

Risk Analysis for Road Tunnels – Light at the end of the tunnel?

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Since 1999, road tunnel safety has become a subject of growing interest in the public as well as among tunnel specialists. This is largely because of different incidents that have led to an increased risk awareness.

The recent catastrophes in the Mont Blanc tunnel, the Tauern tunnel, and Gotthard tunnel have demonstrated the urgent need for improving the prevention and mitigation of tunnel accidents, including adequate detection systems and being prepared operation staff and emergency services.

This can be achieved by providing safe design and construction criteria for new tunnels, re-organising the management and the configuration of in-service tunnels, providing management with proper decision support safety tools, following-up the state of safety in tunnels and ensuring information and better communications with tunnel users.

The numerous initiatives, which have taken place on national, European and international levels, have led to different regulatory developments. The European Directive 2004/54/EC is now a major legislative text for EU countries and sets basic requirements for tunnels in the Trans-European Road Network (TERN).

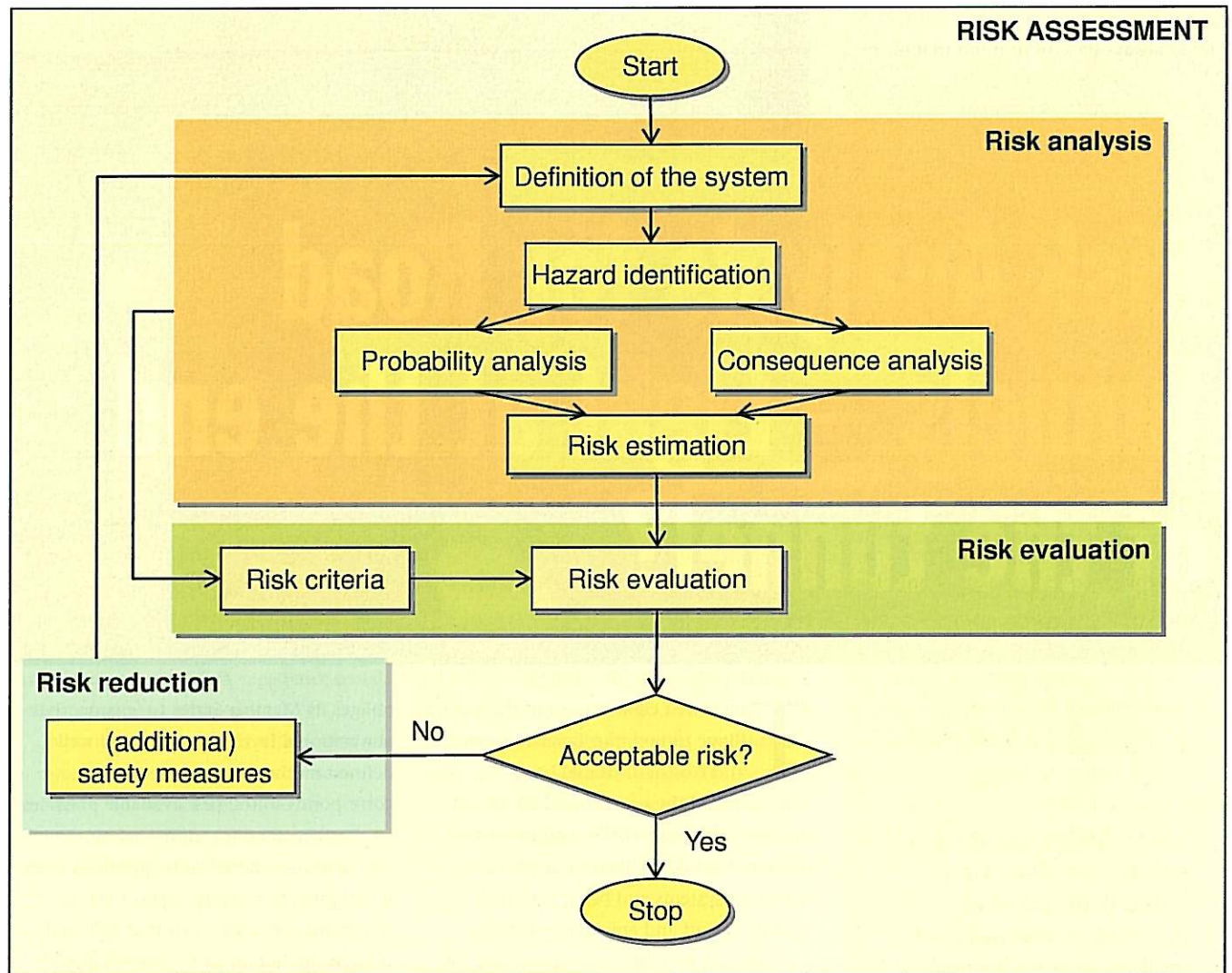
On the one hand, the EU Directive is a prescriptive guideline, defining a set of minimum requirements for the safe design, equipment and operation of road tunnels. On the other hand, in some contexts the EU Directive requires decisions based upon the results of a risk analysis. In article 13, the EU Directive

obliges its Member States to 'ensure, that at a national level, a detailed and well defined methodology is used that corresponds to the best available practices.'

Furthermore, for tunnel safety experts, this definition raises more questions than it can provide answers. A short glance at the theme already reveals that risk analysis is anything but an easily understandable and clearly defined subject; and there is a certain amount of scepticism about this tool amongst tunnel experts and operators, authorities and emergency services.

In view of this situation, the Technical Committee 3.3 Road Tunnel Operation of the World Road Association (PIARC) set-up a working group in 2005 to investigate strategies, tools and best practice for the management of road tunnel safety.

PIARC is an international forum for analysing and discussing the issues related to road tunnel safety. The Technical Committee 3.3 identifies, develops and disseminates best tunnel safety management practice and gives better access to international information with regard to tunnel safety. One of the themes in the strategy of PIARC is the improvement of safety assessments, mechanisms, design and procedures consistent with efficient and effective operations that meet the needs of road users and their safety. One of the goals is



Flowchart of the procedure for risk assessment

to improve the safe and efficient use of the road system, taking into account road structures such as tunnels, including the movement of people and goods on the road network, while effectively managing the risks associated with road transport operations and the natural environment.

Working Group 2, Management of Road Tunnel Safety, of the Technical Committee on Road Tunnel Operation is chaired by Rudolf Hörhan, from the Austrian Federal Ministry of Transport, Innovation and Technology. Mr. Hörhan is assisted by Secretary Alain Jeanneret from the Swiss Road Networks Division and a group of tunnel safety experts from 14 countries. Among other objectives, Working Group 2 focussed on risk analysis, aiming at describing its application to the investigation of safety issues in road tunnels, as well as

identifying the options and benefits of using this method.

The PIARC activities on this subject took up the results of major European research activities – mainly SafeT – and additional contributions prepared by the members of the working group, resulting in a report entitled *Risk Analysis for Road Tunnels*.

What is a risk analysis?

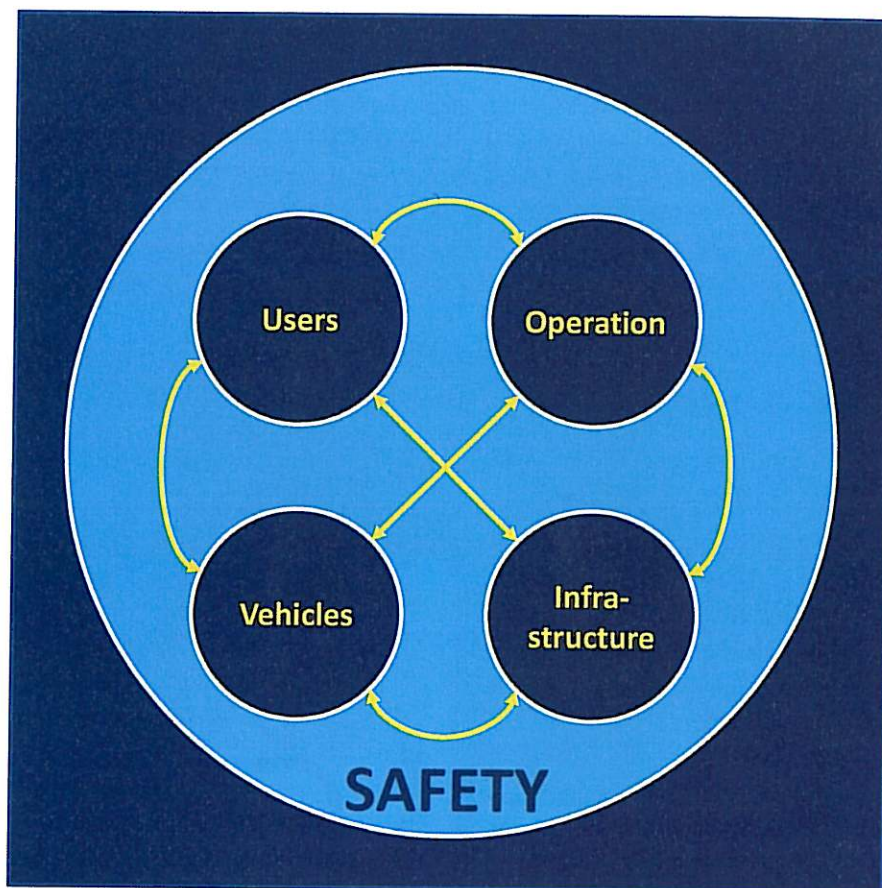
Risk analysis is a tool which was initially developed to investigate the safety of potentially dangerous industrial processes or industrial plants. The application of risk analysis should help to establish a proactive safety strategy by systematically investigating potential risks. This proactive safety strategy was intended to replace experience-based concepts mainly relying on findings from incidents or

accidents that had already happened. During the previous 15 years, some risk analysis methods have been adapted to the investigation of tunnel safety, with road tunnels being an area of particular focus.

In general, risk analysis deals with potential negative consequences of a system in the future. As nobody is able to predict future events, the only option in such a situation is to develop – as realistically as possible – a model of the risks associated with the system in question. As there are basically innumerable possibilities concerning how dangerous effects may develop, it is impossible to take all possible situations into account. Any investigation has to therefore be limited to selected representative scenarios, thereby including the possibility that important situations are missing, or that too much emphasis is put on effects of

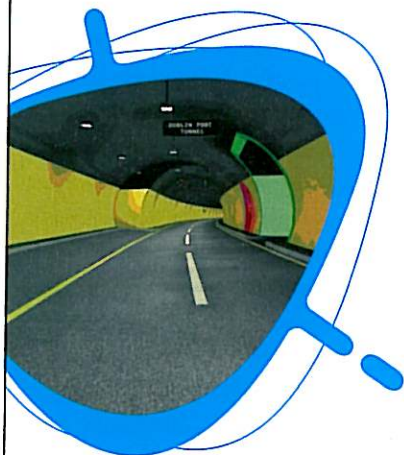
minor importance. For these reasons it should always be kept in mind that every kind of risk analysis – whichever method is used – is a more or less simplified model relying on pre-conditions and assumptions and is not a copy of reality. Nevertheless, risk analysis provides a much better understanding of risk-related processes than merely experience-based concepts may ever achieve.

The term 'Risk Analysis' covers a large family of different approaches, methods and complex models combining various methods for specific tasks. In general terms, a risk analysis for road tunnels can be described as a systematic approach to analyse sequences and inter-relations in potential incidents or accidents, hereby identifying weak points in the system and recognising possible improvement measures. Equally, Risk Analysis can include a quantification of risks which can be used as the basis of a performance-based approach to safety. Or it can take an holistic approach, including infrastructure, vehicles, operation and, last but not least, users.



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What can a risk analysis be used for?

Safety in road tunnels is currently controlled in many countries on the basis of prescriptive regulations. A prescriptive requirement specifies particular safety

interaction of infrastructure, technical systems, operation and users.

By contrast, the process of a risk-based approach allows a structured and transparent assessment of risks for a particular tunnel. This includes the

of additional measures for the tunnel. Although risk can be reduced to very low levels, this may be extremely expensive and not economically viable. The results of a risk analysis can also be the basis for additional investigations such as a risk-based cost/effectiveness analysis, which can ensure that the money spent to reduce risk is allocated in such a way that an optimum level of safety is obtained.

Risk analysis can be used to check the general consistency of safety planning, to choose between alternatives, to demonstrate that safety standards are fulfilled, and to optimise safety planning in terms of cost-effectiveness. Hence, the risk-based approach offers an opportunity to achieve a transparent and consistent approach to decision-making about risks. It can be an appropriate supplement to the implementation of measures to satisfy the requirements of standards and guidelines.

The risk assessment process

Risk analysis is a key element of the risk assessment process that covers three major elements. Firstly, Risk Analysis aims to answer the fundamental question; 'what might happen and what are the consequences?' Risk analysis can be carried out in a qualitative or quantitative manner, or as a combination of both. In case of a quantitative analysis, probabilities of accidents and their consequences – for example in terms of fatalities, injuries, property damage, interruption of services – and the resulting risks are estimated. Risk evaluation is directed towards the question of acceptability and has to give an answer to the question, 'is the estimated risk acceptable?' For a systematic and operable risk evaluation, risk criteria have to be defined and it has to be determined whether a given risk level is acceptable or not. Finally, risk reduction and planning of additional safety measures must answer the question, 'which measures are necessary to get a safe and cost-efficient system?' If the estimated risk is considered to be unacceptable, additional safety measures have to be proposed.

The procedure for a risk analysis can be divided into three steps; hazard identification (a systematic process to



Tunnel Bindermichnotrufnische

features, actions, or procedural elements to be included in the design of tunnels or processes, as the means for achieving a desired objective. These requirements more or less have to be implemented without considering the individual characteristics of a tunnel and without investigating the

consideration of the local risk situation in terms of relevant influence factors, their interrelations and possible consequences of incidents. Moreover, risk analysis makes it possible to investigate and compare additional safety measures in terms of risk reduction and to propose an adequate set

identify and structure all relevant hazards, and to analyse their correlating effects), probability analysis (determination of the probabilities of relevant events and scenarios), and consequence analysis (investigation of consequences of relevant scenarios).

The simplified flowchart on page 36 illustrates the main steps of the risk assessment process.

Practical methods

In addition to an introduction to the theoretical background of risk analysis and a description of its application, the PIARC report presents a selection of practically applied risk analysis methods. Furthermore, it contains a short description of each method, its characteristics, results and the associated strategy of risk evaluation.

Special emphasis is placed on information about the range and limits of application of the practical methods, in order to advise the reader about which problems the respective method is suited to or not, specifically referring to the requirements of the EU Directive.



Tunnel Bindermichl Notausgang

The PIARC report presents the following methods; Austrian tunnel risk model TuRisMo, Dutch scenario analysis for road tunnels, Dutch TUNPRIM model, French specific hazard investigation,

Italian risk analysis for road tunnels and the OECD/PIARC DG-QRA model.

To demonstrate their practical application for each of these methods, a case study is presented in Appendix 3 of

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Brandversuch Rauchschichtung

the PIARC report. It can be concluded that all methods exhibit specific advantages and disadvantages – none can claim to be generally the most suitable. The selection of the most suitable method depends on the specific requirements of the problem to be investigated.

Recommendations and Outlook

PIARC does not advocate a specific method, but lays down some recommendations for the practical use of risk analysis. They suggest selecting the best method available for a specific problem, being aware that a model is a simplification of real conditions, and ensuring that risk analysis is only performed by experts with sufficient experience and understanding of the methods they employ. Furthermore, they suggest using specific data for quantitative methods, and also state that risk models inevitably deliver fuzzy results, and advise that this is taken into account when evaluating the results of a risk analysis.

The PIARC report also addresses the possibilities of harmonising the methods of risk assessment for road tunnels,

concluding that these possibilities are limited. Indeed, one unique method cannot cover all relevant issues. However, the standardisation of some specific elements of risk analysis seems to be achievable, without limiting the flexibility of the methods. Hence, in the future it seems to be possible to develop universally applicable guidelines for risk analysis. Another important issue to be addressed in future is risk evaluation. The methods of risk analysis and risk evaluation are strongly dependent on each other; in the future the possibilities and restrictions, advantages and disadvantages of different strategies of risk evaluation should be investigated in a similar way.

The results of the activities of the PIARC Technical Committee 3.3, Working Group 2, Management of Road Tunnel Safety will be presented to the public at the World Road Congress in Paris during September.

The report, Risk Analysis for Road Tunnels, is under finalisation and by the end of this year, can be downloaded for free – like all PIARC publications – from the PIARC website: <http://www.piarc.org>



biography

Bernhard Kohl

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 a member of PIARC C 3.3 Working group 2, Management of Road Tunnels Safety. 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 risk analysis for the 4.4 kilometre Götschka S10 motorway tunnel, 2 kilometre Cebtrat D1 motorway tunnel, and 8 kilometre Great Belt rail tunnel in Austria, Slovakia and Denmark respectively. Furthermore, Kohl was in charge of safety expertise at the 19 kilometre Vereina rail tunnel in Switzerland.