SIP-adus Workshop 2018

A Traffic-based Method for Safety Impact Assessment of Road Vehicle Automation

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Dr.-Ing. Adrian Zlocki, Christian Rösener, M.Sc., Univ.-Prof. Dr.-Ing. Lutz Eckstein

Forschungsgesellschaft Kraftfahrwesen mbH Aachen
Motivation
Public View on Automated Driving

How SAFE is Automated Driving?

► Research Question
What is the safety level of automated driving?

► Methodology
A Traffic-based Method for Safety Impact Assessment of Road Vehicle Automation
Evaluation Methodology
Impact Assessment vs. Safety Assurance

Impact Assessment
- Effectiveness
- Acceptance
- Efficiency
- "Usability"

Safety Assurance
- Safety of Interaction
- SOTIF
- Behavioral Safety
- Operational Safety
- Controllability & Functional Safety

Evaluation Methodology
Impact Assessment vs. Safety Assurance

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Analysis of Automated Driving Field Test Data

Scenario Classification of Real-World Data

Parameter x

Parameter y

Parameter z

Effectiveness field

New generated situations

Variation of measured situations

Accident data

FOTs

Impact Assessment of Automated Driving
Driving Scenarios from Accident Type

Example: Passive Cut-In

646 - Overtaking
Overtaking on carriageway

643 – Decelerating Cut-In (left)

631 – Decelerating Cut-In (right)
Approach: The **types of driving scenarios**, respectively physical accident constellations, do not change with automated driving.

The **frequency of occurrence** and the **severity** of these driving scenarios may change with automated driving.
Impact Assessment of Automated Driving
Definition of Methodology for Impact Assessment

3 Driving scenario-based estimation of effectiveness field

1 Automated driving function
2 Definition of Scenarios
3 Derivation of Effectiveness Field
4 △ Frequency of Occurrence of driving scenarios
5 △ Severity in driving scenario
6 Impact of automated driving function

△f(Sₙ)

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Impact Assessment of Automated Driving

1 Definition of automated driving function and 2 scenarios

2 Motorway-Chauffeur

Automation level (SAE): 3

Operational design domain (ODD):

Operation domain:

Relevant driving scenarios:

- Driving accident
- Approaching static Object
- Approaching vehicle
- Traffic Jam
- Lane change
- Cut-in
- Take over
- Approaching lateral Object
- Crossing intersection
- Turn around
- Turn at intersection
Impact Assessment of Automated Driving

Effectiveness Field and Scenario Classification

Scenario „Approaching vehicle“

Scenario „Cut-in of other vehicle“

Scenario „Lane change“

Parameter x

Parameter y

Parameter z

Effectiveness field

Accident data

FOTs
Driving scenario-based estimation of effective field

Accidents in Germany according to ODD

Accidents in Germany in 2016
308,145 A(P)

- Rural road: 25%
- Municipal road: 38%
- County road: 14%
- Federal highway: 17%
- Federal motorway: 6%

Accidents in domain „Motorway“
19,010 A(P)

- not addressable driving scenarios: 14%
- no car participation: 11%
- driver and vehicle related limits: 11%
- functional limits: 17%
- Effectiveness field: 47%
Driving scenario-based estimation of effective field

Input data for scaling-up and simulation

### Driving scenarios in effectiveness field
9.395 A(P)

- Approaching static object: 2%
- Approaching leading vehicle: 43%
- Approaching traffic jam: 18%
- Lane change: 18%
- Driving accident: 17%
- Passive cut-in: 16%

### Number of accidents for scaling-up of effectiveness

<table>
<thead>
<tr>
<th>Driving scenario</th>
<th>Accidents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passive cut-in</td>
<td>1.219</td>
</tr>
</tbody>
</table>

### Accident statistics

- GIDAS
- FOT

### Situational variables for effect of function by simulation

- $v_1 = 67$ km/h
- $v_2 = 93$ km/h
Safety Impact Assessment of Automated Driving

Identification of \( \Delta \) frequencies of driving scenarios

\[ \Delta f(S_n) \]
Identification of $\Delta$ frequencies of driving scenarios

4 FOT-data
Impact Assessment of Automated Driving

Identification of $\Delta$ Frequency from FOT Data
Identification of \( \Delta \) frequencies of driving scenarios

Traffic simulation
Severity in driving scenarios by re-simulation

Simulation framework

- Human driver performance models from driving simulator study/FOT for reference

Driving scenario "passive cut-in"

Simulation of reference

Simulation with ADF

Severity
Safety Impact Assessment of Automated Driving

Impact Assessment Results
Safety Impact Assessment of Automated Driving

Impact Assessment Results

Accidents with personal injuries per year

- accidents in domain, of them
- without involvement of passenger car
- outside the functional limits
- none or ambiguous effect
- avoided

Traffic Jam – Chauffeur

Motorway – Chauffeur

Commuter – Chauffeur

Universal – Chauffeur

Urban Robot – Taxi
Safety Impact Assessment of Automated Driving

Impact Assessment Results

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Traffic Jam-Chauffeur
Motorway-Chauffeur
Commuter-Chauffeur
Universal-Chauffeur
Urban Robot-Taxi

% effectiveness in domain

Motorway-Chauffeur
Traffic Jam-Chauffeur
Commuter-Chauffeur
Universal-Chauffeur
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Motorway-Chauffeur
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% effectiveness in domain
Key results

- Motorway-Chauffeur can reduce **30 % of all accidents** on **German motorways** at a market **penetration of 50 %**. This equals **2 % of all accidents on German roads**.

- The Urban Robot-Taxi **can avoid 26 % of all accidents** with personal injury within city-limits at a market **penetration of 50 %**. This equals **17 % of all accidents on German roads**.

- However, there will be accidents remaining that automated vehicles cannot avoid (due to weather conditions or physics). But we can show that a human cannot avoid these accidents either.
Piloting Automated Driving on European Roads
L3Pilot – Real World Data for Impact Assessment

- Large-scale Level 3 piloting
- 1,000 test drivers, 100 vehicles in 11 European countries
- EC funded in Horizon 2020
- 34 partner

- Website: http://www.l3pilot.eu
L3Pilot
Evaluation Levels

Data Management

Technical & Traffic Evaluation

User evaluation

Impact Evaluation

Socio-economic impact evaluation

Single Vehicle  
Fleet  
Europe

Subjective data

Objective driving data

\[ \Delta \text{ Frequency of driving scenarios} \\
\Delta \text{ DMs, PI}s \text{ per driving scenarios} \]

e.g. Effect in Transition of control  
Long-term effects, usage

Safety impact (e.g. avoided accidents)  
Environmental impact (e.g. fuel consumption)  
on European target level
L3Pilot Evaluation Workflow

**Fleet**
- Vehicles – Obj. Data
- Subj. Data

**Data**
- CDF Time series data
- Digital version

**Evaluation**
- Technical Evaluation
- Technical & Traffic Evaluation
- User & Acceptance Evaluation
- User Evaluation

Performance Indicators per driving scenario

Other inputs (e.g. accident & baseline data)

Impact Assessment

Socio-Economic Impact Assessment

Estimated Impacts

Socio-Economic Impact Assessment
Summary

- Prospective safety **impact assessment** for automated driving requires new methodologies.

- Automated driving provides many challenges with regards to impact assessment since **limited real world data is available yet** and many new aspects (e.g. user-interaction) needs to be taken into account.

- Safety impact assessment shows **positive results** with different automation function.

- Current research in L3Pilot start **data collection for safety impact assessment**.

- Safety Impact Assessment in L3Pilot will provide results based on **data from vehicles combined with simulation** for the first time.
THANK YOU FOR YOUR ATTENTION!

QUESTIONS?

Dr.-Ing. Adrian Zlocki
fka Forschungsgesellschaft Kraftfahrwesen mbH Aachen
Steinbachstr. 7
52074 Aachen
Germany

Phone  +49 241 80 25616
Fax    +49 241 8861 110
Email  zlocki@fka.de
Internet www.fka.de