Safety-Relevant Scenarios for Teleoperated Driving of Highly Automated Vehicles (SAE Level 4) in the Context of Public Transport

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Teleoperation: A Technology to Bridge the Gap

• Fully automated vehicles (AVs) at SAE L5 without requiring human support not feasible in the next few years
• **Teleoperation**: promising approach to bridge the gap between current technological shortcomings and the effective use of AVs
• Teleoperation = monitoring and controlling devices including vehicles remotely by “Technical Supervisor“
  • **Advantage**: Vehicle’s automation does not need to fulfil all ODDs (operational design domains) to become operable
• **Objective**: Human-machine interface (HMI) for the teleoperation of AVs needs to be developed in a user-centered design process → Basis for this process: deriving and analyzing relevant scenarios
Design Process

- Observation and expert interviews
- Deriving potential tasks
- Deriving potential scenarios
- Deriving user requirements
- Designing prototype of workplace
- Conducting user tests and evaluation
Definition of Scenarios

Relations between *use case cluster* (UCC), *use case* (UC), *scenario*, and *scene* (adapted from Ulbrich et al., 2015; Wilbrink et al., 2018)
Sources of Scenarios

Sources

- Control Centers
  - Participatory Observation
  - Interviews with Staff
- Traffic Environment
  - Video-Based Interaction Analysis
- Highly Automated Vehicle
  - Structured Interviews with On-Board Operators
- Projects
  - Project-Specific Context
Current Research Projects (Selection)

RealLabHH
33 Mio. € - national
On-demand shuttle service integrated in public transport in Hamburg
Design and evaluation of an workstation for teleoperation

U-Shift 33
3.6 Mio. € - national
Modular vehicle concept: automated driveboard and capsules
Design of a workstation for teleoperating driveboard + capsules

AHEAD
< 1 Mio. € - with WFP
Transporting aid supplies to crisis regions using automated amphibious vehicles
Design of an HMI for teleoperating the amphibious vehicle

Hi-DRIVE
37 Mio. € - EU H2020
Large-scale trials of connected and automated driving → Teleoperation to extend ODDs
Interaction strategies for teleoperation and design of workstations
Model of Interaction

Passengers

Technical Supervisor

Highly Automated Vehicle (SAE L4)

Additional Actors

Context
Structure of Scenarios

**UCC**
- Disposition

**UC**
- Extraord. Demand
- Maintenance
- Charging
- Mending

**Interaction TS – Passengers**
- Conflicts
- Incidents Requiring TS's Intervent.
- Incidents Not Requiring TS's Intervent.

**Interaction TS – AV**
- Initiated by AV
- Initiated by TS
- Unclear Initiator

**Interaction TS - Add. Actors**
- Internal Actors
- External Actors
- Infrastructural

**Interaction AV - Add. Actors**
- Car2Infrastucture
- Car2Car
- Other Infrastructural
- Other TPs

**State TS**
- Sickness

**Contextual Factors**
- Weather

**Technical Malfunction**
- Internal Cause
- External Cause
- Unknown Cause

**TS** = Technical Supervisor (teleoperator in the control center); **TP** = Traffic Participant
Chain of Cause and Consequence (CCC)

- **Cause**
- **Incident**
- **Consequence**
- **Required Measures**

**Sender**

**Recipient**
Template for Scenario

Generic template:

<Incident> happens. This is due to <Cause> and results in <Consequence>. The information about the incident is transmitted from <Sender> to <Recipient>. Required measures are: <Required measures>.

Example:

The fire alarm is activated. This happens because there is smoke from cigarettes. This results in the AV not being able to operate further. The information about this is transmitted from the AV to TS. Required measures are: TS makes an announcement through the on-board speaker that smoking is prohibited on the AV; if necessary, they expel the smoking passenger from the AV.
<table>
<thead>
<tr>
<th>Szenario 1</th>
<th>Anmerkung Szenario 1</th>
<th>1. - Ursache / Wurzel passiv</th>
<th>2a. - Wirkung / Fälligkeit</th>
<th>2b. - Detaillierung / Wurzel regel</th>
<th>2c. - Empfind</th>
<th>3. - Folgen / Wozu geführt</th>
<th>4. - notwendige Handlungen</th>
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</thead>
<tbody>
<tr>
<td>AV keine Energiequelle</td>
<td>AV Aufgaben nicht gestellt</td>
<td>AV nicht operieren</td>
<td>AV muss geplant werden</td>
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Next Steps

• Conducting a validation study to evaluate the catalogue of scenarios

  • **Method:** Questionnaire-based interview
  • **Participants:** Group of experts from public transportation facilities and associations and potential users
  • **Dependent variables:**
    (1) Probability for a scenario’s occurrence
    (2) Criticality for safe teleoperation
    → **Priority score** will be calculated from product of probability and criticality
  • **Purpose:** Priority classification will help understand most pressing security-relevant scenarios, among others, and provide a pathway to address them effectively

• Deriving **user requirements** and developing **HMI prototype** for teleoperation workstation
• Using requirements to create a **checklist** for assessing the quality of a Technical Supervisor’s workstation from a human factors perspective
• Using requirements to compile **guideline** for process of selecting and training Technical Supervisors
Thank You for Your Attention!

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• Simon Ulbrich, Till Menzel, Andreas Reschka, Fabian Schuldt, and Markus Maurer. 2015. Defining and Substantiating the Terms Scene, Situation and Scenario for Automated Driving. In IEEE International Annual Conference on Intelligent Transportation Systems, 982–988. https://doi.org/10.1109/ITSC.2015.164