Use of simulators to investigate complex issues relating to human factors

Jürg Suter, Nicole Stoller
1. Complexity in railway systems
2. Measuring situation awareness
3. Use of simulators
4. Conclusions
Complexity in railway systems

Automation

Train operator → Centralization
Train driver → Assistance systems

Important changes in working conditions
Complexity in railway systems

Changes in working conditions

• Staff: change from operator to controller
• Lack of system knowledge
• No more direct communication
• Requirements for management of incidents in a complex socio-technical environment
Complexity in railway systems

Example

Train 60180 stops due to technical disturbance
Complexity in railway systems

Example

Incoming passenger Train 12376

Main signal applied to both tracks

Train 1736 overtaking
Complexity in railway systems

Example

![Diagram of a railway system with a station and main signals applied to both tracks]
Complexity in railway systems

Problem of SPAD (Signal Passed At Danger)

<table>
<thead>
<tr>
<th>Year</th>
<th>Numbers of SPAD in Switzerland</th>
<th>Increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>118</td>
<td>100%</td>
</tr>
<tr>
<td>2011</td>
<td>124</td>
<td>+5%</td>
</tr>
<tr>
<td>2012</td>
<td>136</td>
<td>+15%</td>
</tr>
<tr>
<td>2013</td>
<td>139</td>
<td>+18%</td>
</tr>
</tbody>
</table>
Complexity in railway systems

Problem of SPAD (Signal Passed At Danger)

<table>
<thead>
<tr>
<th>Year</th>
<th>Departure at danger</th>
<th>Error, mistake</th>
<th>Distraction</th>
<th>Confusion of signals</th>
<th>Confusion train and shunting itinerary</th>
<th>Misinterpretation of order</th>
<th>Communication</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>26</td>
<td>9</td>
<td>14</td>
<td>10</td>
<td>4</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>2011</td>
<td>37</td>
<td>35</td>
<td>18</td>
<td>6</td>
<td>5</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2012</td>
<td>30</td>
<td>37</td>
<td>15</td>
<td>7</td>
<td>11</td>
<td>8</td>
<td>1</td>
</tr>
</tbody>
</table>

Q4 Q5 Q3 Q2 Q6 Q1 Q7
Complexity in railway systems

The railway as a system

**Infrastructure**
Tracks
Interlocking
Signalling

**Operation**
Timetable
Trains
Operation management

**Environment**
Landscape
Cultural area
Interfaces

Use of simulators to investigate complex issues
Jürg Suter, Nicole Stoller
Complexity in railway systems

The railway as a system

- Infrastructure
  - Tracks
  - Interlocking
  - Signalling

- Environment
  - Landscape
  - Cultural area
  - Interfaces

- Operation
  - Timetable
  - Trains
  - Operation management

Complexity caused by unpredictable factors:

- Human-machine interface

Use of simulators to investigate complex issues

Jürg Suter, Nicole Stoller
Complexity in railway systems

The railway as a system

• The repercussions on the system of particularly spurious actions are not entirely predictable.

• Human factors are not quantifiable.

• Complexity often arises at human-machine interfaces.

• Simulators are necessary for investigating complex problems.
Measuring situation awareness

Why situation awareness?

• Integral part of the education and training of pilots / air traffic controllers

• Many human factors research studies in aviation, medicine, nuclear power plants

→ Situation awareness is also relevant for train drivers

→ How can we measure situation awareness?
Measuring situation awareness

Definition and model

“The perception of the elements in the environment (…), the comprehension of their meaning and the projection of their status in the near future” (Endsley, 1995)
Measuring situation awareness

Example of situation awareness in railways

Perception level 1
The train driver sees a light signal

Comprehension level 2
He knows what this light combination means

Projection level 3
He knows what has to be done in the next few seconds/minutes
### Measuring situation awareness

**Performance measure**

<table>
<thead>
<tr>
<th>Dilemmas in scenario B</th>
<th>Criteria</th>
<th>yes=2 / no=0</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Only upper lamp of shunting signal working</td>
<td>Has dispatcher been advised?</td>
<td></td>
</tr>
<tr>
<td>2 Traction loss</td>
<td>Start breaking before advance signal?</td>
<td></td>
</tr>
<tr>
<td>3 Speed restriction section 80 km/h</td>
<td>(V_{\text{IST}}) 80 km/h begin signal?</td>
<td></td>
</tr>
<tr>
<td>4 Protective section</td>
<td>Correct process protective section?</td>
<td></td>
</tr>
<tr>
<td>5 Exit signal closed (neighbouring signal open)</td>
<td>Is process correct?</td>
<td></td>
</tr>
<tr>
<td>6 Advance signal 60 km/h</td>
<td>Main signal 60 km/h?</td>
<td></td>
</tr>
<tr>
<td>7 Extra-stop at Zürich-Altstetten</td>
<td>Has train stopped at Zürich-Altstetten?</td>
<td></td>
</tr>
<tr>
<td>8 <strong>Incoming emergency call/unclear voice</strong></td>
<td>Line-of-sight driving ((V_{\text{max}} \leq 40 \text{ km/h}))?</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Has dispatcher been advised?</td>
<td></td>
</tr>
<tr>
<td>10 Only lower lamp of shunting signal working</td>
<td>Has train been stopped?</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Has dispatcher been advised?</td>
<td></td>
</tr>
</tbody>
</table>

→ **Performance score**
Measuring situation awareness

Self rating assessment

→ Self-rating score
Use of simulators

Requirements for simulators

• Case studies with train drivers
• Interaction between train dispatchers and train drivers
Use of simulators

The driving simulator (Re 460)
Use of simulators

Execution of tests

• 20 train drivers
• Each train driver drove the two scenarios:
  • one with time pressure
  • one without time pressure
  → 2 performance scores
• Self-rating SART after each scenario
  → 2 self-rating scores
Use of simulators

Situation awareness

• Effect of time pressure on performance: not significant
• Effect of time pressure on self-rating: not significant

• BUT final sequence of scenario (dilemmas 8-11): significantly lower performance in scenarios with time pressure

→ Time pressure has a negative effect on performance in situations with an increased workload
→ The effect of stressors on a train driver’s situation awareness should be further investigated
Use of simulators

Data sample of driving simulator

Graph showing the speed (km/h) over time (seconds) with and without time pressure. The x-axis represents the time before and after the approach signal Rupperswil, and the y-axis represents speed (km/h). Two lines indicate the data with and without time pressure.
Use of simulators

Data sample of driving simulator

Entry signal: 40 km/h

Distant signal: disturbed

Geschwindigkeit (km/h)

Streckenkilometer (km), Einfahrt Brugg

with time pressure

without time pressure
Use of simulators

Mistakes **without** time pressure

- Break control
- Signal: to advise dispatcher
- Speed restriction 80 km/h
- Protective section
- Exit signal closed
- Advance signal 80 km/h
- Extra-stop at Zürich Altstetten
- To close the doors
- Incoming emergency call
- To advise dispatcher
- Disturbed shunting signal
- To advise dispatcher

<table>
<thead>
<tr>
<th>Task</th>
<th>Mistakes</th>
<th>Partially Correct</th>
<th>Correct</th>
</tr>
</thead>
<tbody>
<tr>
<td>Break control</td>
<td>100%</td>
<td></td>
<td>0%</td>
</tr>
<tr>
<td>Signal: to advise dispatcher</td>
<td>100%</td>
<td></td>
<td>0%</td>
</tr>
<tr>
<td>Speed restriction 80 km/h</td>
<td>100%</td>
<td></td>
<td>0%</td>
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<td>Protective section</td>
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</tr>
<tr>
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<td></td>
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<td>100%</td>
<td></td>
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<td>Extra-stop at Zürich Altstetten</td>
<td>100%</td>
<td></td>
<td>0%</td>
</tr>
<tr>
<td>To close the doors</td>
<td>100%</td>
<td></td>
<td>0%</td>
</tr>
<tr>
<td>Incoming emergency call</td>
<td>100%</td>
<td></td>
<td>0%</td>
</tr>
<tr>
<td>To advise dispatcher</td>
<td>100%</td>
<td></td>
<td>0%</td>
</tr>
<tr>
<td>Disturbed shunting signal</td>
<td>100%</td>
<td></td>
<td>0%</td>
</tr>
<tr>
<td>To advise dispatcher</td>
<td>100%</td>
<td></td>
<td>0%</td>
</tr>
</tbody>
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Use of simulators

Mistakes with time pressure
Conclusions

Need for detailed simulators
Conclusions

Interlocking and driving simulator

The investigation of complex problems in the fields of railway operation requires an integrated simulator system: simultaneous participation of train drivers and train operators.
Conclusions

Interlocking and driving simulator
Thank you for your attention
Any Questions?

→ www.desm.ch