Upgrading of the Austrian Tunnel Risk Model TuRisMo-
Methodical and Practical Aspects

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Upgrading TuRisMo – Methodical and Practical Aspects

Outline

- Background
- Methodical Approach
- Modifications in Risk Model
- Risk Evaluation and Mitigation Measures
- Extended Application
- Conclusions
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Background

• The Austrian Tunnel Risk Model TuRisMo was one of the first methods for a quantitative assessment of road tunnel safety in Europe.

• It was first published in the guideline RVS 09.03.11 in 2008.

• After 5 years of practical experience the Austrian Federal Ministry for Transport Innovation and Technology and the Austrian motorway operator ASFiNAG started an initiative to upgrade the risk model.

• The upgrading process was embedded in a working group of the Austrian Association for Research on Road, Rail and Transport (FSV).
Main objective: eliminate limitations in practical application:

Objectives shall be achieved by:

- Implementing additional parameters influencing fire risk in the existing, standard model – in particular for unidirectional tunnels
- Evaluating and implementing the data collected on tunnel collisions and fires in Austrian motorway tunnels since 2006
- Opening the model for simulations to be able to study individual parameters for individual tunnels specifically
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Methodical Approach

- **Methodical components of TuRisMo**
  - **Frequency analysis**
    Event tree analysis to calculate the frequencies of a set of characteristic incident scenarios (collisions and fires).
  - **Consequence analysis – collision**
    Default values to estimate the damage of collisions depending on vehicle involvement and collision scenario.
  - **Consequence analysis – fire**
    Default values (standard method) or simulations of smoke propagation and evacuation (detailed method) to estimate the damage due to fires for different fire scenarios.
Methodical components of TuRisMo

**Frequency analysis – Relevant parameters**
- Incident types
- Traffic volume
- Incident rates
- Traffic composition
- Ignition
- Vehicle categories

**Consequence analysis – Relevant parameters**
- Tunnel system, technical systems, evacuation, vehicle categories

**Event tree**
- Initial event → Incident scenarios

**Expected risk value**
- (fatalities/year)

**Results**
Modifications in risk model – frequency analysis

Frequency analysis – Relevant parameters
- Incident types
- Traffic volume
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Consequence analysis – Relevant parameters
- Tunnel system, technical systems, evacuation, vehicle categories

Event tree
- Initial event
- Incident scenarios

Results
- Expected risk value (fatalities/year)

- R

- Dangerous goods
- Fires
- Mechanical accidents

- X
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Modifications in Risk Model – Frequency Analysis

- **Enhanced modelling of event tree**

- **Different scenarios for congested traffic**
  
  - Congestion due to traffic overload (stop and go)
  
  - Evolving congestion after previous initial event – breakdown or collision
Motivation:

- Improved assessment of scenarios with congested traffic (high damage potential in fires)
- Measures influencing congestion or management of initial events
3 different fire scenarios – with respect to traffic situation and airflow conditions

- Primary fire scenario: fire in normal traffic, vehicles queuing behind scene of event
- Secondary fire scenario: fire as consequence of a collision at the end of an evolving congestion
- Tertiary fire scenario: fire in congested traffic – stop and go

Motivation:
Improved assessment of fire scenarios with congested traffic (high damage potential – specific airflow conditions at beginning of event)
Modification of input data

- Reduction of collision rates – as a consequence of a general increase of traffic safety in Austrian motorway tunnels (based on statistical data)

<table>
<thead>
<tr>
<th>Basic collision rates – motorway tunnels</th>
<th>Unidirectional</th>
<th>Bidirectional</th>
</tr>
</thead>
<tbody>
<tr>
<td>RVS 09.03.11 – 2008</td>
<td>0,112 / 10^6 veh-km</td>
<td>0,077 / 10^6 veh-km</td>
</tr>
<tr>
<td>RVS 09.03.11 – 2014</td>
<td>0,078 / 10^6 veh-km</td>
<td>0,054 / 10^6 veh-km</td>
</tr>
</tbody>
</table>
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Modifications in Risk Model – Frequency Analysis

**Modification of input data**

- Modified relative frequencies of vehicle fires – as a consequence of a detailed study of tunnel fires (see paper Rattei/Lentz)

<table>
<thead>
<tr>
<th>Vehicle category</th>
<th>Type of fire: Fire after breakdown</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passenger car</td>
<td>0.0015 / breakdown</td>
</tr>
<tr>
<td>HGV</td>
<td>0.01 / breakdown</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Type of collision</th>
<th>Type of fire: Fire after collision</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single car accident</td>
<td>0.012 / collision</td>
</tr>
<tr>
<td>Front – end collision</td>
<td>0.006 / collision</td>
</tr>
<tr>
<td>Head – on collision</td>
<td>0.020 / collision</td>
</tr>
</tbody>
</table>

- Refined modelling of HGV fires taking development of fire scenario into account

**Motivation:**

Implementation of expanded knowledge due to much better data base improvement of options for assessment of emergency response
Modifications in risk model – Consequence analysis

### Frequency analysis – Relevant parameters
- Incident types
- Traffic volume
- Incident rates
- Traffic composition
- Ignition
- Vehicle categories

### Consequence analysis – Relevant parameters
- Tunnel system, technical systems, evacuation, vehicle categories

#### Event tree
- Initial event
- Incident scenarios

#### Expected risk value
- (fatalities/year)

- Dangerous goods
- Fires
- Mechanical accidents

- Results
General objective

- The new model shall include features for a specific study of all relevant parameters influencing consequences of tunnel fires

- In the past model was based on default values only - no specifications for simulations included

Implementation in risk model: two different versions

- **Detailed model**: based on simulations specifically applied for the tunnel under investigation

- **Standard model**: provides new, more specific default values (for unidirectional tunnels), calculated on the basis of the new detailed model

- Range of application of standard model expanded; if not applicable – detailed model required
Parameters covered by the standard model
Default model values for consequences of fires are provided for the subsequent parameters

- 3 Fire scenarios: primary, secondary, tertiary
- 3 Fire sizes: 5MW / 30MW / 100MW
- Tunnel cross section: vaulted / rectangular – 2 lanes
- Tunnel length: 0.5 - 8.0km
- Gradient: -3.0% / horizontal / +3.0%
- Emergency exit distance: 125m – 500m
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Modifications in Risk Model – Consequence Analysis

- Parameters covered by detailed model – smoke propagation
  Combined transient 1D/3D Simulations

Influencing Factors

- Time of closure
- Portal pressure
- Vehicles entering the tunnel
- Jet Fans
- Number of driving vehicles
- Number of stopped vehicles
- Buoyancy
- Smoke Extraction
- Gradient
- Portal loss
- Vehicles leaving the tunnel

Implementation

Global Factors

Local Factors

Global Factors
Influencing factors covered by 1D simulation
- Movement and stoppage of vehicles in the tunnel
- Number and configuration of stopped vehicles in the tunnel
- Parameters influencing flow conditions (portal loss, drag at tunnel walls etc.)
- Buoyancy depending on longitudinal inclination
- Development of effects of ventilation with respect to time

Influencing factors covered by 3D simulation
- Detailed tunnel geometry (cross section, local gradient)
- Traffic configuration (local turbulence due to vehicles)
- Heat transition to tunnel walls
- Smoke stratification
- All local effects of ventilation
Processing of results of smoke propagation simulation

- Output: temperature, flue gas concentrations, extinction co-efficient at a height of 1,6m
- Transferred directly into egress model, influencing the movements of people during evacuation
- Visibility influences walking speed, accumulated physiological effects may cause immobility (Purser model)
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Modifications in Risk Model – Consequence Analysis

- **Process for calculation of representative model values**
  
  - Fire site is shifted systematically along tunnel axis – to cover all representative emergency exit configurations
  
  - Zones with different survival probabilities – superposed with areas where people are present
  
  - Calculation of expected damage value of one basic fire scenario: by combining and summarizing the damage values and respective probabilities of the individual scenarios
  
  - This procedure is repeated for all basic fire scenarios investigated, covering different fire sizes, different fire locations and different traffic scenarios
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Modifications in Risk Model – Consequence Analysis

- No changes with respect to the basic principles of risk evaluation

<table>
<thead>
<tr>
<th>RELATIVE APPROACH</th>
<th>ABSOLUTE APPROACH</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Risk of tunnel under investigation (special characteristic)</td>
<td>• Based on absolute risk value</td>
</tr>
<tr>
<td>• Risk of reference tunnel (fulfilling minimum safety requirements)</td>
<td>• Tunnel is assigned to 1 of 4 danger classes</td>
</tr>
<tr>
<td>• Modified risk of tunnel under investigation (with risk mitigation measures)</td>
<td>• Danger class determines prescriptive requirements (standard of equipment)</td>
</tr>
</tbody>
</table>

**Expected risk value EV**

<table>
<thead>
<tr>
<th>Lower limit</th>
<th>Higher limit</th>
<th>Danger classes</th>
</tr>
</thead>
<tbody>
<tr>
<td>-</td>
<td>0,02</td>
<td>I</td>
</tr>
<tr>
<td>&gt; 0,02</td>
<td>0,10</td>
<td>II</td>
</tr>
<tr>
<td>&gt; 0,10</td>
<td>0,50</td>
<td>III</td>
</tr>
<tr>
<td>&gt; 0,50</td>
<td>-</td>
<td>IV</td>
</tr>
</tbody>
</table>
Detailed specifications are added on the following topics

- The requirements for the reference tunnel are specified in detail (with respect to traffic parameters, tunnel system, geometry, ventilation)
- A specific approach for temporary traffic phases with bidirectional traffic is added
- The conditions for the intervention of the fire brigade are included in the evaluation process (reference value for intervention time of fire brigade: 15 minutes)

Principles for mitigation measures

- Measures for compensation shall address topics, where specific problems were identified in the analysis
- The ALARP principle is introduced for the selection of the most suitable mitigation measures
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Extended Application

**Range of application of standard model (unidirectional tunnel)**

- Natural ventilation, longitudinal ventilation
- Vaulted / rectangular cross section / 2 lanes
- Tunnel length: 0.5 – 8.0 km
  (dependant on cross section type and ventilation system)
- Longitudinal inclination: 0-3% ascending / descending slope
- Distance of emergency exits: 125m – 500m
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Extended Application

Range of application of detailed model

- Tunnel geometry
  - Unconventional or changing tunnel cross sections
  - Gradient with special characteristics
  - Varying emergency exit distances
  - Continuous emergency lane
  - Distance of lay-byes
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Extended Application

- Traffic and operational aspects

  - Influence of vehicle movements and all measures influencing traffic movements
  - Speed regulation and speed control
  - Type / location of facilities for tunnel closure
  - Specific traffic characteristics
  - Influence of time delays of detection systems and other safety-relevant systems (e.g. activation and control of ventilation)

Stop barrier in front of the Oresund Tunnel; Source: Oresundsbron
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Extended Application

Safety systems

- Special characteristics of individual ventilation system (e.g. varying or insufficient capacity, leakages etc.)
- Influence of ventilation control over time
- Specific meteorological conditions (e.g. big pressure differences at portals)
- Effects of fixed fire fighting systems (FFFS)
In 5 years of practical experience new requirements for the application of TuRisMo came up due to:

- An increased relevance of costs as critical factor for investments in tunnel safety
- An increased application of the method for existing tunnels with specific characteristics, requiring a high flexibility of the risk model
- An increased application as decision making tool for complex problems

As a consequence the model was upgraded:

- By implementing new data and additional parameters in the standard model
- By providing a new detailed model with a simulation-based approach for fire risk
Thank you for your attention!

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Thank you for your attention!

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