in the sense of an upgrade of an existing tunnel; to be considered if a reconstruction is planned.	

I-40	Escape routes (routes, handrails, marking)

General description and goal

Provision of walkways in tunnels to facilitate escape (normally beside tunnel wall, also in or between tracks if there is not enough space). Handrail along the tunnel wall and especially around obstacles. The escape route and directions is marked by pictograms.

Relevant aspects

- A quick walking speed is essential for a successful escape in case of fire
- In new tunnels the cross section allows wide walkways
- Must be combined with I-41 (Tunnel lighting/emergency lighting)
- Type of traffic: e.g. if only freight trains → escape routes are less relevant
- Optimal height of walkway depends on specific situation (means to leave a train, intervention concept, space in a tunnel): → No specification of height.

Specifications

- Minimum width for new tunnels: >70cm, optimally 1.20m
- In double track tunnels on both sides of tunnel
- Existing tunnels: optimisation of surface (e.g. compressed gravel, cable duct with larger slab)
- Hard and smooth surface, free of obstacles as far as possible
- Handrail leads around obstacles
- Signs are to be placed where lighting is: indication of escape direction and distance to nearest exit.

Effects on safety

+ Increase walking speed, reduces tailbacks and enables longer escape distances
+ Is useful too, if people must leave a failed train
+ Walkways also serve for rescue services
– Signs can be misleading

Risk-reduction: medium

Further effects

Can be used for maintenance too

Cost-effectiveness

New tunnels: good cost-effectiveness ratio, because walkways can be integrated without relevant additional expenses.

Existing tunnels: medium cost-effectiveness ratio for tunnels with increased risk.

Conclusion from phase 1

For new tunnels there is a common understanding, that walkways, handrails and signs are necessary (differences exist in specific dimensions). Also for existing tunnels it seems to become a standard measure.

Recommendation

New Tunnels

Recommended as standard measure as specified

Existing Tunnels

Improvements to enable adequate movement are recommended for existing tunnels as basic equipment, solutions shall be optimised and consider the specific risk situation (tunnel length, traffic, rescue concept).

I-41	Emergency tunnel lighting

General description and goal

Lights along one or both tunnel walls for lighting the escape routes in case of a train evacuation. The lighting shall ensure a uniform illumination of the escape route in order to enable a safe walking of evacuees.

Relevant aspects

- Reasonable only in combination with I-40 Escape routes (routes, handrails, marking).
- Visibility under smoke conditions (smoke may fill the complete cross section, depending on time and distance to fire).
- Reliability and autonomy.
- Lights on one or both tunnel walls.
- Remote control for technical and operational conditions.

Specifications (see also recommendations)

The following specifications base on the assumption of an electric lighting. Alternative technical solutions are possible as well if they fulfill the intended functions.

- On one or both sides — single track tube: one side (same as walkway)
double track tube: both sides
- Luminosity poor — enable a safe walking as far as possible also under smoke conditions and visibility
- Height of lights — above walkway, as low as possible, depending on free space
- Autonomy and reliability: ensure
  a) guaranteed power supply for emergency or alternative concepts to high reliability.
  b) supply cables protected against mechanical impact and fire
  c) it is recommended to build sections for power supply/lighting
- Other specifications: aspects are
  – Possibility to switch on from operation centre, portals and inside the tunnel.
  – Minimum distance between portal and first switch is 250 m if security relevant.
  – Under normal operation, lighting is switched off.

Effects on safety

+ Enables people to walk with adequate speed on the walkway, if an evacuation of the train is necessary (consequence reduction).
– – In case of a train stop, a lighting turned on could encourage passengers to leave the train (out of control).
– Installations need additional maintenance: increase of workplace risks may be a consequence.
– If smoke fills the complete cross section, lighting becomes less efficient or even useless.
– Aspect of vandalism/unauthorised access when permanent lighting.

Risk-reduction: medium

Further effects

- Suitable also as lighting for maintenance works (additional light necessary to ensure sufficient luminosity).
- Guaranteed power supply with batteries is expensive in maintenance (intense maintenance necessary in order to keep a reliable functioning).

Cost-effectiveness

New tunnels: good

Existing tunnels: medium; depending on actual situation, for tunnels > 1km and high passenger traffic in general good.

Conclusion from phase 1

For new tunnels there is a common understanding, that tunnel lighting is necessary (differences exist in specific dimensions). Also for existing tunnels it seems to become a standard measure.

I-41	Emergency tunnel lighting

Recommendation

New Tunnels

Recommended for new tunnels as specified

Existing Tunnels

Tunnel lighting is generally recommended for tunnels of about >1 km. Decisions should be based on a risk assessment, considering at least operational data and tunnel length.

In order to keep a good cost-effectiveness ratio, specifications may be reduced: lighting only on one side, lower requirements for luminosity and reliability.

I-42	Emergency phones/communication means

General description and goal

Emergency phones or similar communication means, so that also passengers are able to use them in emergencies, connected with operation centre (independent of train radio or mobile phone). Emergency phones shall permit adequate and reliable communication during any emergency.

Relevant aspects

- The telephone system represents redundancy level for communication.
- The system should be combined with telephones for other operation purposes (maintenance, operational disturbance, etc.).
- Combination with I-43: could be used as for public addresses over the loudspeaker system.

Specifications

- Clearly visible and easy to use (indications necessary).
- Reliability, see I-67.
- Direct and easy to use connection to the responsible operation centre.
- Distance between phones: 500 – 1'000 m as guideline (depending on distance between exits or cross passages).
- Additional/alternative locations: Portals and exits.
- For existing tunnels: Optimisation of existing telephones as far as reasonably possible.

Effects on safety

+ Rapid alarming after an accident.
+ Redundancy of communication after a failure of radio means.

Risk-reduction: small

Further effects

- Can also be used for operational/maintenance purposes.

Cost-effectiveness

New tunnels: good

Existing tunnels: good; presumed existing telephones are optimised and integrated.

Conclusion from phase 1

Railway and emergency telephones can be considered as standard.

Recommendation

New Tunnels

Recommended as standard.

Existing Tunnels

Recommended as standard, optimisation of existing telephones as far as reasonably possible.

I-43	Loudspeaker system in tunnel

General description and goal

Tunnels shall be equipped with a loudspeaker system for passenger information in case of emergency/evacuation (after leaving the train). The system is used by the train crew or by the operation centre.

Relevant aspects

- Should be combined with other communication systems: e.g. telephones (cf. I-42)
- Possibility to use the system from inside the tunnel needs adequate solutions
- In order to give adequate information, the operation centre needs precise information about the accident
- Must be integrated in staff training
- Linked with a concept based on self rescue

Specifications

-

Effects on safety

+ Possibility to give instructions to people outside the train
+ Reduces the possibility of panic or other bad reaction
– If information of staff is incomplete or wrong (which probably will be the normal case), evacuees can get wrong instructions
– Misunderstandings: e.g. language problems

Risk-reduction: small

Further effects

- To ensure high reliability, the system needs ample maintenance
- The system is not used for any other purpose

Cost-effectiveness

New and existing Tunnel: Poor

Supposing rather high maintenance costs and an unclear effect (wrong instructions), the cost-effectiveness ratio is assumed to be unfavourable

Conclusion from phase 1

Safety concepts for tunnels, in general do not recommend loudspeaker systems in tunnels (one exception).

Recommendation

New and existing tunnels

- Not recommended as standard measure

I-44	Escape distances

General description and goal

A maximum distance between to safe places (portal, emergency exit, cross passage) in the tunnel is defined in order to enable self rescue. The distance is proposed to be not more than 1'000m.

Relevant aspects

- Any person in the tunnel should have a chance to get in a safe place in the case of an accident.
- The main effectiveness of exits concentrates on fire scenarios.
- To reach a safe place in case of a fire is a central aspect of all rescue concepts.
- The first minutes are decisive (before rescue services reach the place).
- Even with very short distances to safe places, consequences cannot be reduced to zero.
- The distance between safe places is also a function of the expected situation in the tunnel: smoke spread, possibility of rapid displacement, etc..
- Emergency exits or similar constructions are expensive, decision must take into account cost-effectiveness criteria.
- Depending on the topography, a standard for short distances between safe places can imply two single track tubes or a parallel safety tunnel.
- In any case: opportunities like construction shafts/adits or very close place to the surface should be used as emergency exit.
- Cross passages between two parallel tubes are cost-effective compared to exits to the surface. Therefore based on the criteria of the cost-effectiveness, it is reasonable to reduce the maximal distance between to cross passages.

Specifications

- Distance between safe places: 1'000m (→ mean escape distance for self rescue of 500m) as general guideline.
- For two single track tubes and parallel safety tunnel: reduced distance of 500 m (cost-effective).
- A variation, considering the local situation, operational parameters and the *complete safety concept* are possible and reasonable.

Effects on safety

+ Short distance: ensure a rapid escape in case of fire and smoke (central aspect to reduce consequence).
+ Short access distances for emergency services in the main tunnel.

Risk-reduction: high

Further effects

- Can be used also by maintenance staff.

Cost-effectiveness

New tunnels: The cost effectiveness ratio depends very strong on the local situation (costs). Under favourable conditions, a good cost-effectiveness ration can be assumed.

Existing tunnels: For existing tunnels additional constructive work is very expensive and if for safety reasons only, the cost-effectiveness mostly will be very unfavourable.

Conclusion from phase 1

This is one of the most controversial discussions (also in public). The different solutions show the range of opinions (150m up to no fixed limits). Should be a matter of discussion in phase 2.

I-44	Escape distances

Recommendation

New Tunnels

The optimal distance shall be the result of an evaluation of all relevant parameters influencing safety (e.g. daily traffic, traffic mix, rescue concept, tunnel length etc.) The following maximum distances are proposed as guideline:

a) Distance for cross passages between two parallel tubes: 500 m.
b) Distance between emergency exits (to the surface): 1'000 m.

The different distances for a) and b) are based on the criteria of cost-effectiveness.

Existing Tunnels

Additional constructive measures to reduce escape distances are not recommended as standard measure. Under specific conditions an upgrade with emergency exits or similar possibilities may be adequate

- renewal of a tunnel,
- high risk due to the tunnel characteristic and operation mode,
- good opportunities (tunnel close to the surface, construction adits/shafts).

I-45	Vertical exits/access

General description and goal

Construction of vertical exits from the tunnel which are used for escape as well as for access of rescue services.

Relevant aspects

- In general only for tunnels with a single tube (one or two tracks).
- Construction shafts and places near to the surface are preferred locations for lateral exits (optimisation).
- Solution is only possible, if the tunnel lies near the surface: edging or crossing a valley, hills, etc.
- Accessibility of exits outside (cf. I-61, access to tunnel entrance and tunnel exits).
- Can be a solution to improve safety of existing high risk tunnels.
- To be combined with means for rescue services: I-60 (earthing device), I-64 (water supply), I-65 (energy supply), I-69 (provision of rescue equipment) and the access to the tunnel.
- Restrictions for building at the surface: if exits are in natural reserve area or densely populated area.

Specifications

- Maximum height should be less than 30m, width of stairs of about 1.2 m as guideline.
- Design or installation necessary that prevents smoke spreading into the safe place (possible solution: locks or ventilation system).
- Equipped with lighting and communication means (e.g. telephone).
- Design or installation that prevents an unauthorised access from outside.

Effects on safety

+ Ensures escape in case of fire and smoke in a safe place.
+ Leads directly out of tunnel.
+ Access for emergency services.
– Stairs will lead to a tailback and are not suitable for disabled people.
– Interference between escaping people and rescue services entering.

Risk-reduction: medium

Further effects

- Can be used also for maintenance purposes.

Cost-effectiveness

New tunnels: good, if combined with good opportunities (construction, nearness to the surface).

Existing tunnels: not applicable in general.

Conclusion from phase 1

The requirements of the different evaluated guidelines are similar (e.g. max. height, equipment, locks, smoke free space).

Recommendation

New Tunnels

If vertical exits are planned, a distance of about 1000m between the exits and provisions as determined under "specifications" are recommended.

Existing Tunnels

In general not applicable.
For high risk tunnel: possibility to improve tunnels in the course of a total renewal, if opportunities (nearness to surface) exist. Decision should be made based on a sound evaluation.

I-46	Lateral exits/access

General description and goal

Construction of lateral exits from the tunnel which are used for escape as well as for access of rescue services.

Relevant aspects

- In general only for tunnels with a single tube (one or two tracks).
- Construction adits and places near to the surface are preferred locations for lateral exits (optimisation).
- Solution is only possible, if the tunnel lies near the surface: edging a valley, hills, etc..
- Accessibility of exits outside (cf. I-61, access to tunnel entrance and tunnel exits).
- Can be a solution to improve safety of existing tunnels with high risk.
- To be combined with means for rescue services: I-60 (earthing device), I-64 (water supply), I-65 (energy supply), I-69 (provision of rescue equipment) and the access to the tunnel.
- Restrictions for buildings at the surface: if exits are in natural reserve area or densely populated area.

Specifications

- Cross section: 2.25 m x 2.25 m as guideline.
- Maximum length of about 150 m as guideline, if more: accessible with road vehicles (see requirements for parallel safety tunnel, I-48).
- Design or installation that prevents smoke spreading into the safe place (possible solution: locks).
- Equipped with lighting and communication means (e.g. telephone).
- Design or installation that prevents an unauthorised access from outside.

Effects on safety

+ Ensures escape in case of fire and smoke in a safe place.
+ Leads directly out of tunnel.
+ Access for emergency services
– Emergency exists may be used for sabotage.

Risk-reduction: medium

Further effects

- Can be used also for maintenance purposes.

Cost-effectiveness

New tunnels: good, if combined with good opportunities (construction, near to the surface).

Existing tunnels: not applicable in general.

Conclusion from phase 1

The main difference between the evaluated documents is, if or under what condition an adit should be accessible with road vehicles.

Recommendation

New Tunnels

If lateral exits are planned, a distance of about 1000m between the exits and provisions as determined under "specifications" are recommended.

Existing Tunnels

In general not applicable.
For high risk tunnels: possibility to improve tunnels in the course of a total renewal. Decision should be made based on a sound evaluation.

I-47	Cross passages

General description and goal

Cross passages between two single track tunnels or between a double track tunnel and a safety tunnel.

Relevant aspects

- See also I-44 (escape distance), I-21 (two single track tunnels) and I-48 (parallel service and safety tunnel).
- Cross passages have the function to connect the main tunnel to safe places, they are not yet the safe place, because in general they are not spacious enough for a large number of people.
- Cross passages are relatively low priced → a shorter distance between cross passages than between exits is cost-effective.

Specifications

- Cross section: 2.25 m x 2.25 m as guideline.
- Design or installation that prevents smoke spreading into the safe place.
- Equipped with lighting and communication means (e.g. telephone).
- Design or installation that prevent an unauthorised access to the neighbouring tube if operation is still going on.

Effects on safety

+ Ensures escape in case of fire and smoke to a safe place.
+ Access for emergency services.

Risk-reduction: medium

Further effects

- Cross passages can also be used for technical installations.
- Can also be used for maintenance purposes

Cost-effectiveness

Cost-effectiveness is governed by the basic decision about the tunnel system (double track, two single track, etc.). The distance between cross passages and the main equipment is secondary. Compared to vertical or lateral exits, the solution with cross passages has usually a better cost-effectiveness.

Conclusion from phase 1

If planned, the main requirements concern the transgression of smoke in the neighbouring tube.

Recommendation

New tunnels

If cross passages are planned, a distance of about 500m between the passages are recommended (see I-44, escape distance).

Existing tunnels

In general not applicable.
For high risk tunnels: possibility to improve tunnels in the course of a total renewal. Decision should be made based on a sound evaluation (see I-44, escape distance).

I-48	Parallel service and safety tunnel

General description and goal

Provision of a service and safety tunnel parallel to the main tunnel (double track). The tunnel is kept free of smoke and provides a place of safety in case of fire and other accidents. The safety tunnel can also be used by emergency services.

Relevant aspects

- Parallel exploratory tunnel can be used as safety tunnel.
- Solution should be the result of a thorough evaluation based on cost-effectiveness consideration.
- Needs space in the portal area (lateral distance to the main tunnel axis).
- A parallel tunnel may cover only parts of the tunnel length (in combination with shafts or adits)

Specifications

- Cross passages to the main tunnel: see I-46 and I-48.
- Cross section: 3.5m x 3.5m as guideline, accessible by road vehicles, possibilities to reverse and pass .
- Independent ventilation system (or similar installation) in order to keep the safety tunnel free of smoke (produce overpressure related to the cross passages and the main tunnel)

Effects on safety

+ Provides a safe place for any accident, possibility to leave the tunnel independently of the main tube.
+ Possibility to reduce the escape distance in the main tunnel with cross passages.
+ Independent access for emergency services, possibility to reach closely to the accident place.
– - Passengers are not yet outside the tunnel.
– Interference between rescue services and escaped people.

Risk-reduction: medium-high

Further effects

- Can be used also for maintenance purposes.
- In principle also feasible for existing tunnels

Cost-effectiveness

New tunnels: medium; if additional profit can be drawn the cost-effectiveness ratio may be balanced, otherwise unfavourable.

Existing tunnels: poor; very bad ratio can be assumed if the construction is motivated by safety reasons only

Conclusion from phase 1

In general mentioned as possibility to provide a safe area. Requirements are similar to lateral accesses (e.g. smoke free conditions, because of the length also accessible with road vehicles)

Recommendation

New Tunnels

Should be the result of a evaluation of the optimal system. Not recommended as general solution.

Existing Tunnels

In general not applicable.
For high risk tunnels: possibility to improve tunnels in the course of a total renewal. Decision should be made based on a sound evaluation.

I-60	Earthing device

General description and goal

Disconnection of the overhead line for the entire tunnel. Earthing devices including voltage measuring instruments are positioned at entrances, portals and emergency exits.

Relevant aspects

- Rescue services cannot enter safely a tunnel, if the overhead line is under power.
- Disconnection of the overhead line through the railway company.
- If earthing shall be carried out by fire brigades: stringent rules and procedures including training is necessary.
- Involve only specified and instructed people (preferably professional fire brigades).

Specifications

- Earthing devices and measuring instruments are positioned at all tunnel entrances, communication means (e.g. telephone) and an illumination of the place is ensured.
- Procedures and responsibilities are defined (including communication between rescue services and responsible centre).

Effects on safety

+ Prevent accidents with electricity in case of maintenance and emergency.
+ Reduce time delays for entering the tunnel.
+ Earthing can be done by emergency services if well organised.
– Danger of accidents, if not handled correctly (additional risk to rescue services).

Risk-reduction: small

Further effects

- To be used also by maintenance staff

Cost-effectiveness

Good cost-effectiveness

Conclusion from phase 1

Generally recommended at tunnel entrances.

Recommendation

New and existing tunnels

- Recommended as safety measure at tunnel entrances as specified.

I-61	Access to tunnel entrance and tunnel exits

General description and goal

Access road for rescue services to portals and emergency exits.

Relevant aspects

- Possibility for access is necessary, independently of the intervention concept (fire brigade or railway means).
- Topography: mountain or city area, combination of tunnel and bridges → determine optimisations.
- Existing tunnels are different from new tunnels (access for construction can be used for operation phase).

Specifications

- Access roads shall be drivable by normal vehicles of fire brigades.
- Solid surface (damages after a large intervention are acceptable).
- Minimal width: 3 m.
- The road ends at the rescue area or at a solid turning place.
- As close as reasonable to the entrance, depending on local topography.

Effects on safety

+ The portal area can be reached rapidly by road vehicles (different purposes).
+ People transport to and from the tunnel (e.g. injured people).

Risk-reduction: low-medium

Further effects

- Can be used also for maintenance purposes.
- Rights to use roads must be registered.

Cost-effectiveness

New tunnels: good; because access roads normally are still used for construction phase.

Existing tunnels: poor (if additional construction work is necessary).

Conclusion from phase 1

Can be considered as standard for new tunnels. Differences between the guidelines exist in design requirements (e.g. width of roads)

Recommendation

New tunnels

Recommended in combination with rescue area (I-63).

Existing tunnels

Recommended to improve situations as far as reasonably practicable. If not possible: Helicopter landing areas in the vicinity should be defined and prepared as far as reasonably practicable.

I-62	Track accessible for road vehicles

General description and goal

Track is accessible for road vehicles of rescue services. It allows to enter rescue services immediately into the tunnel by their own means.

Relevant aspects:

- Double track or single track tunnel: different "traffic management", one way or bi-directional.
- Intervention concept for rescue services must be based on fire brigades.
- Appropriate fire brigades must be in the vicinity of the tunnels (preferably professional fire brigades).
- Accessibility of tunnel portals for road vehicles and possibility to drive on the track.
- Stringent rules and procedures to run on track are necessary (e.g. railway staff on site) .
- All means are transported by road vehicles, no further rail vehicles required.
- Combination with other fixed installations like water supply is useful/necessary (depending on the intervention concept).

Specifications

- The complete surface is smooth and drivable (plates between the tracks are necessary).
- In double track tunnels, areas to turn vehicles are necessary (depending on traffic management).
- Areas at portals to get access on the track, access routes must be safeguarded (prevent access under normal operation).

Effects on safety

+ Fire brigades are rapidly on site to decide on the optimal intervention strategy and for first aid.
+ They can use their own equipment and supply system, they can also use their proper heavy means .
– If rules and procedures to use the track are not followed strictly or if the access to the track is not physically prevented → risk of collision with running trains.
– If several vehicles enter the tunnel they can block the way (→ stringent rules necessary).

Risk-reduction: small

Further effects

- Can be used also by maintenance staff.
- Impedes track maintenance.

Cost-effectiveness

New tunnels: poor; because of high investment and maintenance costs.

Existing tunnels: Not a realistic safety measure.

Conclusion from phase 1

The German and Spain safety concept prescribe road vehicles/drivable tracks in single track tunnels for evacuation reasons. Other guidelines mention the measure as "possibility" but not generally recommend it.

Recommendation

New Tunnels

- Not recommended in general. May be reasonable if access for road vehicles is part of a comprehensive intervention and rescue concept which bases on fire brigades. Not recommended, if the intervention strategy also bases on railway means.

Existing Tunnels

- Not feasible

I-63	Rescue areas at tunnel entrance or exits

General description and goal

Rescue areas are placed in the vicinity of tunnel entrances and emergency exits as the base for rescue operations.

Relevant aspects:

- Topography, settlement area, accessibility with road vehicles.
- Differences between new and existing tunnels.
- Rescue areas and all installations must be indicated on emergency plans (O-30).

Specifications

- The area at the entrances of *new tunnels* should include:
  - Access road to the area, drivable with fire fighting lorries, solid road surface, possibility for two vehicles to cross on the way.
  - Area of about 500 m^2, accessible for road vehicles.
  - Power supply, lighting, fixed provisions/installations for communication.
  - Possibility for water supply (on site or in the vicinity).
  - Defined helicopter landing area (20x20m) with road connection to the rescue area.
  - Access to the portal.
- The area at exits should include:
  - Access road to the area, drivable with fire fighting lorries, solid road surface, turning area, if not possible: Helicopter landing area.
  - Power supply, lighting, possibility for water supply (on site or in the vicinity).
- The area for existing *tunnels* should include
  - Access road to the area, drivable with heavy fire fighting lorries, turning area and/or defined helicopter landing area (20 x 20 m) as fahr as reasonably practicable.
  - Power supply, lighting, possibility for water supply (as far as reasonable practicable).
- Local possibilities have to be taken into account → optimisation.
- Existing roads, places and land area shall be integrated in the considerations.

Effects on safety

+ Rapid transport of rescue means to the portal, the area provides the base for rescue or fire fighting intervention.
+ Triage and first aid for injured people, organisation of further transport to hospitals.
+ Minimising time delay for rescue operation and evacuation.

Risk-reduction: samll-medium

Further effects

- Can be used also by maintenance staff.
- Rights to use areas and roads must be registered.

Cost-effectiveness

New tunnels: good; depending on situation, good ratio especially if the access is easy.

Existing tunnels: good; depending on situation, good ratio especially if the access is easy.

Conclusion from phase 1

Rescue areas are generally recommended, but design requirements differ largely (e.g. required surface).

Recommendation

New Tunnels

- Recommended as standard safety measure according specifications considering local possibilities.

Existing Tunnels

- Generally recommended under the following restriction: local topography and possibilities shall be taken into account for optimising.

I-64	Water supply (at access, in tunnel)

General description and goal

a) Continuous water main through the tunnel: permanently filled or dry pipe
b) Branch lines to tunnel entrances: portals, emergency exits: permanently filled or dry pipe

Relevant aspects

- Permanently filled or dry: depending on local situation.
- Usefulness depends on the general intervention concept: based on fire brigades (→ fixed installations preferable) or rail services (→ supply with tank wagons possible).
- Tunnel length and location are relevant: short tunnels may be provided by mobile means, location in mountain area may be far away of any water supply.
- Scenarios where a rapid and effective fire fighting is important: Fires in a very early stage, retarded ignition after a train accident (→ protection with foam), if possible to cool wagons in the construction to prevent further damages, etc.
- Course of events: depending on the local situation and the rescue concept, fire brigades will need about 15 to 45 Minutes to be on site. In that time the relevant actions of self rescue should already have taken place.

Specifications

- Supply of water pipe: pool, hydrant in the vicinity, connected to water supply system, other sources (e.g. river).
- Reserve of 100m3 at tunnel entrances if based on pools.
- Hydrants in the tunnel: every 250 m if there is a continuos pipe; at emergency exits, if supply is only through these exits.
- Filled or empty, depending on the local situation.
- Installed on one side of the track.
- Design should especially consider maintenance aspects.

Effects on safety

+ Saving time to start fire fighting
+ Depending on the scenarios: prevent ignition
+ Main effect: reduces damage to the construction
+ Strike down toxic gases
– Contact with electrical installation, especially the power line, if rules and procedures are not handled strictly
– Contact between water and certain chemicals can lead to violent reactions
– Time needed to fill a dry pipe

Risk-reduction: small

Further effects

- Maintenance costs (no other need for water in tunnels)
- Frost may damage permanently charged mains
- Frost, chalk, corrosion and other (small and hardly visible) damages can lead to a relevant reduction of effect

Cost-effectiveness

New tunnels: poor to medium

Existing tunnels: poor

Conclusion from phase 1

Looking at the guidelines, water supply in tunnels with water mains tend to become a standard.

I-64	Water supply (at access, in tunnel)

Recommendation

New Tunnels

Water supply as continuous pipe through the tunnel, or branch lines to portals and exits are recommended as standard. Alternative solutions with mobile railway means are adequate too, if they are based on "professional" rescue organisation (e.g. fire fighting and rescue train).

Existing Tunnels

If the intervention concept bases on railway means: mobile water supply is recommended (e.g. rescue train). If the concept bases on fire brigades: water supply to the tunnel entrances is recommended, e.g. mobile means by road, water reserves in the vicinity.

Additional equipment of an existing tunnel only in the course of a renewal.

I-65	Electrical supply for rescue services

General description and goal

Power supplies suitable for emergency services' equipment in tunnels.

Relevant aspects

- The electrical supply has to be protected against heat, water and mechanical damage (see I-67).
- The electrical supply helps the emergency services in handling an accident.
- Portable provision may be acceptable in short tunnels.

Specifications

- Distance between outlets: 125 – 250 m
- Ensure compatibility for rescue service and maintenance
- Location in niches, concentrated with other electrical installations and communication means
- Protected as indicated in I-67
- One or both sides of the track
- For short tunnels and/or existing tunnels: mobile means as alternative

Effects on safety

+ Enabling rescue services to use their equipment (e.g. water pumps, additional lighting). Rather in a second phase of an intervention when fire fighting actions take place or for a recovery phase

– May not serve primary in a first stage, when the life saving actions take place

Risk-reduction: small

Further effects

- Not only for safety reasons, also for maintenance

Cost-effectiveness

New tunnels: good; if integrated in a general concept of power supply, including maintenance purposes.

Existing tunnels: medium; if realised in the course of a renewal of a tunnel.

Conclusion from phase 1

Electrical supply for rescue services is general standard, differences exist in actual requirements (e.g. tunnel length, distances between outlets)

Recommendation

New tunnels

- Recommended to realise, integrated in a comprehensive concept of power supply and installations

Existing tunnels

- Recommended to upgrade existing tunnels in the course of a renewal of a tunnel, else to provide mobile means

I-66	Radio installation for rescue services

General description and goal

Ensure radio communication for emergency services in the tunnel between emergency services, operation centre, railway personal (in general: Own frequencies for rescue services).

Relevant aspects

- Communication is a central element of any intervention, high priority.
- Reliability and redundancy in case of accident.
- Alternatives to fixed radio installations are possible: mobile wire telephones, mobile radio net.
- Mobile phones (handy) are no alternative because of a rapid breakdown in case of accidents.

Specifications

- Channel with common frequency necessary.

Effects on safety

+ Rapid and adequate acting of emergency services.
– During big accidents like fire, break downs can not be excluded.

Risk-reduction: medium

Further effects

- Not only for safety reasons, also for maintenance.
- Strive for combination/synergies with train radio.

Cost-effectiveness

New tunnels: good.

Existing tunnels: medium; the cost–effectiveness of an upgrade depends on the specific situation.

Conclusion from phase 1

Radio installations for rescue services are a standard equipment.

Recommendation

New Tunnels

- Recommended as a standard measure.

Existing Tunnels

- Generally recommended, but depending on the specific situation, alternatives possible.

I-67	Reliability of electrical installations (fire resistance and autonomy)

General description and goal

Protection of equipment (technical components, wiring, cables) in tunnels against mechanical impact and heat/fire.

Relevant aspects

- Protection from mechanical impact and heat.
- Grade of protection depends on the function of the installation and the intervention/rescue concept.
- Optimisation and redundancy aspects.

Specifications

- Emergency lighting, communication systems, power supply (except overhead line): Availability for 60 minutes, independent supply by two sources, fire resistant cable covering or protected cable ducts. Alternative availability depending on the rescue/intervention concept (suitable spectrum from 30 – 90 minutes).
- Physical protection of cables against impacts from derailments or constructional works (optimal location of cables).
- Use of non-flammable/defined material concerning smoke emission (see I-24).

Effects on safety

+ Ensure rescue
+ Ensure functioning of vital safety installations (communication, lighting)
– Limited protection, does not cover any case

Risk-reduction: small

Further effects

-

Cost-effectiveness

New tunnels: good; applying these rules for a new construction is assumed as cost-effective

Existing tunnels: good; if realisation during renewal works.

Conclusion from phase 1

Guidelines recommend to protect vital supply lines for emergency installations against mechanical impacts and heat.

Recommendation

New Tunnels

- Recommended for new tunnels

Existing Tunnels

- Recommended in case of upgrading existing tunnels (renewal works)

I-68	TV monitoring (portals and tunnel)

General description and goal

The tunnel including the portals is equipped with a TV monitoring system.

Relevant aspects

- The information is transferred to the operation centre. It serves to identify irregularities in the tunnel and at portals (security) and to get information in case of accident.
- Equipment in the tunnel to manage an accident effectively from the operation centre.
- Space for installations, permanent lighting
- Security aspects: intervention concept for the case that irregularities are detected (e.g. people entering the tunnel)

Specifications

- Several cameras necessary to ensure adequate information from the tunnel
- Installations at portals (security)
- Monitoring equipment at operation centres

Effects on safety

+ In case of an accident, the operation centre has additional information to act adequately
+ Reduce vandalism
– Small information because of close space and poor lighting in tunnel
– Not suitable in case of smoke or other invisibility

Risk-reduction: small

Further effects

- High maintenance costs supposed, reliability.

Cost-effectiveness

Poor cost-effectiveness ratio

Conclusion from phase 1

In general not treated (is not a relevant issue)

Recommendation

New and existing tunnels

Not recommended as standard safety measure. For security reasons under defined conditions TV-monitoring of portal areas may be reasonable (e.g. close city areas, c.f. I-10, access control)

TV-monitoring inside tunnels is a system to control road traffic but not adequate for railway purposes.

I-69	Provision of rescue equipment

General description and goal

Provision of rescue equipment enables fire fighting in the tunnel.

Relevant aspects

- For any rescue action in tunnels breathing apparatus are inevitable (for long term use).

Specifications

- All responsible/involved rescue services are equipped with breathing apparatus to enable fire fighting in the tunnel.
- Rolling pallets are located at the tunnel entrances and at exits. Depending on the rescue concept further minimum equipment is located at entrances.

Effects on safety

+ Ensure safety of rescue services
+ Enable reconnaissance under smoke conditions
+ Rolling pallets: easier transport of material or injured people
– Rolling pallets: Small effect, restricted on specific situations (short tunnels, no other railway vehicles available).

Risk-reduction: small

Further effects

-

Cost-effectiveness

Good cost-effectiveness ratio can be assumed.

Conclusion from phase 1

A small set of specific equipment is recommended by several guidelines (e.g. rolling pallets).

Recommendation

New and existing tunnels

- The equipment of adequate breathing apparatus is a standard measure (prerequisite for an intervention).

I-70	Control System

General description and goal

Tunnels with large electromechanical installations shall be equipped with a centralised control system (tunnel centre).

Relevant aspects

- The task is to ensure and manage the correct functioning under normal and emergency conditions.
- Only for new tunnels with respective installations.
- In general very long tunnels with more than 15 km.
- Simplicity and reliability are of very high importance.

Specifications

- Control of: ventilation/smoke extraction system, lighting, communication means, power supply and all other safety systems, etc.
- Security measures like TV
- Eventually also operational tasks
- Professional staff/24h-operation

Effects on safety

+ In case of an accident, the staff of the control centre is able to take adequate actions: alarming rescue services and give first information to passengers and rescue services
+ To ensure optimal functioning, adapted to the respective accident situation

Risk-reduction: small

Further effects

- The centre can be integrated in a comprehensive management for the tunnel including operation, maintenance, safety and security (= tunnel operator)
- Regulation of competence between the tunnel operator and the infrastructure company of the tunnel

Cost-effectiveness

New tunnels: poor; not cost-effective by safety reason only.

Conclusion from phase 1

Control centres for (single) tunnels are exceptional solutions. Of course much of these functions are integrated in normal operation centres and therefore not specially mentioned in tunnel safety guidelines.

Recommendation

New Tunnels

- Control center specific for tunnels: Not recommended for new tunnels less than 15 km. It is reasonable to integrate these functions into ordinary operation centres which are also responsible for the stretches on the access to the tunnel.

Existing Tunnels

(For new tunnels only)

I-71	Rail vehicles for rescue (tunnel rescue train)

General description and goal

Railway vehicles for rescue purpose can be defined on different levels:

a) Provision of railcars to carry rescue vehicles and tank wagons for water supply. Fire brigades load their vehicles on the railcar and are transported by a locomotive or tractor.

b) Special rescue unit/train: rescue train for rapid transport of staff and equipment. The train is specially built for intervention and serves as transport means, bases for fire fighting, medical first aid, transport of injured people and for communication. The staff is composed of railway staff and local fire brigades.

Relevant aspects

- a) Can be considered as minimal transport means
- b) Rescue concept bases primary on railway means, need for railway rescue services
- b) Sound concept for localisation of rescue trains (optimal network) IS necessary, picket element and rapid alarm organisation
- b) Balanced concept between fixed installations for intervention and mobile means (e.g. water supply)

Specifications

-

Effects on safety

+ a) Heavy means can be transported to the accident place, including water for fire fighting
+ a) Possibility to evacuate a greater number of people (injured or not)
– a) and b) In general, trains must be placed on strategic stations with an adequate number of railway staff, therefore it needs some travelling time to reach the tunnel
– a) and b) In case of a big accident (e.g. large evacuation or long duration of fire fighting) the capacity is not sufficient
– b) Time consuming procedures until means are loaded, not suitable for larger accidents, poor effect

Risk-reduction: medium

Further effects

- Can be used for accidents and fires in several tunnels and also on the open stretch
- High staff costs, if continuous standby is required
- Nevertheless co-operation with rescue services is necessary

Cost-effectiveness

Good; if the railway means are part of a comprehensive concept (e.g. network of locations).

Conclusion from phase 1

Several different concepts based on railway means are used: permanent rescue vehicles/trains, auxiliary vehicles for rescue purposes, rail and road vehicles combined. National organisation of the rescue system is generally decisive.

Recommendation

New and existing tunnels

- a) Recommended if it is part of a comprehensive rescue concept, which includes alternative ways to get on the accident place in the tunnel (e.g. through exits) or if it is a single tunnel in a lower risk class.
- b) Recommended if it is part of a comprehensive rescue concept, which bases primary on railway means for rescue

I-72	Rail/Road vehicles for rescue

General description and goal

The responsible fire brigades are provided with rail/road vehicles which are able to run on track for rapid transport of staff and equipment to the accident place. The main goals are interception, support of self rescue, first aid and first fire fighting actions.

Relevant aspects

- Intervention concept for rescue services based on fire brigades.
- Appropriate fire brigades must be in the vicinity of the tunnels (preferably professional fire brigades)
- Accessibility of tunnel portals for road vehicles and possibility to put them on track
- Rules and procedures to run on track are necessary (railway staff on site)
- For larger accidents and fire fighting, additional means are necessary (fixed installations or railway means)

Specifications

-

Effects on safety

+ Fire brigades are rapidly on site to decide on the optimal intervention strategy, for first aid and first fire fighting actions
– The rail/road vehicle is not sufficient for a larger intervention: if additional means are transported by rail the road/rail vehicles blocks the way
– Creates new risks if the rules and procedures to use the track are not followed strictly.

Risk-reduction: small

Further effects

- Can also be used for accident and fires on open stretch

Cost-effectiveness

Good; balanced cost/effectiveness ratio can be assumed, if road/rail vehicles are part of a comprehensive rescue concept, which bases on fire brigades.

Conclusion from phase 1

Rail/road vehicles are mentioned under special conditions.

Recommendation

New and existing tunnels

Only recommended if road/rail vehicles are part of a comprehensive rescue concept which bases on fire brigades.

A3 Rolling stock

Preliminary remarks:

Communication systems within the train and from the train to the operation center are treated under I-2 (train radio).

R-1	Fire protecting measures (fire load, prevent fire spreading)
General description and goal a) Constructive measures/vehicle design to prevent outbreak and spread of fire. b) Avoiding the use of materials which produce toxic substances/large amount of smoke in case of fire.	
Relevant aspects • Ensure that these aspects are integrated in specifications for new coaches and if coaches are renewed. • Integrate the aspect of fire protection in future specifications. For existing coaches the scope is limited (renewal) • Define common standards for measuring and defining toxicity • In the period of outbreak and spread of fire it is still possible for passengers to escape; this possibility should not be further reduced by excessive smoke and toxic fumes from the burning material. Materials should therefore be selected with this in mind. • The material choice does not only depend on safety, but also on passenger comfort, weight, internal fitting etc. • The quality of maintenance and inspection of the rolling stock have an influence on the effectiveness of a) and b).	
Specifications • Reduction of the fire load; separation (compartment-type construction with interconnecting doors constructed as fire doors); use of fire-resistant materials; replacing-flammable by hardly-flammable material; introducing fire-resistant layers inside seats although these increase the fire load.	
Effects on safety + Preventing or reducing rapid spread of fires in vehicles (enables to drive out the tunnel or gives more time for a successful self rescue) + In case of fire it reduces the toxic effect of smoke – Fire resistant materials will burn as well, but it needs more energy for ignition. Risk-reduction: medium	
Further effects • The material/design choice has also to regard stability to derailments or crashes	
Cost-effectiveness Good cost-effectiveness ration can be assumed for new coaches.	
Conclusion from phase 1 Some documents postulate min. standards, but contain no detailed specification.	
Recommendation **New and existing tunnels** It is recommended to emphasise and integrate the aspect of fire safety in the specifications for new rolling stock and also to ensure that it is taken into account for renewals of coaches.	

R-2	Onboard fire detection (traction units and/or coaches)

General description and goal

a) Automatic fire detection on traction units to discover fires at an early stage (with notification to the driver)

b) Automatic fire detection on coaches to discover fires at an early stage (with notification to the driver)

Relevant aspects

- Different possibilities for location of detectors in coaches: technical compartment (electrical installations, air conditioning), passenger compartment, sleeping cars, restaurant car
- The most frequent location of fires: 1. traction unit, 2. technical compartments, 3. special utilisation like restaurant car, sleeping car, toilets, 4. passenger compartment

Specifications

-

Effects on safety

+ The train driver is able to act more adequate: stop before entering a tunnel or try to leave the tunnel
+ Gives the possibility to start fire-fighting with less delay (not only in tunnel)
+ Operation centre and rescue services can be alarmed in an early stage of a fire
– Frequent false alarms reduce the confidence into the measure (e.g. false alarm of rescue services too)

Risk-reduction: small

Further effects

- Aspect of false alarm (also provoked false alarm especially with detectors in passenger compartments), which leads to operational disturbances.

Cost-effectiveness

a) Good; for traction units (limited number of installations)

b) Poor; for passenger coaches (large number of installations, less effect, more false alarms)

Conclusion from phase 1

Recommended under specific conditions for traction units.

Recommendation

New and existing tunnels

a) Recommended for traction units

b) Not recommended for passenger coaches in general. To be considered for technical installations in separate compartements.

R-10	Derailment indicators on train

General description and goal

Automatic derailment detectors on the train/on coaches to detect derailed axles.

Relevant aspects

- Possible technical solutions: e.g. simple solution based on a measurement of acceleration or measurement of multiple parameters in order to detect irregularities before a derailment.
- Type and number of wagons to be equipped: e.g. tank wagons for dangerous goods, high speed trains.
- Looking at the large number and different types of wagons a complete equipment is not realistic.

Specifications

-

Effects on safety

+ Depending on the system: prevent a derailment, caused by a rolling stock failure or at least detect the derailment in a early stage in order to stop the train immediately (e.g. not to drive over switches).
– False alarms are possible and lowers the effectiveness of such indicators considerably.
– The effectiveness sinks if only part of the carriages are equipped.

Risk-reduction: If all cars are equipped; medium-high effect on derailment risks (dependent on the capabilities of the system).

Further effects

- It is not a tunnel specific safety measure, main effect will be on open stretch.

Cost-effectiveness

Poor; under the point of view of tunnel safety only.

Medium-good; considering also effects on open stretch and supposing that only specific wagons or trains are equipped (e.g. tank wagons and high speed trains) the cost effectiveness can be assumed as balanced or even favourable.

Conclusion from phase 1

No issue in current regulations. Derailment is not a problem specific to tunnels.

Recommendation

New and existing tunnels

General strategy/priorities:

a) Recommended for new trains like TGV, ICE etc.
b) Existing rolling stock: recommended for certain types/conditions like transportation of dangerous goods but not as standard measure for all cars.

These principles are based on the consideration, that the measure has an effect on the whole network and not only in tunnels.

R-11	a) Emergency brake neutralisation b) Maintaining the movement capability

General description and goal

a) Neutralisation of emergency braking 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 comprehends adequate design and materials for the body in order keep stability and shape and vehicle design to reduce sensitivity of electrical wiring for train control (optimal location, fire resistance).

Relevant aspects

- General concept in case of train fires: leave the tunnel whenever possible (except very long tunnels).
- Different technical systems for the neutralisation of emergency braking are possible (by-pass braking or alarm system to the cab).
- International traffic .
- Compatibility requirements for electrical wiring.
- Agreement and definition under what condition, e.g. tunnel length, a 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 case of fire, a train should be able to leave a tunnel even if the signal is showing a red light).

Specifications

- Different technical systems for emergency braking are possible:

- The braking is activated and the driver has to deactivate it.
- The activation of the braking leads to a sign in the cab and the driver has to decide about a braking.

Effects on safety

+ Increases the probability that in case of fire, a passenger train can leave the tunnel.
+ In the open, there are better rescue possibilities.
– sudden running gear failure, derailment, or other emergency: the train cannot be stopped by an emergency braking in the tunnel.
– no influence on fires in the traction unit.
– If the braking is activated immediately, the train may stop even if the driver deactivates it instantly (e.g. if train speed is low).

Risk-reduction: 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.

Conclusion from phase 1

Neutralisation of emergency braking in tunnels and a running capability of 15 minutes under fire conditions form a common basis. But there is not a common definition of the tunnel length, where neutralisation of emergency braking is required.

Recommendation

New and existing tunnels

General strategy/priorities:

a) Minimum standard: Sign near emergency brake ("do not use the emergency brake in case of fire ...").
b) Introduction of neutralisation of emergency brake is recommended.
c) As a long term goal, the emergency brake should be replaced by a communication system.

R-12	Onboard fire extinguishing equipment (traction units and/or coaches)

General description and goal

a) Portable fire extinguishers on traction units and in coaches. (see UIC Leaflet 564-2). The use of more effective extinguishing agents would improve extinguishing performance, reliability and ease of use.

b) Automatic or manually-operated extinguishing systems on traction units (e.g. sprinklers for defined compartments).

c) Automatic fire-extinguishing systems in coaches (technical compartments, passenger compartments).

Relevant aspects

- Location of a fire: 1. traction unit, 2. Technical compartments, 3. special utilisation like board restaurant, sleeping car, toilets, 4. passenger compartment (→priorities).
- Regional or international traffic, urban or suburban traffic (especially in the case of c).
- Portable fire extinguishers can be handled by everybody in the train.

Specifications

-

Effects on safety

+ Rapid fire fighting is possible in a very early stage (not only in tunnels).
– False alarms may lead to a train stop and provoke new risks (e.g. people leaving the train) and operational disturbances.
– Limits of functioning: in a fire caused by a train accident, the fire extinguishing system can be damaged too, not all places and fire sources in a train can be monitored, (long term) reliability of the system.

Risk-reduction: medium

Further effects

- High installation and maintenance costs considering c) with a large number of concerned.
- Management of a large number of coaches with automatic extinguishing systems.
- Aspect of false alarm and sprinkling especially in case of c).
- A very quick and efficient extinguishing system on the train may also influence the whole fire fighting and rescue concept: less safety provisions in this part could be the consequence.

Cost-effectiveness

a) Portable extinguishers: good cost-effectiveness ratio

b) Automatic system in traction units: good for new units

c) As a generally introduced measure: poor.

Conclusion from phase 1

Portable fire extinguishers are a general standard. Automatic systems are mentioned only for traction units.

Recommendation

New and existing tunnels

a) Portable fire extinguishers on traction units and coaches: Recommended as a standard measure, ensure proper functioning and improve the effectiveness.

b) Automatic or manually-operated extinguishing systems on traction units: Recommended for new traction units and defined mechanical or electrical components which are operated in large tunnel networks (especially very long tunnels).

c) Automatic fire extinguishing systems in coaches: Not recommended as installations for all coaches. May be a reasonable solution under defined conditions like: closed network, operation with fix compositions (typically commuter trains).

R-13	Central control of air conditioning
General description and goal Central facility for switching off air-conditioning in an emergency to slow down the spread of fire and smoke in the coaches.	
Relevant aspects • Technical possibilities to solve the problem for existing and new coaches/trains.	
Specifications -	
Effects on safety + Slow down the spread of fire and smoke in the coaches. + Prevent or reduce the penetration of smoke or toxic gases from outside the coach. Risk-reduction: small	
Further effects • Loss of passenger comfort in case of false alarm	
Cost-effectiveness Good; for new coaches. For existing rolling stock it is depending on possible technical solutions.	
Conclusion from phase 1 -	
Recommendation **New and existing tunnels** The safety measure is recommended as reasonable	

R-14	Ability to split trains

General description and goal

The evacuation bases on the concept, that passengers move in the intact part of a train and that this part is split and moved out with a traction unit.

Relevant aspects

- The splitting is supported/prepared/automated by technical measures (e.g. special coupling).
- Scenarios, where the splitting has an effect (positive and negative), especially fire scenarios.

Specifications

-

Effects on safety

+ Under certain conditions (specific scenarios) it can be very effective.
+ May be suitable in case of a fire in a goods train, in order to pull out the intact part of the train.
  - Depending on the fire scenario (location of the fire), a greater part of passengers can't move in the intact part of the train.
  - If the splitting fails (technical problems, unable to split the train manually, power failure), no effect or even worse (time lost).
  - If the traction unit to pull out the train comes from outside the tunnel (=rescue vehicle), large time delay would be the consequence.

Risk-reduction: small

Further effects

- If splitting is supported by a technical solution, all cars of a train passing the tunnel must be equipped.

Cost-effectiveness

Poor; as the effect is rather questionable and a technical solution would be rather expensive, cost-effectiveness must be assumed as unfavourable.

Conclusion from phase 1

Only one indication to that item: it may be a questionable measure and it is problematic to carry out for relevant scenarios (e.g. fire and smoke conditions).

Recommendation

New and existing tunnels

Not recommended as a general concept. It may be adequate in a specific situation, but the decision to split and pull out the train must be taken in the specific situation.

R-15	First aid equipment on board
General description and goal Each train is equipped with at least one First Aid Box. First aid in case of a (small) accident is immediately possible.	
Relevant aspects • The box must be located on a place which is easily accessible for the train staff but secure enough for vandalism. • Not a specific for tunnel safety measure	
Specifications -	
Effects on safety + First aid for small injuries (not only in tunnel) – No effect in large accidents (in that case, the train staff will have other tasks) Risk-reduction: poor.	
Further effects • The box needs to be checked and filled regularly	
Cost-effectiveness medium; Low cost, low effect	
Conclusion from phase 1 Not a safety measure specific for tunnels.	
Recommendation **New and existing Tunnels** Recommended as general safety measure (not only tunnel safety).	

R-20	Escape equipment and design of coaches (including access for rescue services)

General description and goal

a) Escape equipment: the train crew is equipped with megaphones for communication and lamps to be able to inform passengers in case of evacuation also outside the train.

b) Escape design: the coaches (doors, windows, shell) are designed with defined emergency exits/accesses. The respective places are visible/indicated for passengers and rescue services.

Relevant aspects

- a) Megaphones and lamps must be located on a place which is easily accessible for the train staff
- b) Integrate the aspect of escape design in future specifications. For existing coaches the scope is limited (indicate emergency exits)
- b) Equipment of rescue services with adequate tools to open the body or windows in case of emergency

Specifications

-

Effects on safety

+ a) Facilitates a guided self rescue (advice to passengers)
+ b) Facilitates an evacuation of the train after a derailment/collision
+ b) An optimised escape design has also an effect on open stretches
– a) In case of emergency the train staff has to carry out a lot of different tasks: probably it will not have the time to get and search that equipment.

Risk-reduction: small

Further effects

The megaphones and lamps need to be checked regularly

Cost-effectiveness

a) Medium; "low cost, low effect" (balanced ratio)
b) Good, if part of further specifications

Conclusion from phase 1

Different aspects are mentioned but no clear standard or concept is visible. Is not a safety measure specific for tunnels.

Recommendation

New and existing Tunnels

a) Recommended as suitable

b) It is recommended to integrate the aspect of emergency exits/accesses in further specifications for coaches (but it is not a tunnel specific issue)

A4 Operation

O-1	Regulations for operation (especially passenger/freight train)

General description and goal

Restrictions on the encountering of trains (especially passenger and freight trains) in tunnels is prevented by an optimised timetable.

Relevant aspects

- Traffic density (→ possibility to define time windows)
- Percentage of goods and passenger trains (mix)
- Day and night operation of passenger and freight trains (separated)
- Train speed (aspect of aerodynamic influences)
- Double or single track tunnels
- Is the tunnel a single object or is it part of a network of further tunnels (e.g. several tunnel in a chain, which is more difficult to manage)
- In some situations, it might be necessary to exclude certain types of vehicles on certain types of routes (e.g. old rolling stock on lines with long tunnels)

Specifications

Timetables are designed the way that there is no (or minimum number of) planned encountering.

Effects on safety

+ Elimination or reduction of accidents involving two trains, especially passenger and freight trains (with dangerous goods): collisions, collisions after a derailment, fires (especially large fires with dangerous goods).

– If e.g. goods trains are diverted on routes without tunnels the accident frequency may increase (longer way, new risks like level crossings).

Risk-reduction: medium

Further effects

- Reduces the productivity especially for freight traffic due to
- restricted utilisation of the sections of route concerned,
- provision of additional sidings in marshalling yards (in order to stop/regulate goods traffic).

Cost-effectiveness

The cost-effectiveness can vary strongly depending on the actual situation (see relevant parameters and considerations)

Conclusion from phase 1

Several documents do formulate rules for mixed traffic, depending on defined conditions, but there is no common consensus.

Recommendation

New and existing Tunnels

Not recommended as standard measure, but only for high risk tunnels, and if operational conditions do allow it (optimise operation under safety considerations).

O-2	Regulations for transportation of dangerous goods

General description and goal

Restrictions on the passing of passenger and freight trains with dangerous goods in tunnels (similar to O-1):

a) dangerous goods in general (including single loads or cars in a goods train)

b) block trains with dangerous goods only

Relevant aspects

- A general restriction of dangerous goods (a) means in practice, that all goods trains are concerned. To sort out single loads or cars with dangerous goods is therefore hardly practicable.
- The same relevant parameters and considerations as for O-1 can be applied.

Specifications

-

Effects on safety

+ Elimination or reduction of accidents involving passenger and freight trains with dangerous goods: especially very large consequences because of fire or toxic releases are prevented. It is a safety measure to reduce catastrophic risk.
+ Large fires with dangerous goods can also cause relevant damages to the tunnel construction. Special aspect: under sea tunnels and tunnels closely under built area.
– If goods trains with dangerous goods (especially block trains) are diverted on routes without tunnels, risks on these routes may increase if the line passes through densely populated area, lines with a lower track standard, or sensitive environment (ground water, surface water).

Risk-reduction: small to medium (depending on fraction of dangerous goods)

Further effects

- See O-1
- If only block trains are concerned (b) the operational restrictions are less severe, because of the limited number of such trains

Cost-effectiveness

For a) poor

For b) medium; the cost-effectiveness may be balanced

Conclusion from phase 1

If restrictions are valid for freight trains they also apply for dangerous goods, see O-1 (a clear separation of freight trains with and without dangerous goods is hardly practicable.

Recommendation

New and existing Tunnels

Recommended for high risk tunnels, if operational conditions do allow it (optimise operation under safety considerations).

O-10	Stop following or encountering trains (out of the tunnel) in case of incident

General description and goal

Stop following/encountering trains out of the tunnel as soon as there is an information on an incident in the tunnel. The measure applies mainly for double track tunnels.

Relevant aspects

- Minimal tunnel length is necessary.
- Double or single track tube (different procedures).
- Existing train protection system.
- In order to operate the measure, adequate communication means and stop signals near the tunnel portals are necessary.
- Rules are necessary to handle the measure in order to limit false stops.

Specifications

-

Effects on safety

+ Prevent or reduce the frequency of multiple train accidents: reduce catastrophic consequences (especially under fire conditions, smoke spread).

Risk-reduction: small

Further effects

- For two single track tubes and tunnels with more than 15 km additional or other procedures may be necessary.

Cost-effectiveness

Good cost-effectiveness ration

Conclusion from phase 1

Required by several guidelines.

Recommendation

New and existing Tunnels

- Realise the measure, and set signals considering also this aspect optimal.

O-20	Emergency information for passengers (preparation for emergencies)
General description and goal Passengers are informed about the behaviour in case of emergency with special emphasis on incidents in tunnels.	
Relevant aspects • It should have a relevant number/length of tunnels in the concerned rail net • Language and form of such an information • Simplicity of information • Integrate in general safety campaigns • Repetition, continuity	
Specifications • Means are: Posters, leaflets, spots, onboard TV.	
Effects on safety + Passengers that have read/heard the information, may act better in case of an incident, not only in tunnels. – The information can provoke a feelings of anger and insecurity. Risk-reduction: small	
Further effects • Similar information is already spread for traffic in road tunnels (people are familiar to hear/read about safety in tunnels) • Campaigns should be carried out by professional communication specialists, because it is a delicate issue	
Cost-effectiveness Good cost-effectiveness ratio is assumed	
Conclusion from phase 1 Not yet a commonly applied measure (only single examples).	
Recommendation **New Tunnels and existing tunnels** • Realise	

O-21	Training of train crew

General description and goal

The crew of all train operators is regularly trained for the prevention and handling of incidents in tunnels: verify an incident, report to the operation center, decision making, first rescue/fire fighting actions, trigger self rescue etc.

Relevant aspects

- Different operating companies
- Knowledge in different languages
- Important part of training is prevention of incidents (e.g. checking train for smoke, fire before entering a long tunnel in night trains)

Specifications

- Checklists

Effects on safety

+ Accidents in tunnels can be very time critical. A rapid and correct action of train crew is very essential to reduce risks: e.g. that people misleadingly leave the train or stay in train if a evacuation is necessary
+ A good training has also a positive effect on safety out of tunnels
– Wrong decisions can not be prevented

Risk-reduction: small (or medium, depending on intensity of training)

Further effects

-

Cost-effectiveness

Good cost-effectiveness ratio is assumed

Conclusion from phase 1

Clearly recommended/required by several standards (estimated as important organisational measure)

Recommendation

New Tunnels and existing Tunnels

- Is an accepted standard measure, should be intensified and ensured that all staff/operators is trained

O-30	Emergency and rescue plans

General description and goal

Preparation of emergency plans that consist of:
- Strategy for dealing with critical events
- Emergency call-out plans
- Tunnel-specific plans for rescue services

Relevant aspects

- Rescue plans: tunnel-design, access- and escape routes, rescue areas, control-system, ventilation-system, track drainage system, communication-system in the tunnel, electrical installation, water supply, earthing device, access-control, special equipment etc.
- On paper or/and computer basis
- All services involved should have the (same) information
- Details may vary, depending on the rescue service organisation in a country/region

Specifications

-

Effects on safety

+ Guarantee a proper intervention
+ Minimising time delays for intervention (e.g. knowing the fastest way to an entrance)
– No plan can cover the multitude of possible occurrences right down to the last detail

Risk-reduction: medium

Further effects

- Reasonable not only for tunnels, has a general positive effect

Cost-effectiveness

Good cost-effectiveness ratio is assumed

Conclusion from phase 1

Generally required safety measure (basis for rescue service actions)

Recommendation

New Tunnels and existing Tunnels

- Recommended as a standard measure

O-31	Exercises with rescue services (communication and co-ordination railway/rescue service)

General description and goal

Exercises for tunnel accidents with all rescue services: to exercise the teamwork between rail and other rescue services, to get used with tunnel and railway specific conditions.

Relevant aspects

- As tunnel accidents may have large consequences, such exercises should also be carried out in "large scale" (e.g. regional forces and staffs, problematic of communication with mass media).
- Exercises need a good preparation and evaluation, reports should be spread more intensely (interested organisations, railways).
- Integrated approach is important, including information and communication.

Specifications

-

Effects on safety

+ To maximise the effectiveness of rescue services, reduce time delays for rescue operations under hard and difficult conditions.

– No exercise can cover the multitude of possible occurrences right down to the last detail.

Risk-reduction: medium

Further effects

- Reasonable not only for tunnels, has a general positive effect.
- Large scale exercises may lead to operational restrictions.

Cost-effectiveness

Good cost-effectiveness ratio is assumed.

Conclusion from phase 1

Recommended by several standards.

Recommendation

New Tunnels and existing Tunnels

- Recommended as a standard measure.

O-32	Information on the transport of dangerous goods

General description and goal

a) Notification of movements of exceptionally dangerous goods (to be defined, e.g. chlorine, propane, vinyl chlorine) to inform concerned rescue services along the route to be prepared in case of emergency and to be able to take the right actions in time (e.g. evacuations).

b) Information system, that allows to identify rapidly the involved loads in case of an accident, in order to take the right precautions and actions for intervention (precise and rapidly accessible database).

Relevant aspects

- For a): relevant goods must be defined on an international level (e.g. fixed in RID regulations), rules to pass the information to the responsible operation centres and rescue services must also be implemented.
- For b): information is available in general already today by train numbers and freight information, but it may not be available in the required time and precision.

Specifications

-

Effects on safety

+ Reduce time delays for rescue operations in case of an accident with dangerous good, take the right actions and precautions.
+ Reduce risk for rescue services.
– False or unclear information can worse the consequences.

Risk-reduction : small

Further effects

- The measure would have its main effect on open stretches.
- Implies complex organisational procedures.
- Technological development in the field of telematics opens new ways for geographical localisation and data transfer.

Cost-effectiveness

Poor: Under the point of view that such measures are introduced for tunnel safety only.

Conclusion from phase 1

Not a tunnel-specific safety measure. If introduced, it is first required for accidents outside tunnels (e.g. toxic gas releases in populated areas).

Recommendation

New Tunnels and existing tunnels

- Reasonable as general safety measure, if information concerning the transportation of dangerous goods is improved, but not recommend as tunnel specific safety measure.
