Tunnel safety – do we behave in the right manner?

Four years have passed since the European Directive 2004/54/EC on minimum safety requirements for tunnels in the Trans-European road network became effective in 2004. In almost all EU member states, the EU Directive considerably changed the legislative background of road tunnel safety as well as the relevant national technical guidelines.

Bernhard Kohl
Head of Linz Branch, Austria, ILF Consulting Engineers

Bernhard Kohl MSc studied for a Civil Engineering degree at the University of Innsbruck and postgraduate studies in Risk and Safety of Technical Systems at ETH Zurich and Ecole Polytechnique Fédérale de Lausanne. He is presently the Head of the ILF branch office in Linz, Austria and Coordinator of PIARC TC4 working group, Risk Analysis. Kohl has been a Project Manager for the safety design of the 32 kilometre Koralm rail tunnel and 13 kilometre Wienerwald rail tunnel, both in Austria. He was also involved in the development of a risk analysis methodology for road tunnels in Austria (TuRisMo) on behalf of the Austrian Ministry of Transport, Innovation and Technology as well as in the risk analysis for the 4.4 kilometre Götschka S10 motorway tunnel, 2 kilometre Cebrat D1 motorway tunnel, and 8 kilometre Great Belt rail tunnel in Austria, Slovakia and Denmark respectively. At the moment, Kohl is Project Manager for the A26 motorway tunnel, a complex urban tunnel system with several ramps in Linz, Austria.

The EU Directive thus initiated an impetus towards harmonisation of regulations in Europe. At the same time, it animated the communication between countries with many years of experience of routine road tunnel operations and those countries, which do not have many tunnels in their existing network, but which are going to build many kilometres of new road infrastructure in near future. The 4th International Conference on Tunnel Safety and Tunnel Ventilation offered a perfect stage to continue and enhance that communication.

From 21 to 23 April 2008, 250 tunnel experts from 22 countries all over the world met in Graz, Austria, to discuss new developments in tunnel ventilation and tunnel safety. This was already the 4th international conference on that topic organised by the Institute of Internal Combustion Engines and Thermodynamics of the Graz University of Technology. The conference is chaired by Prof. Peter Sturm and takes place every two years in the lovely Austrian city of Graz.

Whereas initially this event dealt with classical road tunnel ventilation aspects, it meanwhile widened its focus on all relevant safety aspects, thus coming up to the requirements of a holistic approach to tunnel safety. This conference is not only dedicated to high quality technical presentations and vivid discussions, but traditionally also contains a realistic, practical demonstration of an emergency situation in a tunnel. In Austria, the mechanical ventilation of tunnels of the Austrian motorway network has to be checked on a regular basis, in order to prove the function of the systems. Part of such a function test is a hot smoke fire test. This year the participants of the conference could take part in a system check in the Schartnerkogeltunnel, a 1,300m long unidirectional tunnel at the A9 motorway, 20km north of Graz. Part of the exercise was also the demonstration of a malfunction of the ventilation control system in order to monitor the effects on smoke dispersion. The natural stratification of the smoke was destroyed by reversing the prevailing airflow in the tunnel and activating the jet fans in the vicinity of the fire source. For many participants, it was a surprising experience to witness how fast a whole tunnel cross section can be filled with dense smoke as a consequence of a simple operational failure.

One important issue addressed at the conference was the discrepancy between increasing safety requirements and limited financial resources. Namely operating companies highlighted the investments they already made and are still going to make in future in tunnel safety. The ASFiNAG (operator of the Austrian motorway network), for instance, pointed out that tunnels will be the dominating cost factor in the future. Between 2007 and 2010, ASFiNAG will invest

approximately €850 million for adding second tubes and the repair and refurbishment of existing tunnels. Between 2010 and 2020, 30-35% of all investments in infrastructure will be spent on construction of new tunnels and the repair and refurbishment of existing tunnels. Although these expenses cannot be directly allocated to safety, they nevertheless demonstrate the importance of the topic for tunnel operating companies.

Although it is beyond dispute that these investments in tunnel safety caused a big step forward in tunnel safety, these figures may also provoke critical questions, such as:

- Are these big investments really cost-effective?
- Is there the right balance between investments (and its effects) in road safety in general and tunnel safety in particular?
- Do we focus too much on spectacular scenarios like big fires or accidents with hazardous goods, which in reality almost never happen?
- Do we pay enough attention to less-spectacular but more effective aspects like prevention?
- Do we sufficiently take advantage of (existing) operational experience to bring our safety management concepts closer to reality?

In this ambiance, special attention was paid once again on tools, which can be used to evaluate tunnel safety. The EU Directive requires in several contexts decisions based upon the results of a risk analysis, thus establishing risk analysis as an important supplement to prescriptive guidelines. These can be used to investigate and compare safety measures in terms of risk reduction, by implementing the cost of these measures into the analysis, this tool can be used to optimise safety planning in terms of cost effectiveness.

In recent years, the World Road Association (PIARC) has been investigating risk analysis methods for road tunnels in an international working group with risk analysis experts (see report in *Eurotransport*, Issue 4, 2007), the results of these activities were presented at the World Road Congress in Paris in September 2007. The report, Risk Analysis for Road Tunnels (ISBN 2-84060-302-4; 2008), has meanwhile been published and can be downloaded for free, like all PIARC publications, from the PIARC website: http://www.piarc.org.

Test arrangement for the fire test

This report presents two families of suitable risk-based approaches for the risk assessment of road tunnels:

- A scenario-based approach, which analyses a defined set of relevant scenarios in terms of frequency and/or consequences; the risk assessment is done separately for each individual scenario

Session Risk Assessment: Philippe Pons (BG) during his presentation

- A system-based approach, which investigates an overall system in an integrated process, including all relevant scenarios influencing the risk of the tunnel, thus obtaining risk values for the whole system

At the Graz conference the session on risk assessment focused on the practical demonstration of the application of different methods of risk analysis. Christoph Zulauf (Ernst Basler & Partner, Switzerland) presented the application of a system-based approach.

By applying a system-based approach, risk values for an overall system can be estimated. Thus all events or scenarios which can affect persons in the considered system are taken into account. The risk assessment is done for the whole tunnel system, investigated on the basis of the risk values of the system. A typical application of a system-based approach is the evaluation of different additional safety measures in terms of their influence on risk.

System-based methods are normally quantitative methods. Different scenarios and possible subsequent events are analysed and the relevant influences are identified. For each path of subsequent events the scenario-specific frequency and/or consequences are estimated. The quantitative parameters that affect the development of a specific event are identified and the appropriate risk is determined.

Principle of a system – based risk model

A substantial advantage of using quantitative methods is the transparent representation of the risk estimated, whereby a better understanding of complex correlations can be achieved. On the other hand, there are problems which cannot be modelled in an adequate way (with reasonable resources of time and money) and it also may happen that insufficient quantitative data is available to quantify the most important parameters properly. Quantitative approaches are often characterised by a high degree of complexity, which makes them less comprehensible.

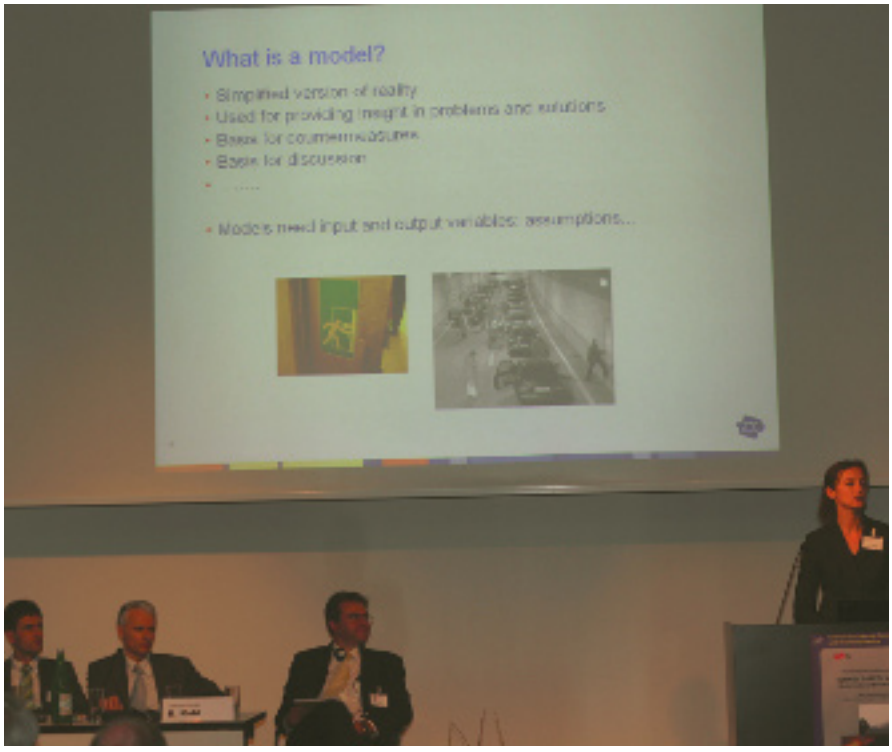
Philippe Pons (Bonnard & Gardel, France) demonstrated a scenario-based approach in the context of the French process for evaluating road tunnel safety.

In a scenario-based approach, a set of relevant scenarios are defined and the possible resulting consequences are analysed. Additionally, the probabilities of each scenario can be estimated. The risk assessment is done separately for each single scenario on the basis of its characteristic indicators (e.g. frequency of scenario, parameters describing effects and consequences of scenario). A typical application of a scenario-based approach is the optimisation of design of escape routes. Scenario-based approaches allow a detailed investigation of a specific problem including the correlation of various effects without the necessity to quantify every single influencing parameter. For example, scenario-based approaches are well suited for a detailed time-dependent analysis of sequences of events, which can be used for a realistic planning of emergency response measures. The results of a scenario based risk analysis can also be used as an illustrative basis for a discussion with emergency services.

Risk analysis inevitably depends on assumptions, for example, assumptions of the reaction (correct or incorrect) of the technical systems and also assumptions of human behaviour in case of an emergency.

Such assumptions can be:

- People know what is going on in an emergency
- People do not move until they realise they may be in danger (tunnel filled by smoke)
- At the start of an evacuation, all people leave their cars immediately, go directly to the next emergency exit and do not go back



Session Risk Assessment: Christoph Zulauf (EBP), Bernhard Kohl (ILF, session chairman), Philippe Pons (BG) and Marieke Martens (TNO, presenting)

Are these assumptions correct and reliable? This question was investigated thoroughly by Marieke Martens (psychologist from TNO, the Netherlands). She pointed out, that simulator studies and realistic evacuation exercises carried out in the European UPTUN project gave reason to assume that this is not the case.

One reason is lack of information. Many tunnel users have insufficient information about the tunnel environment, the available safety infrastructure (like emergency exits), the situation they have got into and its possible consequences, and the way they should react. This is even the case when they get specific information before the test (like the EU-leaflet about behaviour in tunnels). She particularly pointed out the importance of group effects, which normally are not taken into account in risk analysis. In an evacuation process there typically is a long hesitation phase; if some people start to evacuate, others follow, when nobody reacts, no one evacuates. One person may initiate new movement and people often follow movements of others. In railways, for example, this effect is taken advantage of by initiating evacuation by members of the train staff. In road tunnels an evacuation could efficiently be supported by situation-related information given by the operator (via loudspeakers etc.).

Tunnel Control Centre – the focus point in an emergency

Bernhard Kohl of ILF Consulting Engineers, Austria, who was chairing this session, focused on the relevance of human behaviour for the success of safety measures. There are many indications, that the humans (tunnel users, tunnel operators, but also members of a rescue team) often are the weak point of the safety chain. They are responsible for the causes of many accidents and often for severe consequences as well. Yet this also provides a chance, and the key to use this chance seems to be better knowledge of the tunnel users about tunnels in general and accurate information about the situation in an emergency in particular. To take advantage of the enormous amounts of money invested in tunnel safety in an optimised way, it is crucial to improve integration of human behaviour in the risk management process, a big task for the future!

The proceedings of this conference are published by the Institute for Internal Combustion Engines and Thermodynamics, Graz University of Technology (Vol.90, ISBN 978-3-85125-008-4) and can be purchased directly at the University (contact: institute@vkma.tugraz.at). ●