Evaluation methodology for automated vehicles in AdaptIVe and beyond
Evaluation Areas

User-Related Assessment

Technical Assessment

Impact Assessment
Evaluation Approach in AdaptIve

What should be assessed?

Classification
- Operation time
- Level of automation

Evaluation
- User-related
- Technical
- In traffic

How should it be assessed?

Function/System

Impact Assessment
- Safety
- Environment
Definitions for the Evaluation

- **Traffic Scenario**: A traffic scenario describes a larger traffic context, which includes different (not pre-defined) driving scenarios.

- **Driving Scenario**: A driving scenario is the abstraction and the general description of a driving situation without any specification of the parameters of the driving situation.

- **Driving Situation**: A driving situation is a specific driving manoeuvre (e.g. a concrete lane change with defined parameters).
Classification of Automated Driving Functions

- Classification by SAE levels

- Classification by operation time:
  - **Event based operating**
    - Function that is only active for a short period in time (typically vehicle stands still at the end or the automated driving ends)
    - Examples: Parking, Minimum Risk Manoeuvres
  - **Continuously operating**
    - Function that is active for a longer period in time (typically vehicle is still moving at the end of an manoeuvre respectively automated driving is continued)
    - Example: Highway Pilot
Evaluation Tools

- Several evaluation tools are available today
  - Relevant elements (driver, vehicle & function, environment) are either real or virtual
- Which tool should be applied for which type of assessment?

<table>
<thead>
<tr>
<th>Tool</th>
<th>Application</th>
<th>R</th>
<th>R</th>
<th>R</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field Operational Test</td>
<td>• Impact assessment in reality</td>
<td>R</td>
<td>R</td>
<td>R</td>
</tr>
<tr>
<td></td>
<td>• Assessment of behaviour/components/systems</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Controlled Field</td>
<td>• Assessment of components and systems</td>
<td>R</td>
<td>R</td>
<td>R \ V</td>
</tr>
<tr>
<td></td>
<td>• Assessment of driver behaviour</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dynamic Driving Simulator</td>
<td>• Assessment of driver behaviour</td>
<td>R</td>
<td>V</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td>• Human machine interaction</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Simulation</td>
<td>• Virtual layout and assessment</td>
<td>V</td>
<td>V</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td>• Potential impact assessment</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

R: real, V: virtual
Evaluation Tools in AdaptIVe

- Identification of an appropriate evaluation methodology for the technical, user-related, in-traffic behaviour and impact assessment
  - Systematic analysis of the different test tools
  - Consideration of automation level and operation time

<table>
<thead>
<tr>
<th>Tool</th>
<th>Technical</th>
<th>User-related</th>
<th>In-traffic</th>
<th>Impact</th>
<th>R</th>
<th>V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field Operational Test</td>
<td>Yes Continously</td>
<td>Yes</td>
<td>(Yes)</td>
<td>No</td>
<td>R</td>
<td>R</td>
</tr>
<tr>
<td>Controlled Field</td>
<td>Yes Event-based</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>R</td>
<td>R</td>
</tr>
<tr>
<td>Dynamic Driving Simulator</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>R</td>
<td>V</td>
</tr>
<tr>
<td>Simulation</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>V</td>
<td>V</td>
</tr>
</tbody>
</table>

R: real, V: virtual
### Evaluation Methodology Technical Assessment

- Identification of an appropriate evaluation methodology for the technical, user-related, in-traffic behaviour and impact assessment
  - Example for technical assessment

<table>
<thead>
<tr>
<th>Event-based</th>
<th>Continuous</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1.</strong> Defining evaluation scope</td>
<td><strong>1.</strong> Defining evaluation scope</td>
</tr>
<tr>
<td>• Definition of research questions, hypotheses &amp; indicators</td>
<td>• Definition of research questions, hypotheses &amp; indicators</td>
</tr>
<tr>
<td><strong>2.</strong> Planning of assessment</td>
<td><strong>2.</strong> Planning of assessment</td>
</tr>
<tr>
<td>• Analyse system description and adaption of hypotheses</td>
<td>• Analyse system description and adaption of hypotheses</td>
</tr>
<tr>
<td>• Planning of test cases</td>
<td>• Planning of test cases and test route</td>
</tr>
<tr>
<td>• (Risk assessment)</td>
<td>• Definition evaluation criteria (distributions &amp; boundaries)</td>
</tr>
<tr>
<td><strong>3.</strong> Tests in controlled field</td>
<td><strong>3.</strong> Pre-/component tests in controlled field</td>
</tr>
<tr>
<td>• Number of test variations</td>
<td>• Basic tests of functionality</td>
</tr>
<tr>
<td>• Logging of test data</td>
<td>• Sensor tests</td>
</tr>
<tr>
<td><strong>4.</strong> Assessment of tests</td>
<td><strong>4.</strong> Tests in real traffic</td>
</tr>
<tr>
<td>• Analysis of hypotheses based on test data &amp; indicators</td>
<td>• Test route and test amount to be determined</td>
</tr>
<tr>
<td></td>
<td><strong>5.</strong> Assessment of tests</td>
</tr>
<tr>
<td></td>
<td>• Analysis of hypotheses based on test data &amp; indicators</td>
</tr>
</tbody>
</table>
Solutions - Baseline for the evaluation

- Description of the baseline for the evaluation
  - Objectives of automated driving functions
    - Objective is a collision free traffic
    - Operation in mixed traffic conditions ( → not disturbing normal traffic)
  - The functions have to be operated within range of normal driver behaviour (and beyond)

→ Data on human driving performance are required
  Analysis of field tests data (euroFOT), in-field observations (parking behaviour), studies and test drives (lane change)
Baseline for the evaluation

- Analysis of euroFOT data
- Acceleration during normal driving
- Data from 98 vehicles
- Motorway, rural roads and urban roads

![Graph showing acceleration and frequency distribution](Motorway Longitudinal Acceleration [m/s^2] Lateral Acceleration [m/s^2] Frequency [km^-1])

- 100
- 10
- 1
- 0.1
- 0.01
- 0.001
- 0.0001
- 0.00001
- 0.000001
Evaluation beyond AdaptIVe

• Challenge for the evaluation of automated driving:
  – How to ensure a comprehensive evaluation of automated driving functions, which covers nearly all possible driving situations?
Evaluation beyond AdaptIVe

- Why using simulation:
  - Limitation of resources of real world tests effort
  - Variation of the situations can be covered (Monte Carlo Approaches)

In the end a trade-off between real world and virtual testing will be required.

Type of assessment and stage of the assessment
Thank you.

Christian Rösener
Institut für Kraftfahrzeuge (ika)
RWTH Aachen
Mail: roesener@ika.rwth-aachen.de