IRSC 2009 Bårstad Sweden, Lloyd's Register Rail Europe, Gert Timmer, Reader Text

Managing Tunnel Safety with changing Legislation and Regulations

How to apply the TSI-SRT as a skilled safety engineer?

Introduction

Congresses have been held and numerous study reports on tunnel incidents have appeared in the past two decades, so one might expect that tunnel safety is now a clear cut issue and should not pose major problems in design, construction or exploitation.
But recent incidents show that a non-foreseen sequence of events or a cause-consequence analysis that was considered a negligible risk, did happen and has caused casualties.

In a world of changing and ever again updated safety requirements for tunnels, the recent TSI-SRT (Safety in Railway Tunnels) [1] is a new one, specifically aimed at the railway world and it is the result of consensus between international railroad tunnel experts. Thereby it is judged by some as the maximum level of safety needed. Others regard it as a starting base for further improvement. Few people judge this TSI-SRT as a serious degradation of yearlong efforts to achieve a high level of safety, sometimes achieved at high cost, both in casualties and financial investments.
Each of these judging parties can provide evidence for their particular views, but all three are ignoring a key issue.

The TSI-SRT has been analysed for its weaknesses and strongpoints.
The results of the safety testing conducted during the design of the Betuweroute in the Netherlands are used to develop a key issue to compensate for the weakness of the TSI-SRT in the design phase of a tunnel project.
Its strongpoints will be emphasized and could be exploited by the railroad world in the future.

The TSI-SRT in relation to current tunnel building practice and tunnel operation

The TSI-SRT is in effect as per July1st 2008 and provides in its Annex a checklist what has to be done to achieve the "minimum" level of safety in cohesion with the other already published TSI's.
Two aspects of its contents deserve special attention:

- It requires for close co-operation with a non-railroad authority, i.e. the fire brigade.
- The TSI requires for approval of the tunnel by a Railroad Notified Body, in which it deviates from the current practice of tunnel building in most countries.

The TSI-SRT provides a "limited" view to tunnel safety as it was prepared from the railway perspective and introduces only one indispensable party if things go wrong, i.e. the fire brigade.
But building practice, laws and regulations which apply to tunnel-building, such as the geotechnical structure of the tunnel surroundings, the civil construction, the building process and its safety and health aspects, the environmental laws an its implications and permits are not mentioned in the TSI-SRT.
Just the need for a safety management system for the railroad operator and infrastructure provider, the need for operational safety procedures and associated personnel training and the need for

disaster preparedness by regular training are addressed, but without much details.

Those who regard the TSI-SRT as the maximum safety level to be provided with the intention to reduce cost as much as possible, clearly forget the existing law and regulations, which do apply to tunnel building, although they deviate over the various countries.
Those who regard the TSI-SRT as a starting base, face a challenge when attempting to integrate all, sometimes conflicting, requirements.
Those who regard the TSI as detrimental to the safety level already achieved should take into consideration that EC-Directives never require for the reduction of "established" levels of safety as a consequence of newly published EC-regulations.

When trying to use the TSI-SRT as the answer to solve outstanding safety debates or discussions on the merits of particular technical safety solutions, one can only conclude that the TSI-SRT is written by experts for experts and is not intended as a handbook to solve safety discussions among experts.

All tunnel incidents from the past decades have been intensively studied and numerous reports and even complete tunnel design handbooks have been published, The civil tunnel constructions show a clear results of these analyses. Double bore tunnels are standard for most projects and the concrete tunnel lining is often protected by a heat-resistant coating.

There is far less evidence that the tunnel installations benefit from all these studies and reports. The debate on the positive or negative aspects of sprinklers is still ongoing and often results in political debates without knowledge of simple technical facts, which are available for more then 100 years.
Hundreds of reports have been published on smoke and heat control in tunnels supported by extensive CFD-analysis, but a clear cut ventilation solution for a particular tunnel construction is seldom found. The reason for safety solutions of limited value is definitely not a lack of knowledge or skills!

The hidden cause for a low overall safety level in a tunnel is often that a tunnel project including the tunnel installations is contracted with a civil engineering company at fixed cost. In the daily practice the civil construction work faces practical problems, which often absorb more then the allocated budget. Overall project cost however remains fixed and the tunnel installations then have to be redesigned by the subcontractor at a lower cost level, which either results in a reduction of the overall safety level or a shift of the cost allocation from the investment budget to the maintenance budget.
The Project Director for the Betuweroute of the Dutch Ministry of Transport, Mr. Leendert Bouter proposed a solution in his retirement interview with the Dutch Society of Engineers (KIVI), in brief: "A tunnel should be contracted with the installation contractor and not with the civil engineering company to assure that the intended safety level is actually delivered".
The challenge is set, but up to know this solution has not been tried anywhere.

What is the practical value of the TSI-SRT in the changing world of tunnel safety requirements?

On its own, one might conclude that the TSI-SRT is of limited value (referring to all omissions mentioned above) but in conjunction with the existing TSI's and existing law and regulations it is a valuable and powerful tool for a skilled tunnel engineer, determined to deliver a safe tunnel,
Please keep in mind that existing law and regulations do not have to be duplicated in a TSI , as a TSI is a Technical Specification for Interoperability and neither a law, nor legislation or a normalisation document.

Two examples:

- new laws have been put in effect in several countries requiring companies to apply safety regulations to the full extend and making the company liable even when the responsible director has not performed personally any illegal actions. Austria introduced such legislation in 2003, Switzerland in 2006 and Great Britain in 2008 (the Corporate Manslaughter Act).[2] Thereby a reference in the TSI-SRT that a railroad company must have a safety management system in operation is sufficient.
- Reference is made to the other applicable TSI's, such as the TSI-Command Control Systems [3], requiring for a systematic hazard analysis and associated risk mitigation as per EN50126, which is easily applied to a tunnel complex using the available tunnel incident analysis reports worldwide available. A tolerable hazard rate for a passenger passing a tunnel can be determined using the methodology as specified in EN50129 and the software for the control of the tunnel installations should of course meet the requirements of EN50128 as the railroad safety systems and the tunnel safety systems are interconnected at certain interface points. So there is no need to identify in the TSI-SRT specific requirements for tolerable hazard rates related to tunnel safety. The tools are available to match the safety of a railroad tunnel with standard railway practice and particular national practice and regulations.

The TSI-SRT has limited value in tunnel building preparation

Going through the details of the TSI-SRT reveals that its value lies in the commissioning and operational phase, not in the building preparation phase. It defines which systems should be present to safeguard operation, not how these systems should be built or integrated, or which capacities these systems should have.

As the TSI-SRT does not provide the ultimate answers we need:

- how do we assure that safety is addressed at the early start of tunnel building preparation?
- how do we assure that safety is not seen as the primary cost driving factor or as the main control valve to keep construction cost down?
- how do we make use of all the data that has emerged from tunnel accident investigations to reduce the chance that certain disastrous events happen again?

This brings us to the key issue for controlling safety as identified in the introduction, using the experience gained in preparing the tunnel installations design for the five tunnels of the Betuweroute.

Development of the key issue driving tunnel safety design

The decision in the initial phase of the Betuweroute project was made that for risk reduction on the existing railroad system through the villages it was required necessary that LPG tank wagons and dangerous goods should be allowed to pass through the tunnels.
In consequence two major threat scenarios were developed in close co-operation with the fire brigades along the dedicated Betuweroute cargo rail line. One major threat scenario was a BLEVE (Boiling Liquid Expanding Vapour Explosion).

The other major threat scenario was a floor fire in the tunnel from liquid hydrocarbons leaking from a tankwagon. The protective measures defined were either a sprinkler or protective fire-resistant lining. The outcome of the scenario analysis between all parties was written down as a technical guideline. But the technical guideline was made part of the building permit by pressure from the fire brigades, introducing completely new safety requirements after the Betuweroute budget had been frozen by Dutch Parliament.

At the start of the design phase it was determined that there was insufficient technical data available as nobody had ever build a sprinkler into a railroad tunnel. Therefore it was decided that research would have to be conducted to determine how to implement these new regulations.

- Fire research (> 20 MW) was conducted to determine the actual sprinkler delivery capacity to allow for the protection of the concrete tunnel lining against “spalling” by means of the “back-throw” of the sprinkler heads.
- The design of the drainage system was optimised using knowledge from the oil refinery industry and insurance companies
- Fire tests with heptane were conducted to determine if AFFF (Aqueous Film Forming Foam) mixed in the sprinkler water would effectively prevent fire spread in the drainage canals and (spilled) water reservoirs.
- Tests were executed in existing tunnels with smoke transport by ventilator force and actual wind pressure
- Fire tests were made to validate the performance of fire detectors of several types from several companies.
- Life water spraying tests on powered high voltage catenary systems were performed to determine if sprinkler water would cause short circuits if the control system had failed to switch off the catenary in time. The secondary target was to verify which standard and special water appliances could be safely used by the fire brigades to avoid electrocution in a high voltage environment.

Research provided the information to counteract the knowledge deficit resulting from the new safety regulations but it was not priceless, neither the research nor the project progress!
Calculating the cost to implement all research results required also the development of the arguments needed to get the necessary budget increase in the public debate that would inevitably follow.
Saving lives was not an argument as the driver would have left the tunnel immediately and the fire brigade would not enter the tunnel, as they would operate the sprinkler “by joystick”.
A reference in a newspaper was the clue when it described the damage to the local economy in the Aosta valley in Italy after the tunnel closure in consequence of the Mont Blanc disaster. An amount in excess of € 1.000.000.000 . was calculated for the closing period of more then a year.
It was clear to the design team that this aspect of damage to the (local) economy was one of the key driving forces for the need to take appropriate measures, as the classic return on investment calculations did not provide adequate answers.
The fire threat was real and was clearly shown by the Channel tunnel fire in 1996. Especially after the civil construction department calculated that a bored tunnel in the soft soil of the Netherlands would collapse after a loss of 20 cm of its 40 cm thick concrete lining. In comparison the Channel Tunnel lost 39 cm of its 40 cm concrete lining in the first fire event, but did not collapse as it was supported by the lime stone surrounding it.
At that time the idea of using the economic damage as an argument for safety measures was not further developed as the need for the sprinkler was decided about in a public debate between

mayors and the Cabinet and the sprinkler requirement was maintained.

Applying the knowledge gained in the research for the design of the Betuweroute tunnel systems and the model for economical damage to decide on the need for certain investment, identifies the key issue earlier referred to:

Can the infrastructure operator/owner afford to loose the tunnel and accept/bear all cost for rebuilding, including liability and lost time?

Background information when deciding on tunnel loss affordability

The answer to the above key issue question is either **Yes** or **No**.
For each of the possible answers some remarks are made to provide some background information.. The aim is to present only some of the most important aspects as each tunnel project will provide its own details to be taken into account before making the final decision on the affordability of a potential tunnel loss.

If the initial answer is **Yes** the *safety measures could be limited to only those needed to get all people in the tunnel out in time, i.e. within 10 minutes*. This time of 10 minutes is derived from the average time before a temperature of 100 degrees Centigrade is reached in several of the published fire curves presented in numerous tunnel safety articles. Above this temperature the human body capability to support an escape is very limited without heat and breathing protection.
All safety measures and or operational preparations to achieve this goal will of course need the approval of the fire brigade as part of the normal legistative process to achieve the necessary building permit(s). When all the people have left the tunnel complex, the fire brigade can withdraw *as there is no requirement for the fire brigade to risk their lives for the protection of goods or structures* and let the tunnel just burn down.
After the fire either the damage to the tunnel is repaired or, when it has collapsed, a new tunnel will have to be build on approximately the same place as the old one. This could easily take up the next 10 years at significantly increased cost, as all the local supervising authorities will have become nervous on the incident that has taken place and consequently will increase their safety requirements!

If the initial answer is **No** the *acceptable threat level* will have to be clearly set in advance of the project start and is *not to be changed during the design, construction or operational phase* (unless off course such a change has been accounted for in the initial design).
The acceptable threat level is also influenced by the insurance arrangements the infrastructure provider/owner is willing to take and insurance companies could ask for certain add-on protective measures as part of their risk acceptance strategies.
The choice is either for a low threat level (no dangerous goods allowed at all) or for a maximum threat level (LPG tank wagons). The defensive measures can range from heat protective lining to sprinklers and each requires its own set of add-on equipment and associated cost!
Please keep in mind that during the lifetime of a tunnel its operational use might change and there is a real chance that after some years shipping companies might deviate from the existing regulations for their own economical reasons, which will not be notified by the operator/infrastructure provider then only after an incident!
Since the Mont Blanc disaster it should be recognized that wheat and butter have a fire load equivalent to a tankwagon with heptane, while wheat and butter are not classified as dangerous

goods! Since the second Channel Tunnel fire it should be recognized that when a train is at fire at standstill it is not unlikely that it will completely burn out!

When detailing the safety case for a possible **Yes** it should be taken into account that transport capacity is made available to the operators against a certain fee and if this capacity is not available (because of a tunnel collapse), this could result in consequential damage claims.

In the preparation of the necessary escape measures, use could be made of the data in the fire safety metro report issued to the Dutch Parliament [4] in which advice is given on the conditions for safe evacuations of passengers and (unprotected) personnel and for safe operations of the fire brigades.
Some of the advice values are presented below:

For escape of passengers:	For operation of the fire brigade:.
Temperature < 50 ˚C	Temperature < 100 ˚C
Heat radiation < 2 kW/m^2	Heat Radiation < 5 kW/m^2
Sight > 10 m	Sight > 7 m or less with heat camera's

Reckoning with the temperature rise in most of the used fire curves, the average time to clear the danger zone of a tunnel should be in the region of no more then 10 minutes

When detailing the safety case for a possible **No** it should be taken into account that the defined threat level and the necessary counteracting systems will need approval from numerous authorities. These are not only the fire brigade(s), but also the environmental authorities, the labour safety authorities, the water authority, the railroad authorities, etc. Each party will bring in its own experiences, its own targets, its own authority and/or its own law to be abided and its own reluctance to cooperate with the other authorities.
Achieving consensus by consultation with all these authorities and achieve the necessary permits within a given time frame when the project standstill cost rapidly grows, is described by some as the ultimate challenge.

The TSI-SRT introduction of the Notified Body for tunnel acceptance

To the above mentioned challenge of achieving consensus with numerous authorities on various safety issues, the TSI-SRT now adds up the requirement that the whole tunnel complex needs the approval of a railroad notified body before it is allowed to go into operation. As such this a standard railway procedure, but it is new to parties with yearlong experience in the approval of tunnels.

Is the introduction of a Railroad Notified Body a benefit or a complication?

The use of a railroad notified body for tunnel acceptance could be beneficial when fulfilling the role of the coordinating notified body as established in the NB rail procedures [5]. The railway notified body could coordinate between all authorities involved and provide the specific railway knowledge not readily available with the other authorities. This is of course with the assumption that these authorities are recognised as independent notified bodies, each within their own role.
If the railroad notified body is however seen by the authorities as just a replacement of the infrastructure operator and not as an independent body, matters could become much more complicated and personal skills en efforts would be required to make the cooperation work effectively, inevitably leading to the delays we would just like to have prevented.

Infrastructure providers should clearly identify in which particular role they require the support of a railroad notified body:

- as a legislative independent safety assessor specifying what needs to be done,
- as en engineering independent safety assessor supervising the safety process of tunnel design and construction, interpreting legislation for practical but always safe solutions.
- as the assessing independent safety supervisor deciding if the legislative requirements are fully met by the design and construction made.

These roles are often confused and should be clearly defined at the start of a project to avoid confusion and conflicts of interest. Some authorities see their role as strictly assessing safety, some are also involved in the legislative process and the engineering ISA role is often assigned to the safety supervisor of the tunnel contractor.

Conclusion

The TSI-SRT as published provides a set of minimum safety requirements to be met in tunnel operations, but is of limited value in the tunnel engineering design process. Careful study of available incident investigation reports can fill the framework of hazard control as per EN50126 and tolerable hazard rates could be defined for tunnel systems using the methodology of EN50129 thus providing. The basic question if the infrastructure provider/owner can afford the complete loss of a tunnel by an incident provides the basis for the definition of an acceptable threat level and the associated counteracting safety systems. The use of a railway notified body as the coordinating notified body could ease the cooperation between the authorities involved in assessing tunnel system safety, provided that the role and authority of the railway notified body is clearly defined to all parties by the infrastructure provider/owner.

[1] TSI Safety in Railway Tunnels
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:064:0001:0071:EN:PDF

[2] Corporate Manslaughter andCorporate Homicide Act 2007
http://www.opsi.gov.uk/acts/acts2007/pdf/ukpga_20070019_en.pdf

[3] TSI Control-Command and Signalling
http://www.saferail.nl/IO/IODOCS/TSI-CR/TSI_06-679_EN_CCS.pdf

[4] Peutz Rapport Brandonderzoek Metro Eindrapportage
Nr. C769-3 dd 2 augustus 2006 D.J. den Boer e.a.
http://www.verkeerenwaterstaat.nl/kennisplein/page_kennisplein.aspx?id=355190&DossierURI=tcm:195-19861-4

[5] NB-Rail Recommendation for Use
Co-ordination between Notified Bodies RFU 2-000-16 Issue 2 Date 01-04-2006
http://circa.europa.eu/irc/nbg/nbrail/info/data/en/information/nbrail/RFU/RFU%202-000-16%20Iss02.pdf