Approaches to Road Tunnel Safety – Current Practice

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Contents of Presentation

- Introduction
- Principles
- Risk based Approach
- Conclusions
Status Quo of Road Tunnel Safety
(23rd World Road Congress, Paris 2007)

- Due to the fire accidents in Mont Blanc, Tauern, Gotthard etc. road tunnel safety became a subject of increased public interest
- Experience, research results and public opinion in many countries lead to adjustments of regulations and safety standards
- Dynamic development of methods and tools
- There is consensus as regards the necessity of taking an integrated approach,
- But significant differences as regards the methods and assessment concepts

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Basic Principle: Integrated Approach

Take the whole system into account

Different Approaches to Road Tunnel Safety

- 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 terms of risk reduction and/or cost effectiveness.
Approaches to Road Tunnel Safety – Principles

- **Prescriptive based Approach**

  Traditional approach to tunnel safety:
  regulations in tunnel design guidelines

  First standard at international level

  - EC Directive 2004/54/EC on Minimum Safety Requirements for Road Tunnels

  Examples of national tunnel design guidelines addressing safety aspects:

  - Austrian standards RVS (09.01.24, 09.02.22/31/41/51, 09.03.11/12)
  - German standard RABT (2006)

- **Risk based Approach**

  What is the purpose of a risk based approach?

  - 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 of safety standards
Approaches to Road Tunnel Safety – Principles

**Different Approaches to Road Tunnel Safety**

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

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**Elements of Tunnel Safety Management**

- Safety organisation:
  definition of responsibilities for tunnel commissioning and tunnel operation (tunnel operator – authorities – independent entities)

- Safety inspections

- Feedback of experience
  (safety exercises, systematic documentation and evaluation of relevant incidents and accidents)

- Safety documentation
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- **Tunnel safety documentation**
  - Includes all safety relevant information of the tunnel
  - “Living” document
  - Must be updated continuously

- Design stage
- Commissioning stage
- Operation stage

**Contents of Safety Documentation**

- Description of tunnel infrastructure and access to tunnel
- Description of traffic situations, transport of dangerous goods
- Information about tunnel operation
- Specific hazard investigation, risk analysis

- Organisation, resources for operation and maintenance, system of feedback of experience
- Emergency response plan

- Evaluation of significant incidents and accidents
- Evaluation of safety exercises
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What is Risk Analysis?

- A big family of different approaches, methods and complex models combining various methodical components for specific tasks
- Systematic analysis of sequences and interaction effects in potential accidents
- Thereby identifying weak points in the system and recognising possible improvement measures
- Risk analysis makes the quantification of risks feasible
Approaches to Road Tunnel Safety – Risk based Approach

**Risk Assessment Process**

![Risk Assessment Process Diagram]

**Quantitative System based Approach:**

investigates an overall system in an integrated process, obtaining risk values for the whole system

- **Input:** Influencing factors
- **Modeling of Consequences:**
  - Tunnel length
  - Traffic volume
  - Portion of heavy vehicles

![Quantitative System Diagram]
Qualitative or semiquantitative Scenario based Approach:

investigates an overall system in an integrated process, obtaining risk values for the whole system.

scenarios:
- scenario 1
- scenario 2
- scenario 3
- ...

Analyse development of scenarios
Investigate effects and consequences of scenarios
Design optimization

Different Types of Risk can be addressed in a Risk Analysis:

- Societal risk: harm to a specific group of people
- Individual risk: harm to an individual person
- Economical loss
- Damage to environment
- Damage to immaterial values

Focus on societal risk of tunnel users
Approaches to Road Tunnel Safety – Risk based Approach

**Societal Risk – Risk Indicators:**

- **Expected risk value (EV)**
  long-term average number of statistically expected fatalities per year

- **FN diagram**
  shows magnitude of consequences in relationship to the (cumulated) frequency of a hazard

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Approaches to Road Tunnel Safety – Risk based Approach

**Background to Risk Evaluation**

- **Risk analysis** – scientific process of identification, structuring, quantification of probabilities / consequences of risk

- **Risk evaluation** – socio-political process including ethical, political and societal factors

*Risk evaluation is strongly influenced by risk perception*
**Approaches to Road Tunnel Safety – Risk based Approach**

- **Example for a quantitative System based Approach:**

  **Austrian tunnel risk model TuRisMo** (defined in RVS 09.03.11)

  **Frequency analysis**

  ![Logical tree](image)

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**Approaches to Road Tunnel Safety – Risk based Approach**

- **Frequency Analysis – Event Trees Approach:**

  ![Initial event → accident](image)

  **Example for resulting scenario:**

  front-end collision, involving HGV, fire (as consequence of accident)

  **accident rates**

  **relative share of accident types**
Example for a quantitative System based Approach:

Austrian tunnel risk model TuRisMo

Frequency analysis

Consequence analysis

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Consequence Analysis

- Mechanical damage of accidents:
  Data base:
  accident statistics; tunnel specific influences are difficult to estimate because representative tunnel specific accident statistics are often not available
Approaches to Road Tunnel Safety –

Risk based Approach

- Consequence Analysis
  - Mechanical damage of accidents:
    Data base:
    accident statistics; tunnel specific influences are difficult to estimate because representative tunnel specific accident statistics are often not available
  - Consequences of tunnel fires:
    Many influencing parameters; statistics insufficient; estimation of consequences requires complex modelling
Approaches to Road Tunnel Safety – Risk based Approach

Modelling of Consequence of Tunnel Fires in Time Steps

Relevant Parameters:

- Fire development
- Smoke propagation, influenced by tunnel ventilation (initial air flow in tunnel, detection time, response time of ventilation system)
- Self rescue of people effected by fire & smoke (information, reaction time, human behaviour, vehicle constellation in tunnel, distribution of people)

Estimation of consequences
**1st step: Modelling of Smoke Propagation**

Typical smoke distribution for tunnel with longitudinal ventilation

**2nd step: Modelling of Self Rescue of People**

bidirectional tunnel with longitudinal ventilation

- Situation after fire break out – people start to evacuate

- Situation after several minutes: people reach emergency exits
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Introduction

Principles

Risk based Approach

Conclusions

General Conclusions

- Strong impact on adjustments of regulations and safety standards after the big fire accidents in 1999 – 2001
- Dynamic development of methods and tools in the past decade
- The EC Directive 2004/54/EG on Road Tunnel Safety is the first standard at international level
- Induces the implementation of a risk based approach in Europe
- Several Countries developed own risk analysis methods
- The Austrian tunnel risk model TuRisMo is such a well established method; it was successfully applied in Austria, Slovakia, Slovenia, Greece and Portugal
Approaches to Road Tunnel Safety –
Conclusions

- **Recommendations for the Practical use of Risk Analysis**
  (PIARC Report “Risk Analysis for Road Tunnels” – www.piarc.org)

  - Select the best method available for a specific problem
  - Be aware, that you are using a model, which is a (major) simplification of real conditions
  - Use specific data for quantitative methods
  - Risk models inevitably deliver fuzzy results
  - Relative comparison may improve the robustness of conclusions drawn

  - Risk analysis should only be performed by experts with sufficient experience and understanding of the methods they use