TC 3.3 ROAD TUNNEL OPERATION

Risk Analysis and Implementation in Austria

Seminar

Road Tunnel Operations Management and Safety

Rudolf Hörhan, Austria

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Introduction

- Risk analysis is an important tool to investigate and improve safety of road tunnels
- major tunnels incidents are infrequently, the consequences can be severe (e.g. damage of the tunnel structure and equipment, impact on the transport economy)

Introduction

- Risk analysis methods were initially developed to assess the safety of potentially dangerous plants and processes in the nuclear, chemical and petrochemical sectors
- the methods have been adapted and applied to road tunnels for a number of years

Introduction

- Risk analysis is explicitly required by the European Directive 2004/54/EC, on minimum safety requirements for road tunnels on the Trans European Road Network
- PIARC WG 2 prepared a technical report for "Risk Analysis for Road Tunnels" studying the worldwide application of risk analysis methodologies.

Basic Principles of Risk Analysis

- Risk analysis involves the identification of hazards and the estimation of the probability and consequences of each hazard. The risks are determined from the product of their probability and consequences of each hazard.
- Risk analysis is a systematic approach to analyse sequences and interrelations in potential incidents or accidents,
- The term "Risk Analysis" covers a big family of different approaches, methods and complex models combining various methodical components for specific tasks

Basic Principles of Risk Analysis

- Risk analysis makes the quantification of risks feasible thus establishing the basis of a performance-based approach for the assessment of safety standards
- A general basic principle of all kinds of risk analysis for road tunnels should be a holistic approach including infrastructure, vehicles, operation and - last but not least – users.

Practical use in the risk management process

Risk analysis can be used

- to check general consistency of safety planning
- to choose between alternatives
- to demonstrate safety, in case of deviations from prescriptions
- to optimize safety planning in terms of cost-effectiveness
- a performance based approach for the assessment

Prescriptive based approach

… a tunnel is safe if it is designed in line with valid regulations

- Specifies particular safety features, actions etc. to be included in the design of tunnels, in processes etc. without considering the individual characteristics of the tunnel.

Risk based approach

… a tunnel is safe if it meets predefined risk criteria

- allows a structured, harmonized and transparent assessment of risks for an individual tunnel and the comparison of different safety measures coming up with the best additional measures in term of risk mitigation.

Conclusion

- Prescriptive based approach and risk based approach have to be used as complementary elements of a safety assessment process.

Tunnel Risk Model for Road Tunnels in Austria

Methodical Approach

The methodical approach combines two basic methodical components

- a quantitative **frequency analysis**
- a quantitative **consequence analysis**

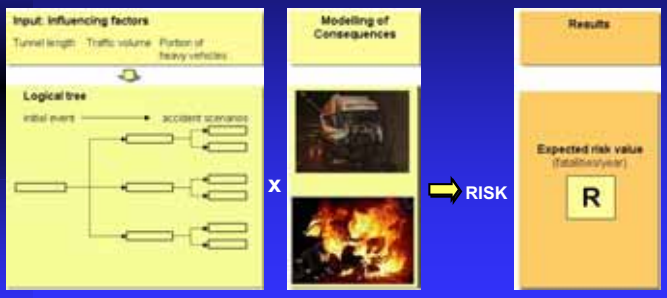
The method investigates **the risk to tunnel users**

- reference value: expected value of the societal risk (fatalities per year)
- the shares in risk of mechanical effects, fire and hazardous goods effects are shown separately

Tunnel Risk Model for Road Tunnels in Austria

Methodical Approach

■ **Sequence of risk analysis**



Tunnel Risk Model for Road Tunnels in Austria

Methodical Approach

■ **Data base of risk analysis**

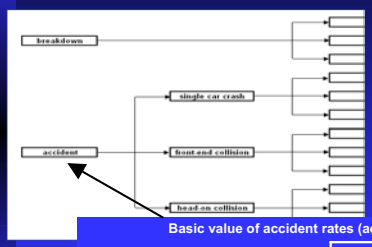
- Evaluation of 447 tunnel accidents with personal injuries [1)]
- Covering 60 uni-directional and 21 bi-directional Austrian motorway tunnels (period 1999 – 2003)

[1)] provided by KfV – Kuratorium für Verkehrssicherheit

Risk Model for Austrian Road Tunnels

Methodical Approach

- **Frequency Analysis – event tree approach**



Basic value of accident rates (accidents with personal injuries):

	bi-directional tunnel	uni-directional tunnel
accident rates (accidents/1Mio vehicle-km)	0,077	0,112

Accident rates are modified in dependence of tunnel length and traffic volume!

Risk Model for Austrian Road Tunnels

Methodical Approach

- **Consequence Analysis**

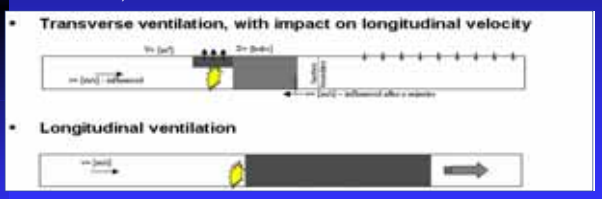
- Estimation of extent of damage of mechanical accidents:
  Evaluation of tunnel accident data base

- Estimation of extent of damage of accidents involving fire:
  Combination of ventilation model with evacuation simulation model

Risk Model for Austrian Road Tunnels

Methodical Approach

- **Consequence analysis – ventilation model**
  - Two different fire scenarios (5 MW, 30 MW)
  - Two different ventilation regimes (longitudinal ventilation, transversal ventilation) [2)]

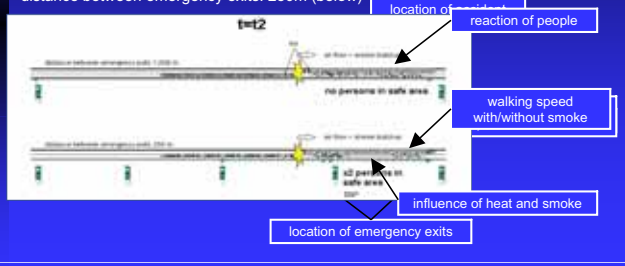


[2)] provided by TU Graz, FVT

Risk Model for Austrian Road Tunnels

Methodical Approach

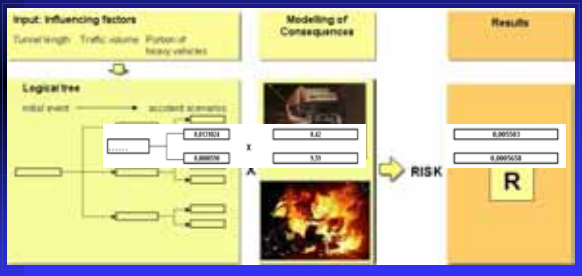
- **Consequence analysis – evacuation simulation model**
  - Software: Building Exodus 4.0
  - Example: fire in a bi-directional tunnel with longitudinal ventilation; distance between emergency exits: 1.000m (above) distance between emergency exits: 250m (below)



Risk Model for Austrian Road Tunnels

Methodical Approach

■ **Methodology – risk calculation**



Risk Model for Austrian Road Tunnels

Risk evaluation

■ **Strategy of risk evaluation**

- Risk evaluation is done by relative comparison, by comparing the tunnel as it is to a reference tunnel, designed and equipped in accordance with the requirements of the EU-directive
- Safety measures which are required according to Austrian regulations but exceed the minimum safety requirements as per EU-directive are considered as alternative measures

Risk Model for Austrian Road Tunnels

Case study

■ **Definition of the tunnel (example for demonstration)**

- Existing single tube tunnel, length 5,5 km
- Bi-directional traffic, 9.500 vehicles per day, 25% heavy goods vehicles
- Emergency exits: every 500m
- Ventilation: transversal ventilation, extraction openings with dampers every 100m

Design and equipment of the tunnel are in line with the requirements of the EU-directive, only share of heavy goods vehicles exceeds reference value of 15%
→ risk has to be assessed

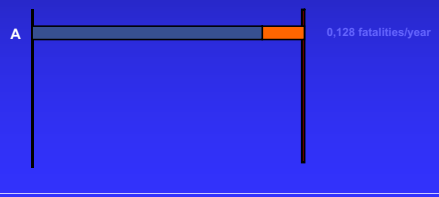
Risk Model for Austrian Road Tunnels

Case study

■ **Results of investigation**

The following cases are investigated

- A – risk of reference tunnel (definition of risk criteria)



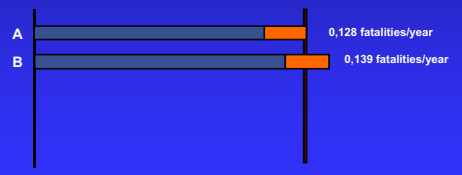
Risk Model for Austrian Road Tunnels

Case study

Results of investigation

The following cases are investigated

- A – risk of reference tunnel (definition of risk criteria)
- B – risk of existing tunnel



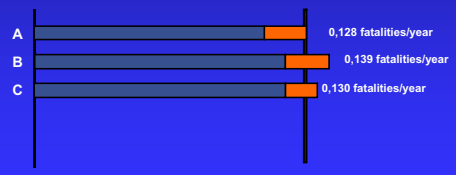
Risk Model for Austrian Road Tunnels

Case study

Results of investigation

The following cases are investigated

- A – risk of reference tunnel (definition of risk criteria)
- B – risk of existing tunnel
- C – alternative measure: reduction of cross passage distance from 500m to 250m



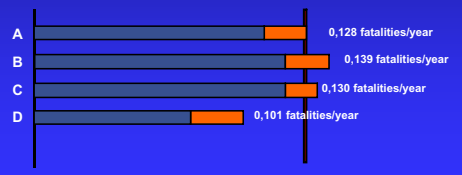
Risk Model for Austrian Road Tunnels

Case study

Results of investigation

The following cases are investigated

- A – risk of reference tunnel (definition of risk criteria)
- B – risk of existing tunnel
- C – alternative measure: reduction of cross passage distance from 500m to 250m
- D – alternative measure: speed limit 60km/h instead of 80 km/h for heavy goods vehicles



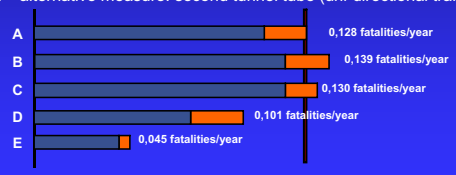
Risk Model for Austrian Road Tunnels

Case study

Results of investigation

The following cases are investigated

- A – risk of reference tunnel (definition of risk criteria)
- B – risk of existing tunnel
- C – alternative measure: reduction of cross passage distance from 500m to 250m
- D – alternative measure: speed limit 60km/h instead of 80 km/h for heavy goods vehicles
- E – alternative measure: second tunnel tube (uni-directional traffic)



Risk Model for Austrian Road Tunnels

Conclusions

- TuRisMo – the new risk model for risk assessment of Austrian road tunnels is now completed and has been successfully applied to several tunnels
- The method is a consistent and understandable basis for a performance based safety assessment of road tunnel
- The method can be used for different applications such as

  - check of general consistency of safety planning
  - evaluation of effectiveness of alternative safety measures
  - optimisation of safety planning in terms of cost-effectiveness
  - demonstration that tunnel safety standards are full filled e.g. in case of deviations from prescriptions

Risk Model for Austrian Road Tunnels

Conclusions

- On the basis of TuRisMo a new simplified method for the safety classification of Austrian road tunnels has been developed (published in the new RVS 09.02.31)
- Risk analysis inevitably deliver fuzzy results, which have to be interpreted accordingly
- Be aware that a risk analysis is always a simplification of real conditions and can never predict the course of real events; however, it enables you to make decisions on a sound basis