Rail Tunnel Evacuation

Karl Fridolf, Researcher at SP Fire Research
Background

- BSc in Fire Protection Engineering
- MSc in Engineering, Risk Management and Safety
- Pursuing a PhD in Engineering
  - Thesis defense on June 12
  - Rail Tunnel Evacuation
- President of SFPE Sweden
- Researcher at SP Fire Research
Thesis work: objectives

Increase the knowledge on rail tunnel evacuation in case of fire by presenting:

1. A theoretical framework that can facilitate the understanding of human behavior in the event of fire in underground rail transportation systems.

2. Information and data on:
   a) Human behavior and the flow rate of people during train evacuation in rail tunnels.
   b) Human behavior and walking speeds in smoke-free as well as smoke-filled rail tunnels.

3. Recommendations on how technical installations in rail tunnels can be designed so as to improve the safety for occupants in the event of fire.
Summary of four papers:


## Thesis work: method

### Step 1: Search and review
- Development of theoretical framework (O1)
- Identification of research areas

### Step 2: Data collection in the laboratory
- Evacuation of a train in a rail tunnel (O2a)
- Evacuation of a smoke filled rail tunnel (O2b & O3)

### Step 3: Data collection in the field
- Evacuation of a train in a rail tunnel (O2 & O3)
Thesis work: Evacuation experiment in a smoke filled tunnel

- “Laboratory” experiment
- Objectives
  - Study effectiveness of way-finding systems in a smoke filled tunnel
  - Study movement speeds in a smoke filled tunnel
- Single bore tunnel
  - Emergency signs on both sides
  - Emergency exit
- Artificial “cold” smoke with acetic acid
  - Visibility approximately 0.6-1.6 m
  - Lighting approximately 1 lux
Thesis work: Evacuation experiment in a smoke filled tunnel

- Five experiment scenarios
  1. Evacuation signs (only)
  2. Evacuation signs and green flashing lights
  3. Evacuation signs, halogen spotlight and green and white continuous lights
  4. Evacuation signs and loudspeaker installation
  5. ”Christmas tree”
Thesis work: Evacuation experiment in a smoke filled tunnel

- 100 participants
  - Recruited from general public
  - 18-66 years
  - 56 men/44 women
  - Took part individually
- Data collected with three techniques (descriptive and explanatory)
  - Observation
    - Recorded with thermal imaging camera
  - Questionnaire study
    - Demographics, experiment and the participants’ behaviors, technical installations and perceived benefit of these, and finally feelings during the experiment
  - Interview study
    - Semi-structured interview while participants were shown the video recording of their evacuation and asked to explain their behavior and thoughts during the different sequences of the evacuation
Thesis work: Evacuation experiment in a smoke filled tunnel

- Results
  - New data on walking speeds
  - Importance of walls
  - Light sources every 8 m extremely valuable
    - Uncertainty reduction
    - Orientation
  - Information about distances extremely valuable
    - Easy to understand
  - Requested (among other things)
    - Hand rails
    - Smooth surface
Thesis work: Evacuation experiment in a smoke filled tunnel

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Thesis work: Evacuation experiment in a smoke filled tunnel

<table>
<thead>
<tr>
<th></th>
<th>Participants [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sound</strong></td>
<td>15</td>
</tr>
<tr>
<td><strong>Signs</strong></td>
<td>72</td>
</tr>
<tr>
<td><strong>Light</strong></td>
<td>95</td>
</tr>
<tr>
<td><strong>Heat</strong></td>
<td>4</td>
</tr>
<tr>
<td><strong>Smell</strong></td>
<td>4</td>
</tr>
<tr>
<td><strong>Surfaces</strong></td>
<td>50</td>
</tr>
</tbody>
</table>
### Thesis work: Evacuation experiment in a smoke filled tunnel

<table>
<thead>
<tr>
<th>Walking posture</th>
<th>Hand position</th>
<th>Normal</th>
<th>In front</th>
<th>On wall</th>
<th>Sum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>Normal</td>
<td>38.0%</td>
<td>25.7%</td>
<td>18.2%</td>
<td>81.9%</td>
</tr>
<tr>
<td>Curved</td>
<td>Normal</td>
<td>2.7%</td>
<td>2.9%</td>
<td>12.5%</td>
<td>18.1%</td>
</tr>
<tr>
<td>Sum</td>
<td>Sum</td>
<td>40.7%</td>
<td>28.6%</td>
<td>30.7%</td>
<td>100%</td>
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Thesis work: Evacuation experiment in a smoke filled tunnel

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<th>No choose exit</th>
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<tr>
<td>Evacuation signs (only)</td>
<td>Same</td>
<td>12</td>
<td>12 (100%)</td>
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<td>Opposite</td>
<td>12</td>
<td>8 (67%)</td>
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<td>11</td>
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<td>Evacuation signs and loudspeaker installation</td>
<td>Same</td>
<td>10</td>
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</tr>
<tr>
<td></td>
<td>Opposite</td>
<td>14</td>
<td>14 (100%)</td>
</tr>
<tr>
<td>“Christmas tree”</td>
<td>Same</td>
<td>1</td>
<td>1 (100%)</td>
</tr>
<tr>
<td></td>
<td>Opposite</td>
<td>4</td>
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Thesis work: Evacuation experiment in a smoke filled tunnel

Illustration and photo: Daniel Nilsson
Thesis work: Evacuation experiment in a smoke filled tunnel

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- Important knowledge on human behavior, orientation and walking strategies
- New quantitative data on walking speed in smoke
- Suggestions on exit design; shows need to
  - Test systems for intended context
  - Consider other senses than vision
- Science partners important
  - Useful to include research activities in initial stages of, e.g., large infrastructure projects
  - Best intention and general knowledge not always enough
  - Avoid design mistakes
  - Support engineers in FSE applications (practically)
Thank you!

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