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Helsinki
June 19th, 2014

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*Automated Driving Applications and
Technologies for Intelligent Vehicles*

Evaluation of automated driving functions

ITS Europe 2014



// Agenda

- Test and Evaluation in General
- SP „Evaluation“ in Adaptive
 - Research Questions for Evaluation
- Evaluation of Automated Driving Functions in Adaptive
 - Technical Assessment
 - Safety Impact Assessment

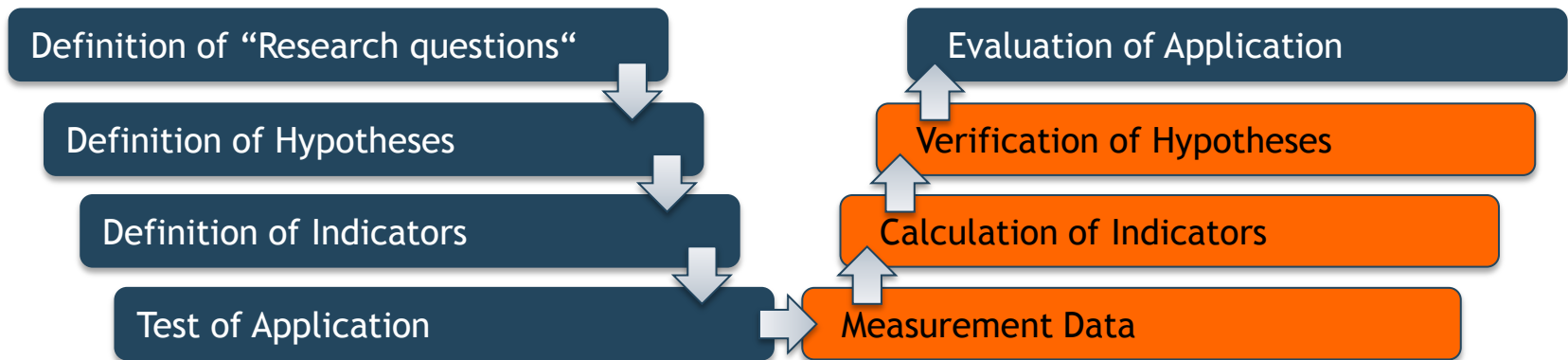
// Test and Evaluation Methodology in Research Projects

Methodology for the evaluation in research projects:

- Step 0: System and function description
- Step 1: Expected impact and hypotheses
- Step 2: Test scenario definition
- Step 3: Evaluation method selection
- Step 4: Measurement plan
- Step 5: Test execution and analysis

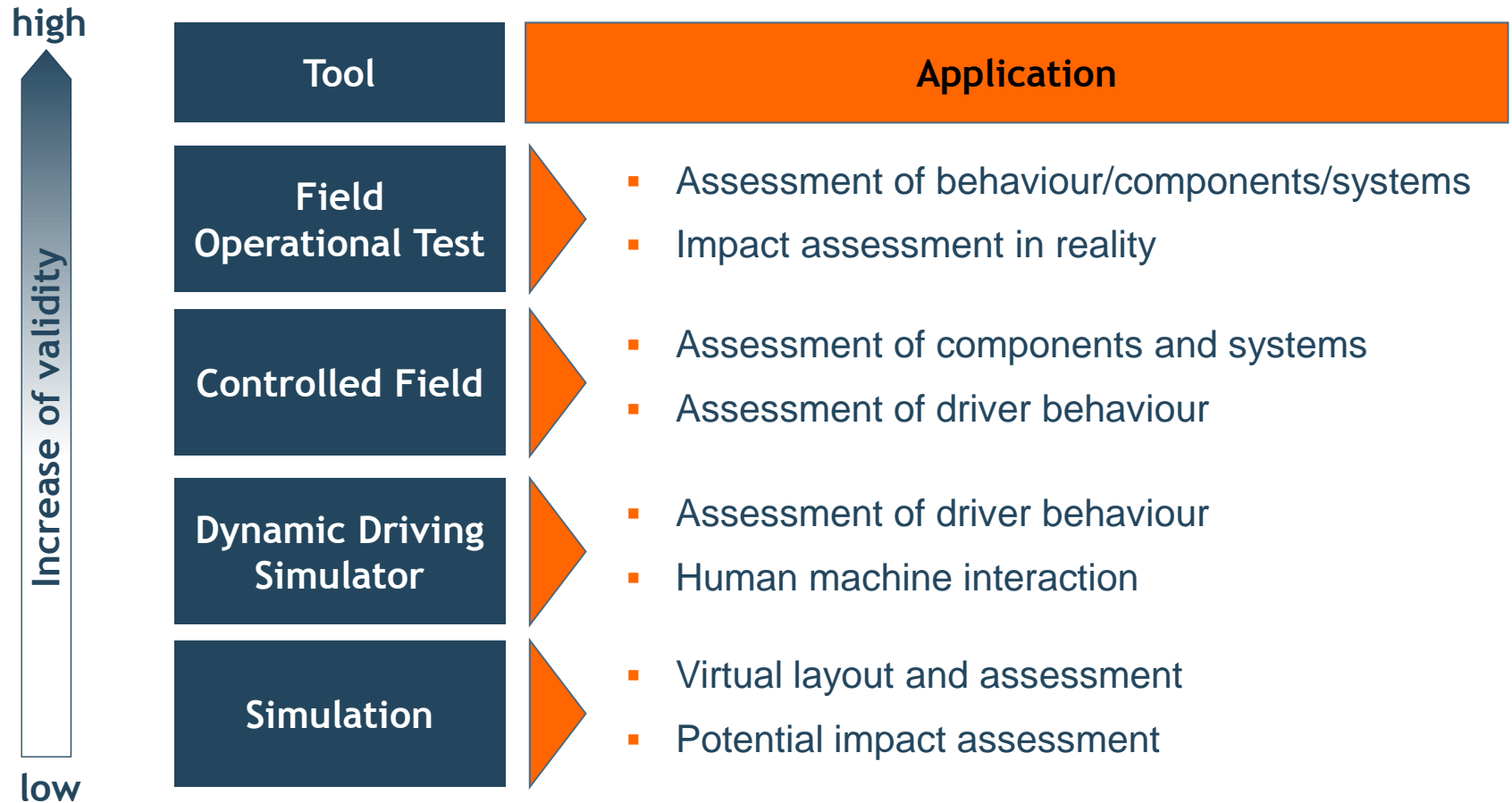
Areas of evaluation: Technical, User-related and Impact Assessment

Assessment of the whole functions (not components)



// Test and Evaluation

Selection of Tools and Methods



// Research Questions in AdaptIVe

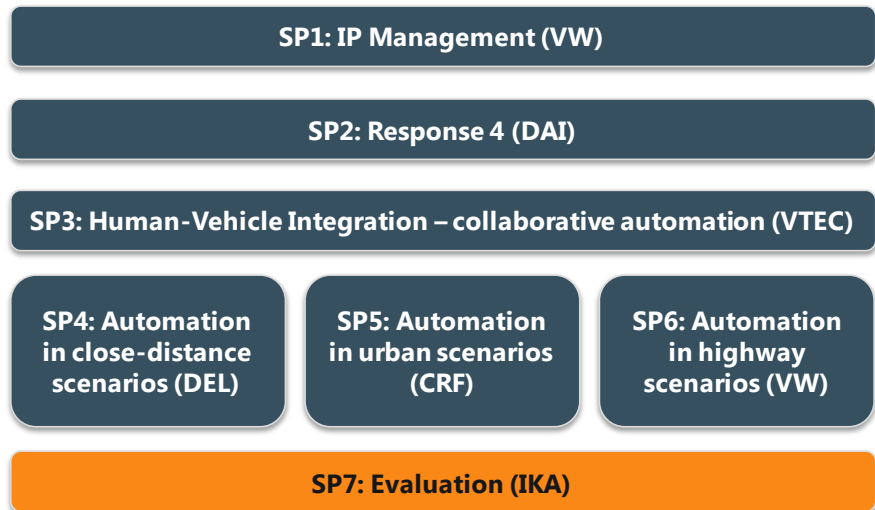
- How is an evaluation framework for supervised automated driving defined?
- What are the requirements for the evaluation of supervised automated driving?
- What are evaluation criteria for supervised automated driving?
- Which tools are necessary for the evaluation of supervised automated driving?
- How is a impact assessment methodology for supervised automated driving defined?
- What is the impact of supervised automated on safety and environment?



EVALUATION?

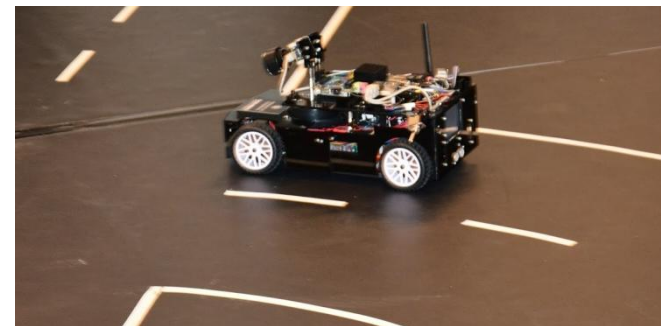
//AdaptIVe: SP „Evaluation“

- Main objectives:
 - Development of an evaluation framework for automate driving functions
 - Methodology for impact analysis of automated driving applications
- Detailed objectives:
 - During the evaluation the developed methods will be applied on selected functions in order to verify the evaluation methods
 - Benefit analysis will focus on developing methods for safety impact assessment and environmental impact assessment -> Derive first recommendations and results on the impact of automated driving applications
- Four evaluation types:
 - Technical
 - User-related
 - In traffic behaviour
 - Impact Assessment
- Partners:
 - ika, BMW, CRF, BAST, TNO, CTAG, Lund



// Development of Evaluation Methods for Adaptive Literature Review

- Initial point for the development of evaluation methodology:
 - Literature review on project dealing the automated driving function as well as on other areas
- Example: Technical Assessment
 - Test in order to check, whether the function operates as defined and functional safety (Konvoi, Sartre, etc.)
 - Test of certain (simplified) use cases (CyberCars II, Sartre)
 - „Benchmark“ tests (DARPA, CarloCup, etc.)
- Can the existing methods be used for the evaluation of automated driving function in Adaptive?



en.wikipedia.org, www.portstrategy.com, cc2014-team-legendary.blogspot.de/

// Technical Assessment

Literature Review (Technical Assessment)

- None of the existing seem to be 100% appropriated for the AdaptIVe functions
 - Test in order to check, whether the function operates as defined and functional safety:
 - Important for the development, but demonstrates only that the function operates as specified
 - No information on how well the function behave in the tests
 - Testing of selected use-case:
 - It could be hard to define use cases for systems that operate over a longer time period
 - The picture that use case tests can provide is quite small (e.g. car following behaviour)
 - Benchmark test:
 - Function are only implemented in a few demonstrator vehicles
 - Benchmark is not the objective for evaluation of research functions
- But there are different aspects that are relevant for the evaluation in AdaptIVe

// Technical Assessment

Proposed Evaluation Approach

Classification of automated driving functions:

- **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

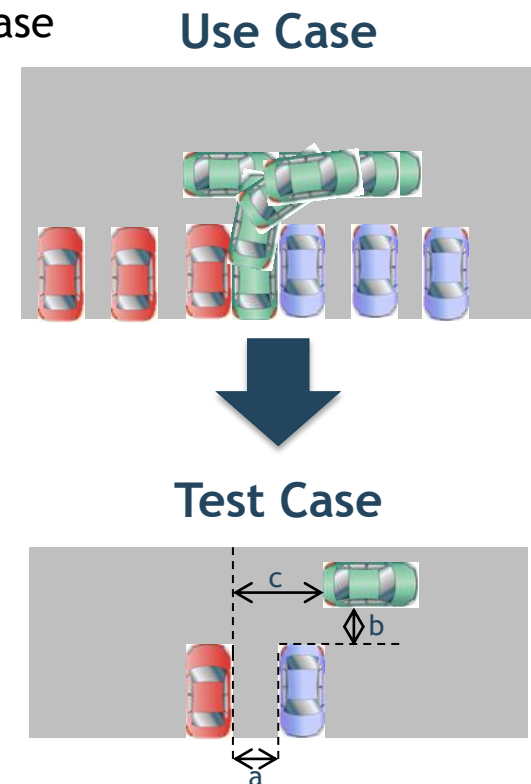


<http://www.kurfuerstenbad-amberg.de>, www.welt.de /

// Technical Assessment

Proposed Evaluation Approach - Event Based Operating

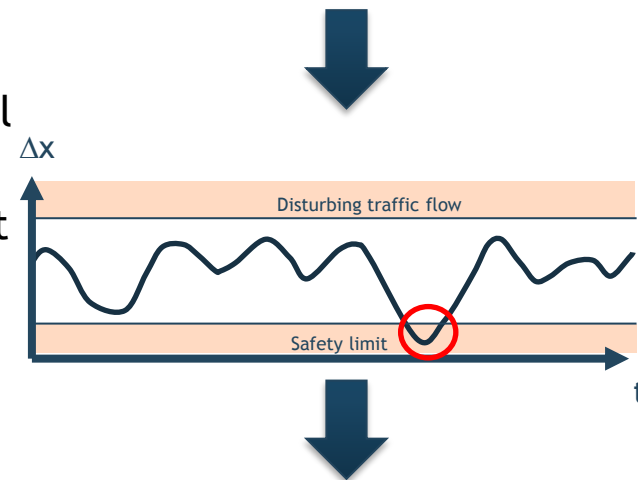
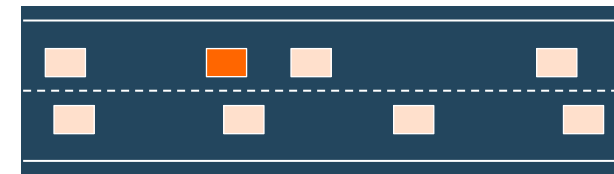
- Main focus of the evaluation:
 - Performance of the function in a certain scenario/use case
 - Similar to the evaluation of ADAS
- Definition of hypotheses
 - Hypotheses focus mainly on function performance
 - Side aspect of the evaluation: function misbehaviour (false positive / negative behaviour)
- Definition of test scenarios (based on use case)
 - Repeating same test scenario several times
- Test environment
 - Controlled field tests (/Simulation)
- Evaluation criteria
 - Appropriate indicators to describe performance
 - Example: Parking
e.g. parking time, min. distance to other object during parking manoeuvre



// Technical Assessment

Proposed Evaluation Approach - Continuously Operating

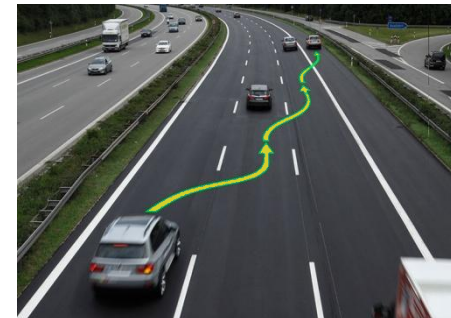
- Main requirements for the evaluation
 - Objective is a collision free traffic
 - Operation in mixed traffic conditions (not disturbing normal traffic)
- Definition of hypotheses
 - The function has to operated within range of normal driver behaviour (and beyond)
 - Driver behaviour needs to be described with respect to e.g. velocity profiles, distance to other vehicles
- Test environment
 - Small field test in real traffic (/Simulation)
- Evaluation criteria
 - Situations, in which defined boundaries are exceeded
- Evaluation of bundle of functions respectively system
 - If sub-components (lane-change functionality) should be evaluated, focus on certain related driving events (lane change)



- Relevant Situation detected per driven distance / driving time
- Decide on the severity

// Safety Impact Assessment

- Classical approach for ADAS
 - Scenario based approach
 - Accident data are analysed
 - Certain accidents are reconstructed and re-simulated accident considering function under study
 - Effect is determined by comparison of accident consequences with and without the function
- Approach for automated driving functions
 - Open issues
 - Today's accident data do not consider collisions of automated vehicles
 - Automated driving function operated already before a critical situation occurs
 - Consider different driving situations and not only accidents
 - Analyse how the traffic flow is affected by means of simulations
 - Identify (new) critical situations and analyse them



// Summary

- Different evaluation methods are known today
- New challenges require new approaches respectively adaptations for the evaluation of automated driving functions
- First ideas for approaches for the technical and safety impact assessment in AdaptIVe were presented
- Many questions are still open. These will be tackled in the next steps (e.g. test amount, use of simulation)
- Methodology will be applied in the end of the project for different automated driving functions



Co-funded by
the European Union

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Thank you.

