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

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Outline

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

Upgrading TuRisMo – Methodical and Practical Aspects

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)

Upgrading TuRisMo – Methodical and Practical Aspects

Background

- **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

Tunnel du Lioran; Source: CETU

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.

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■ Methodical components of TuRisMo

Frequency analysis – Relevant parameters

Incident types
Traffic volume

Incident rates
Traffic composition

Ignition
vehicle categories

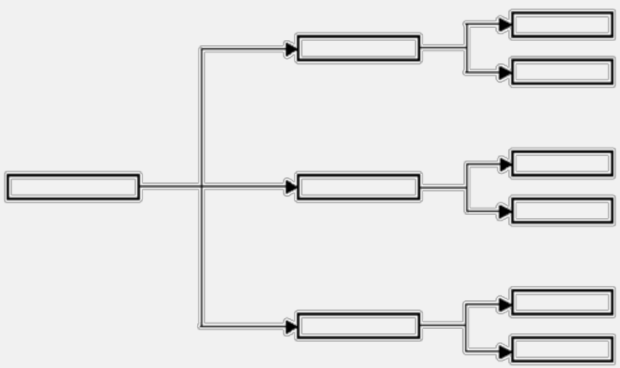
Consequence analysis – Relevant parameters

Tunnel system, technical systems, evacuation, vehicle categories

Results

Event tree

initial event → incident scenarios



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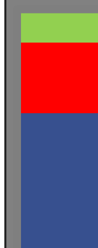
mechanical accidents
(statistics)

fires
(model results)

➔ RISK

Expected risk value
(fatalities/year)

R



Modifications in Risk Model – Frequency Analysis

Modifications in risk model – frequency analysis

Frequency analysis – Relevant parameters

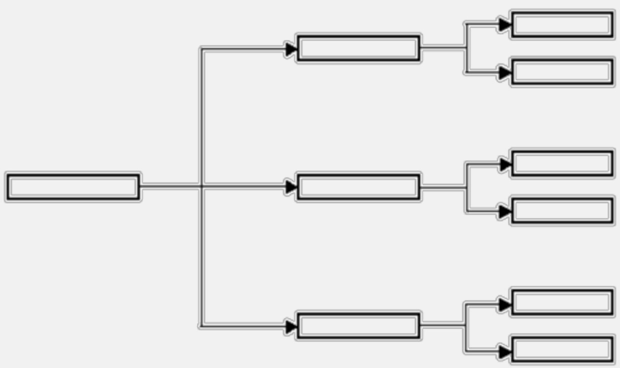
Incident types
Traffic volume

Incident rates
Traffic composition

Ignition
vehicle categories

Event tree

initial event → incident scenarios



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Consequence analysis – Relevant parameters

Tunnel system, technical systems, evacuation, vehicle categories

mechanical accidents
(statistics)

fires
(model results)

RISK

Results

Expected risk value
(fatalities/year)

R

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

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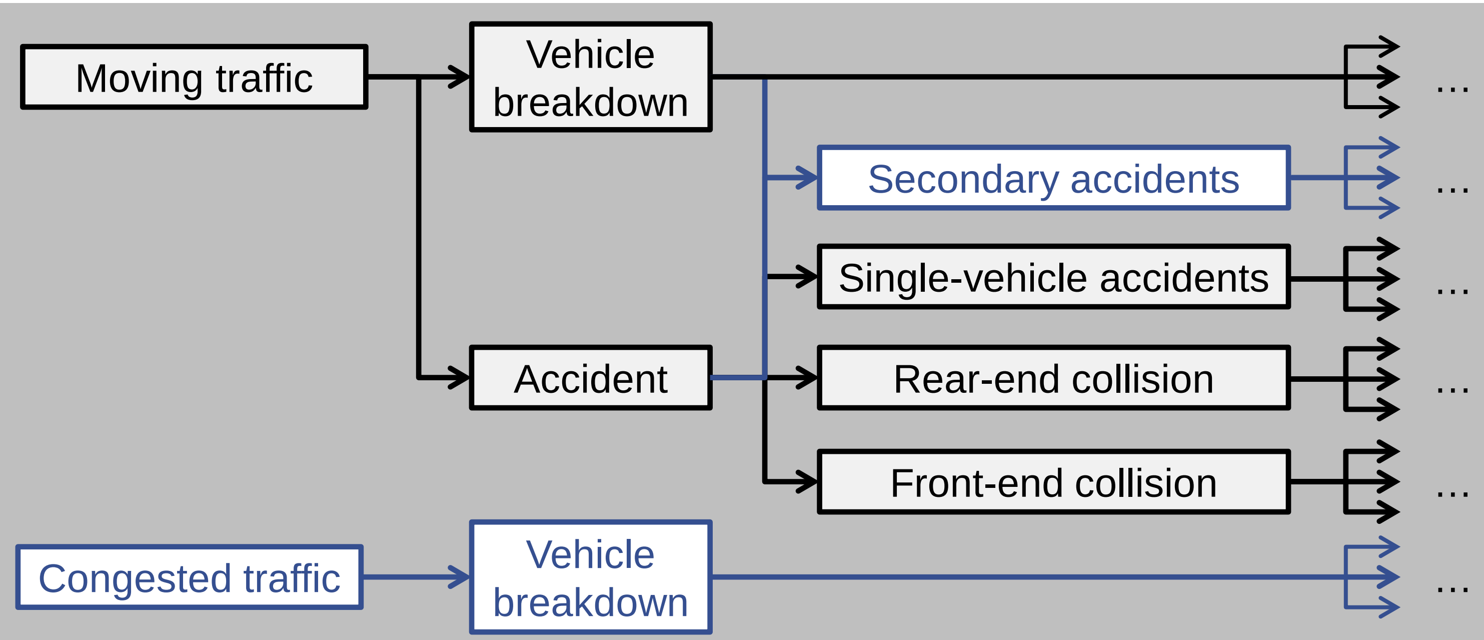
Modifications in Risk Model – Frequency Analysis

- **Implementation by two additional branches in the event tree**



Motivation:

Improved assessment of

- scenarios with congested traffic (high damage potential in fires)
- measures influencing congestion or management of initial events

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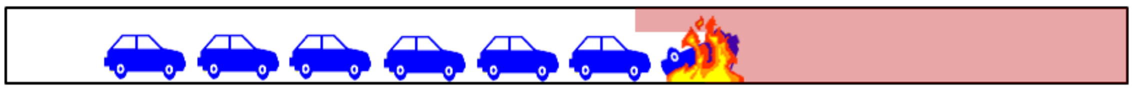
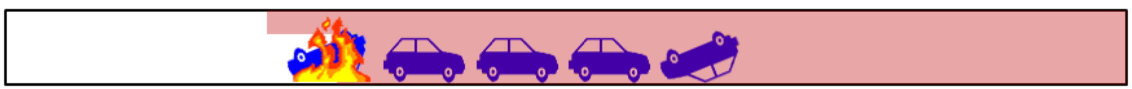
Modifications in Risk Model – Frequency Analysis

- **3 different fire scenarios – with respect to traffic situation and airflow conditions**

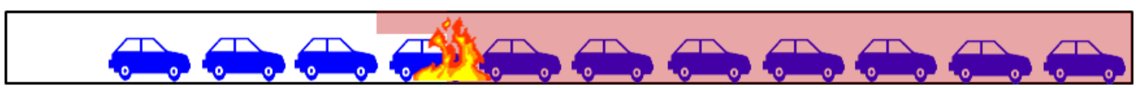
  - Primary fire scenario: fire in normal traffic, vehicles queuing behind scene of event



  - Secondary fire scenario: fire as consequence of a collision at the end of an envolving 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)

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Modifications in Risk Model – Frequency Analysis

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)

Basic collision rates – motorway tunnels		
	Unidirectional	Bidirectional
RVS 09.03.11 – 2008	0,112 / 10^6 veh-km	0,077 / 10^6 veh-km
RVS 09.03.11 – 2014	0,078 / 10^6 veh-km	0,054 / 10^6 veh-km

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)

Vehicle category	Type of fire:	Fire after breakdown
Passenger car		0,0015 / breakdown
HGV		0,01 / breakdown

Type of collision	Type of fire:	Fire after collision
Single car accident		0,012 / collision
Front – end collision		0,006 / collision
Head – on collision		0,020 / collision

- 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

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Modifications in Risk Model – Consequence Analysis

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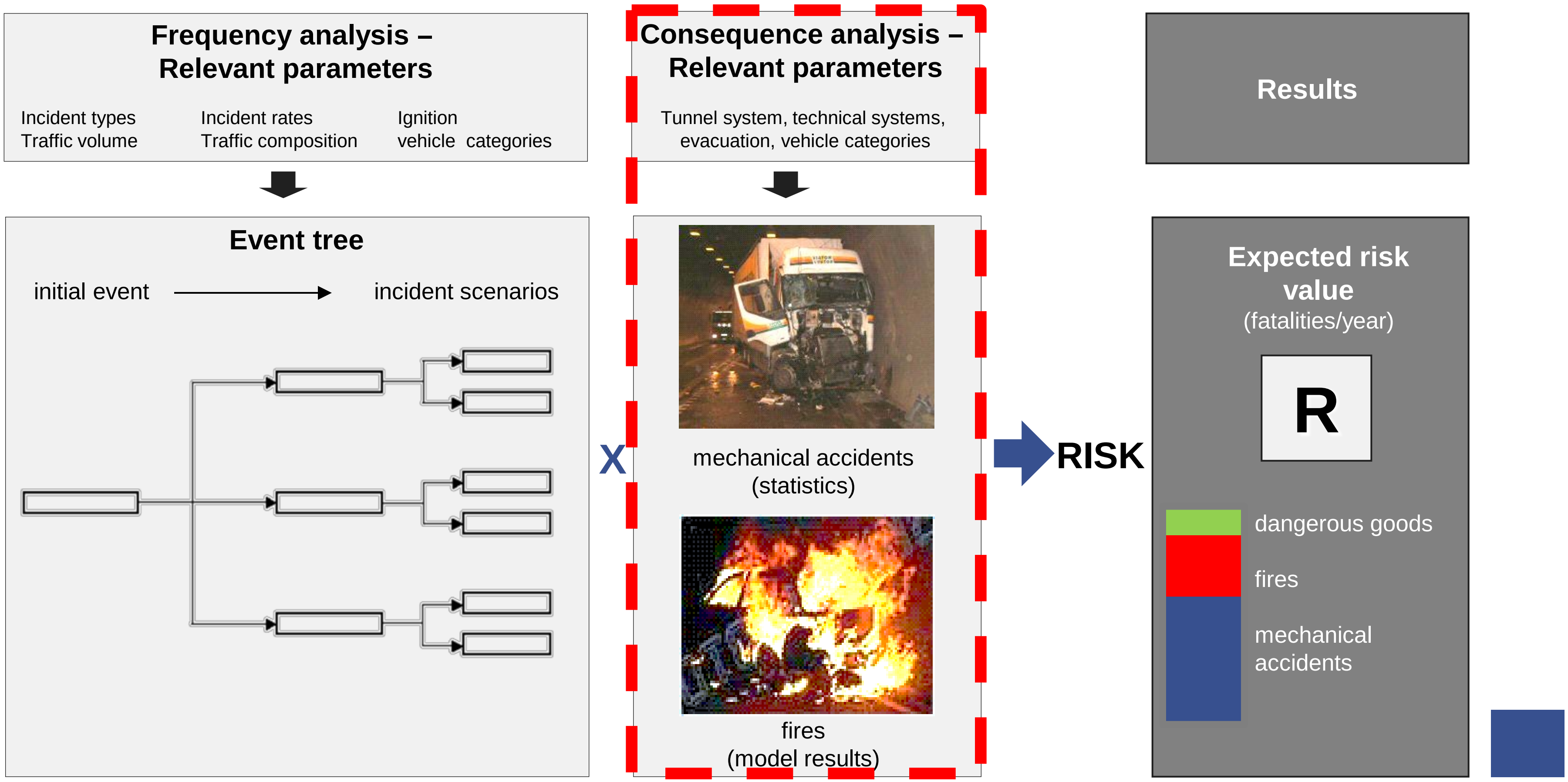
■ Modifications in risk model – Consequence analysis



Modifications in Risk Model – Consequence Analysis

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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

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Modifications in Risk Model – Consequence Analysis

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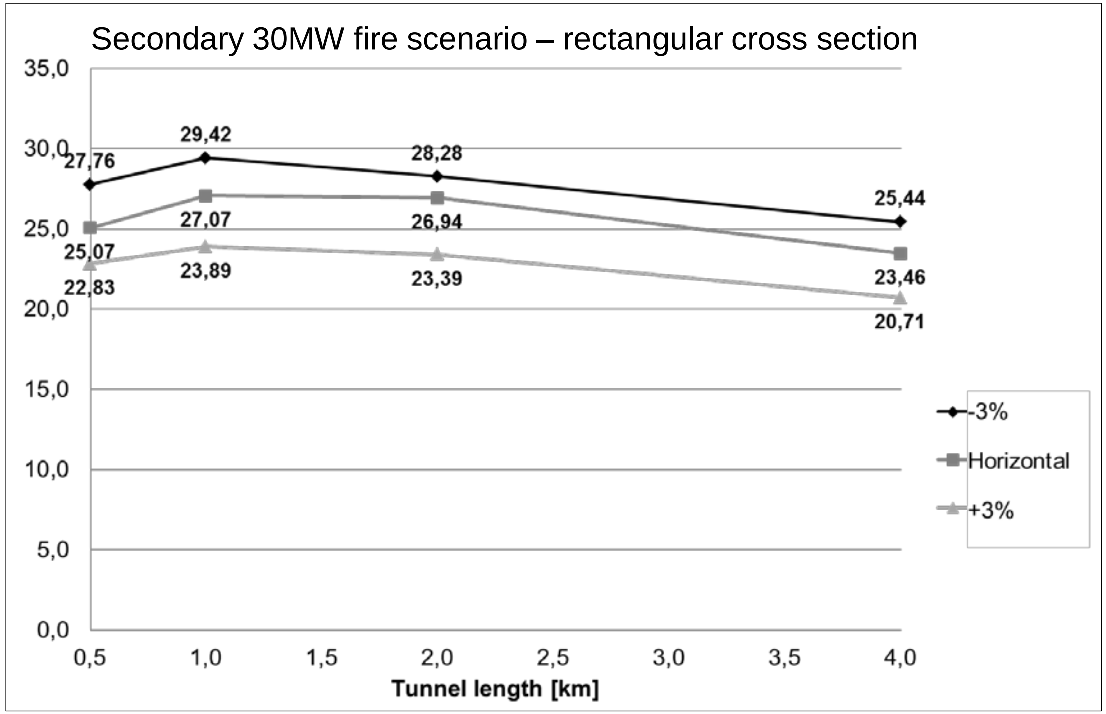
- **Parameters covered by the standard model**

  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

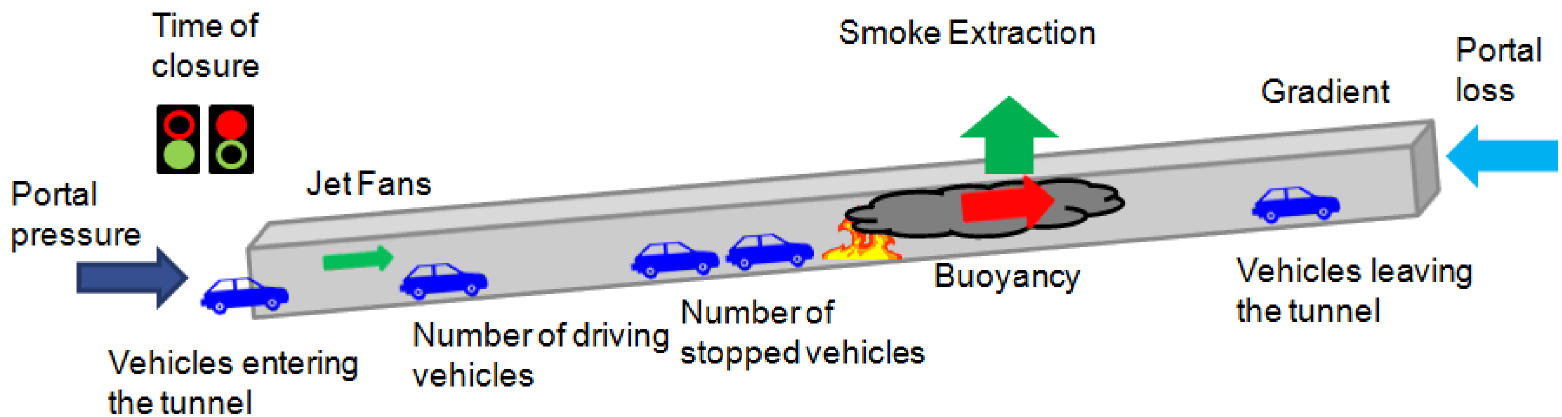


Modifications in Risk Model – Consequence Analysis

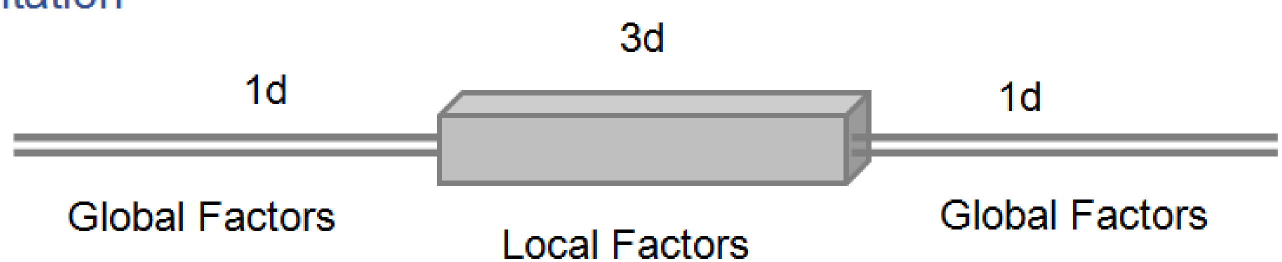
- **Parameters covered by detailed model – smoke propagation**

  Combined transient 1D/3D Simulations

Influencing Factors



Implementation



Modifications in Risk Model – Consequence Analysis

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

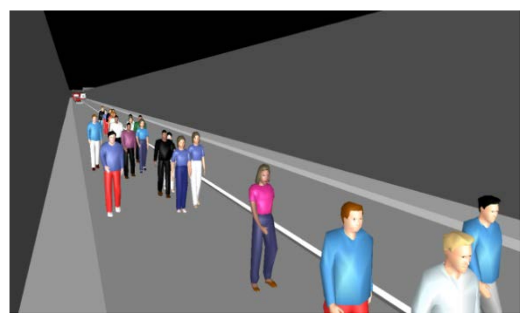
Influencing factors covered by 3D simulation

- 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

Modifications in Risk Model – Consequence Analysis

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)



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

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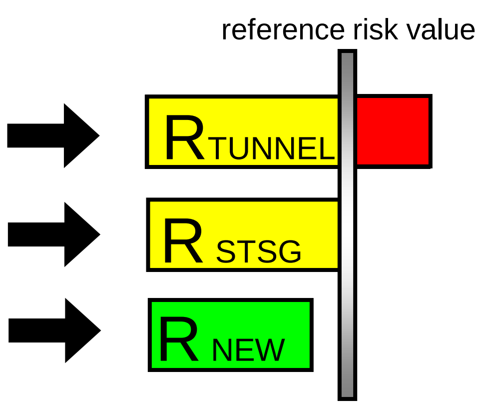
■ **No changes with respect to the basic principles of risk evaluation**

RELATIVE APPROACH

- Risk of tunnel under investigation (special characteristic)
- Risk of reference tunnel (fulfilling minimum safety requirements)
- Modified risk of tunnel under investigation (with risk mitigation measures)



ABSOLUTE APPROACH

- Based on absolute risk value
- Tunnel is assigned to 1 of 4 danger classes
- Danger class determines prescriptive requirements (standard of equipment)

Expected risk value EV		**Danger classes**
Lower limit	**Higher limit**	
-	0,02	I
> 0,02	0,10	II
> 0,10	0,50	III
> 0,50	-	IV

Risk Evaluation and Mitigation Measures

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■ 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

Extended Application

Range of application of standard model (unidirectional tunnel)

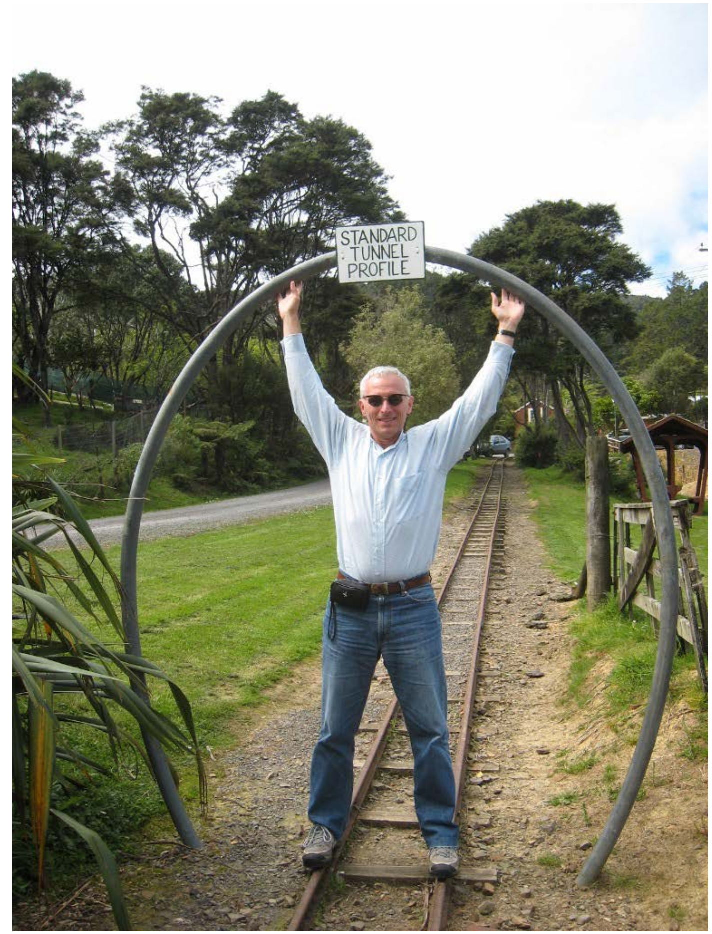
- Natural ventilation, longitudinal ventilation
- Vaulted / rectangular cross section / 2 lanes
- Tunnel length: 0,5 – 8,0 km
  (dependant on cross section type and ventilation system)
- Longitudinal inclination: 0-3% ascending / descending slope
- Distance of emergency exits: 125m – 500m

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 oft he Oresund Tunnel; Source: Oresundsbron

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Extended Application

- **Safety systems**
  - Special characteristics of individual ventilation system (e.g. varying or insufficient capacity, bleakages etc.)
  - Influence of ventilation control over time
  - Specific meteorological conditions (e.g. big pressure differences at portals)
  - Effects of fixed fire fighting systems (FFFS)

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Conclusions

- **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, requiering 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

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7th International Conference "Tunnel Safety & Ventilation" Graz 2014"

Thank you for your attention!

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