Effects of Automatic Fixed Fire Fighting Systems on Tunnel Safety

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Content

- General Context
- Fixed Fire Fighting Systems
- User studies with FFFS
- Results
- Conclusion
Classification of psychologic-behavioral

Safety level/ User safety

Measures
- structural
- operational
- organizational

Consideration
- psychologic-behavioral
- risk-analytical
- economical

social/political/technical influencing factors
Types of FFFS

High pressure systems (up to 150 bar)
- Water mist

Low pressure systems (up to 10 bar)
- deluge
- Compressed air foam
## Regulation for the use of FFFS

<table>
<thead>
<tr>
<th></th>
<th>Germany</th>
<th>Austria</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>guidelines</strong></td>
<td>RABT Draft</td>
<td>RVS</td>
</tr>
<tr>
<td><strong>application</strong></td>
<td>Support of emergency services</td>
<td>Structural protection/availability</td>
</tr>
<tr>
<td><strong>criteria</strong></td>
<td>Individual case by case decision  &gt;3000 m unidirectional traffic &gt;1200 m two-way traffic HRR &gt; 100 MW Other measures do not bring sufficient benefit / uneconomical</td>
<td>Experience of the use of FFFS in a holistic evaluation Detailed requirements which technical and operational criteria are to be observed</td>
</tr>
<tr>
<td><strong>Number of FFFS in operation</strong></td>
<td>2 (type foam)</td>
<td>3 +2 (type high-pressure spray)</td>
</tr>
</tbody>
</table>
User study I: VR study

**Independent comparison of two conditions (each 25 probands)**

**szenario: entry, stop at the fire szenario, then evacuation announcement**

| without activated FFFS | with activated FFFS |

- **VR-tunnel**
  - 1200 m
  - Bi-directional tunnel
  - Equipment according to RABT 2006 + enhancements
  - Activation of the safety elements (announcement, flashing light) shortly before starting up the FFFS
  - FFFS-type: water mist
Independent comparison of two conditions (14/16 probands)

szenario: entry, stop at the fire szenario, then evacuation announcement

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<th>Without activated FFFS</th>
<th>with activated FFFS</th>
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Tunnel Jagdberg, Thuringia

- 3070 m length
- 3 lanes, 2 emergency lanes
- Twin-tube tunnel
- Emergency lay bay every 560m, emergency stations every 140m
- 10 transverse tunnel in a distance of 280m (emergency exits)
- FFFS = measure to allow DG-vehicles in the tunnel
- Foam-based FFFS
Experimental design

- Influence of FFFS
- Fog maschine
- Project leader
- South tube
- Investigation car
Method: szenario

Entrance in the tunnel until the accident with smoke development

In the FFFS group:
- Activation of the FFFS
- 2 min. after FFFS activation

The evacuation announcement begins directly after stopping the vehicle at the accident site

Test duration after the evacuation part *leave the tunnel*: 3 min
**City tunnel Bregenz study: method**

- **Independent comparison of two conditions (26/28 probands single setting) + (3/3 proband pair settings)**
- **Szenario: entry, stop at the fire szenario, then evacuation announcement**

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<tr>
<th>Without activated FFFS</th>
<th>With activated FFFS</th>
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**City Tunnel Bregenz, Austria**

- 1311 m lenghth
- 2 lanes
- Bi-directional tunnel
- One emergency lay bay with emergency station and emergency exit
- **Water mist-based FFFS**
Experimental design

Influence of FFFS

Fog machine

Project leader

tunnel tube

Investigation car
Entrance in the tunnel until the accident with smoke development

In the FFFS group:

Activation of the FFFS

2 min. after FFFS activation

The evacuation announcement begins directly after stopping the vehicle at the accident site

Test duration after the evacuation part *leave the tunnel*: 3 min

Method: *szenario*
Data of behaviour

- Obtained by evaluation of the video recording
  - Head camera, camera at the accident site, 2 cameras in the vehicle, surveillance cameras of the tunnels
- Escape goals
- Time for disembarking
- Walking speed:
  - Distance covered/time during walking
  - Based on behavioural observations

Subjective parameters

- questionnaires
- follow-up survey
  indications from 0 – 100

2. Wie belastend war das Ereignis für Sie?

0..............................................................100
Gar nicht

sehr stark
• Significant difference of the escape goals in FFFS condition (p < .05)
• Water mist (Bregenz): more probands stayed in the vehicle
Time for disembarking

- Principal effect group: no FFFS significant faster than FFFS (p < .05)
- No relevant difference between the FFFS-types (water-mist/ foam)
Walking speed

- Significant interaction effect (p < .05):
  - The probands walking speed in the FFFS-group type water-mist is faster
  - No difference in the walking speed in the investigations with/without foam

- Possible explanation: probands indicated, foam could be slippery
- Water-mist possibly more unpleasant
Subjective ratings

- Water-mist-szenario (Bregenz):
  - less burdensome
  - less dangerous
  - but more realistic

- Foam-szenario (Jagdberg):
  - probands more surprised by activation
    more restricted view in the vehicle

- announcement in Bregenz harder to understand
Proband couple tests

- Higher activity level
- No proband stayed in the vehicle
- Consultation: e.g. one proband went to the accident to help and the other one called the emergency service
- Couples rated the situation as less dangerous (p < .05), but had a lower perception of control (p < .05)
Conclusion

- Not all of the probands left the vehicle within 3 minutes after the announcement started
- Most of the probands evacuated to the emergency exit
- 25% visited the emergency station, although it was expected, that competent authorities were already informed
- The announcement was hard to understand
- Foam impaired the view in the vehicle stronger (without windscreen wiper) and outside the vehicle less than water-mist
• Most of the probands stopped long before the accident site

• In case of activated FFFS type water-mist the probands walked faster
  – foam could be slippery
  – Water-mist: wetter and colder

• passengers seem to influence the behaviour of the tunnel user:
  – More active, leaving the vehicle faster and with a higher probability

• An activated FFFS does probably not hinder the self-rescue, if appropriate measures will be taken
  – important seems to be a comprehensible evacuation-announcement, which shall also be comprehensible by activated FFFS
Thank you for your attention!

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