AdaptIVe

Automated Driving Applications and Technologies for Intelligent Vehicles

Evaluation of the AdaptIVe functions

User-related assessment and In-traffic behavior assessment

András Várhelyi
Erwin de Gelder

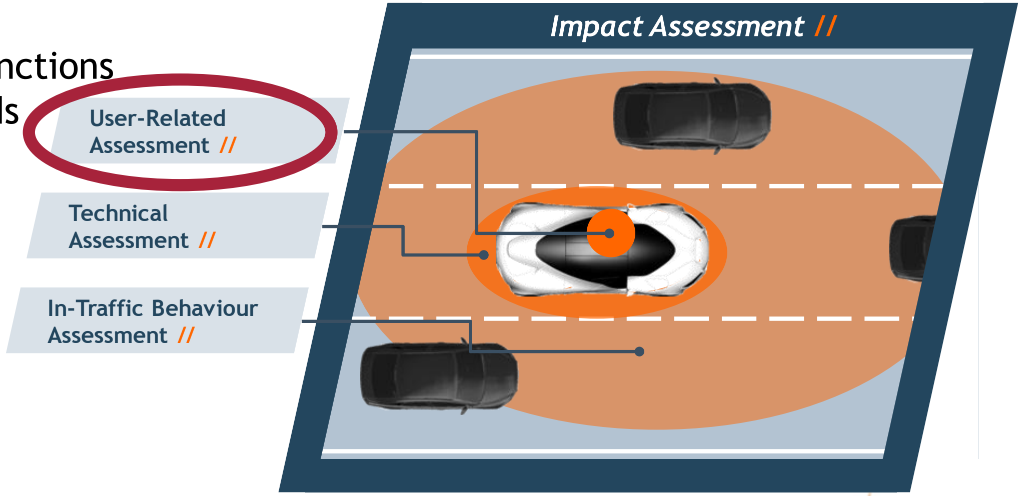
TNO
Lund University

Final Event
Aachen, Germany
29 June 2017

//Evaluation of AdaptIVe functions
AdaptIVe Subproject „Evaluation“

- Main objectives:
  – Development of an evaluation framework for automated driving systems
  – Methodology for impact analysis of automated driving systems

- Detailed objectives:
  – Apply developed methods on selected functions in order to verify the evaluation methods
  – Benefit analysis with focus on safety and environmental impact
    -> Derive first recommendations and results on the impact of automated driving applications



//User-related Assessment - Evaluation tools and topics

“Highway Automation”	“Urban Automation”
Real-life driving with/without	**Driving on test track**
Driver behaviour	-
Workload	-
Understanding the system	Understanding the system
Trust	Trust
Usability	Usability
Opinions about HMI	Opinions about HMI
Experienced effects	-
Expected benefits	Expected benefits
Willingness to pay	Willingness to pay

//Methods

Behavioural observations - two observers in the car (“Highway Automation”)

Logging of driving data - speed, distance, lane keeping (“Highway Automation”)

Questionnaires (both “Highway” and “Urban” Automation)

- Mental workload
- Trust
- Usability
- Usefulness/Satisfactoriness
- Experienced effects
- Expected benefits/disadvantages
- Opinions about the HMI
- Willingness to pay

// "Urban automation" - Driver experiences and opinions

- Most participants found the system easy to learn and use.
- High System Usability Scale (SUS) score: 80 (on a scale 0-100).
- The participants were not fully aware of the system's limitations.
- The majority would be willing to pay between 1,000 and 4,000 Euros.
- There were clear expectations in decreased fuel consumption and increased driving comport among the respondents.
- Some worries expressed:
  "does the car constantly handle new and different situations consistently in real traffic with a lot of drivers around who cannot drive a car and do a lot of stupid things"?

  "driving pleasure disappears with automated driving".

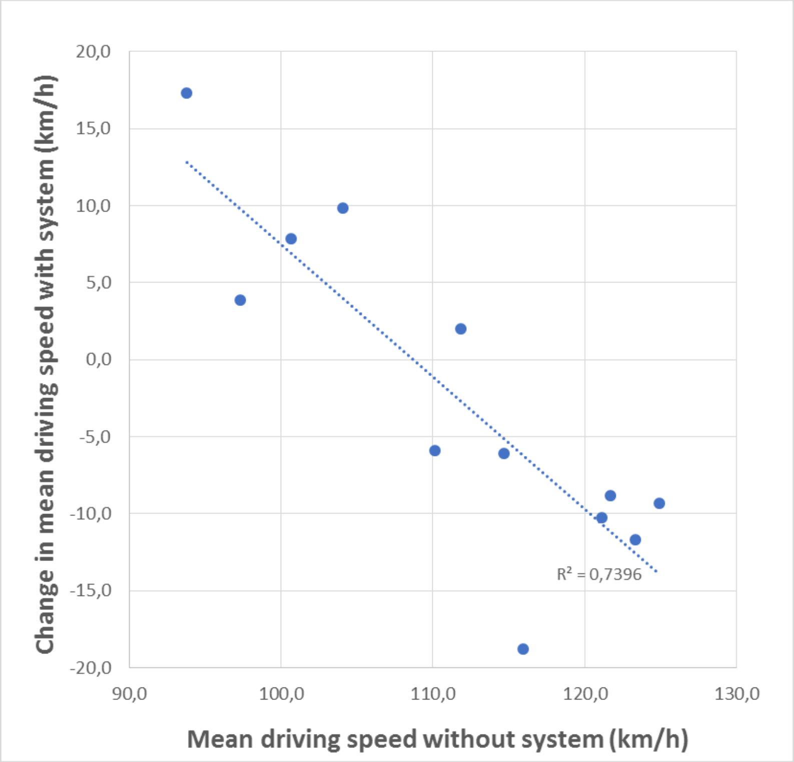
// "Urban automation" - Usefulness and Satisfactoriness

// “Highway automation” - Driving behaviour I

- The drivers used the system as it was intended to be used.
- The system affected driving positively in several ways:
  - \+ Better speed adaptation to speed limit and conditions, less speed variation
  - \+ Better distance keeping ahead
  - \+ Better lane choice (prescribed use of the right lane)
  - \+ Better indicator usage
  - \+ Fewer dangerous lane changes

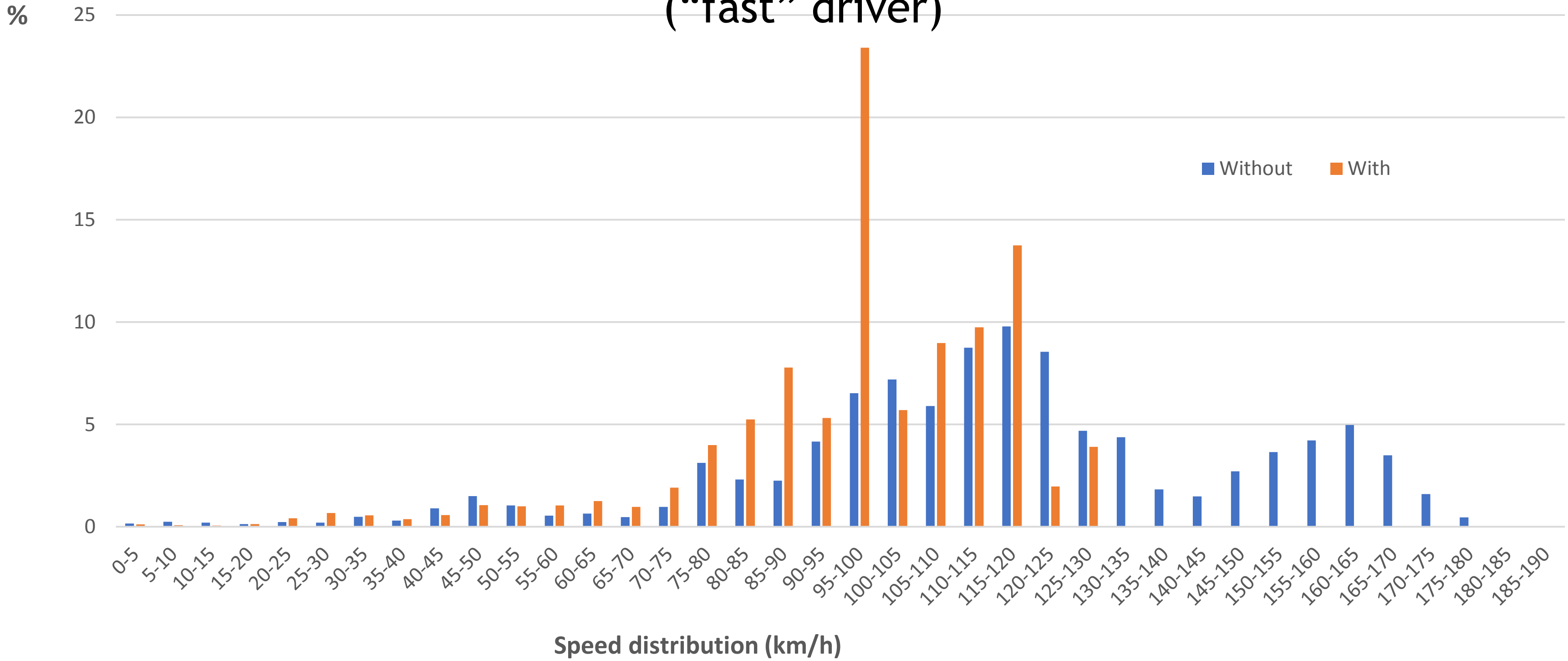
// “Highway automation” - Driving behaviour II

Change in mean driving speed versus mean driving speed without the system

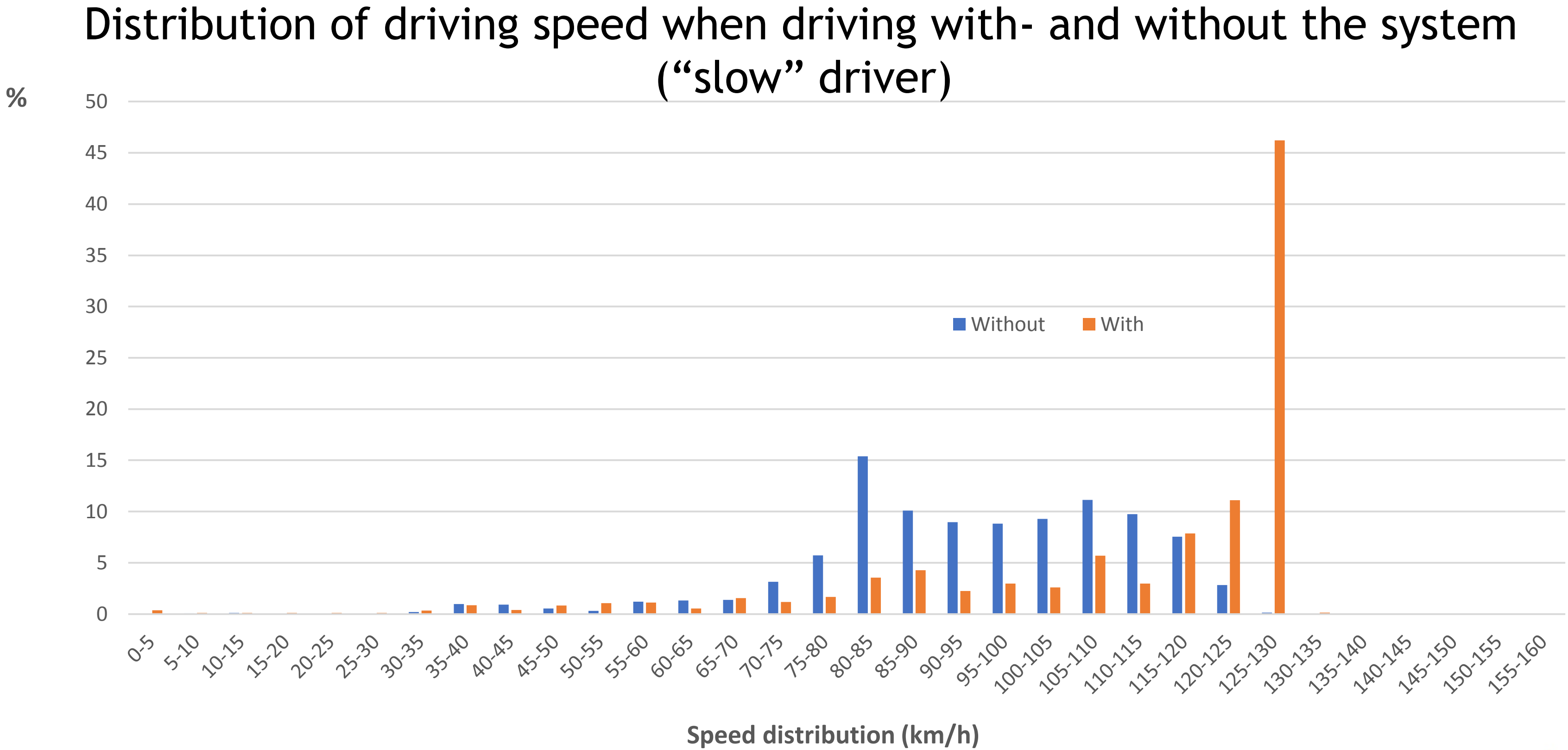


// "Highway automation" - Driving behaviour III

Distribution of driving speed when driving with- and without the system ("fast" driver)



// “Highway automation” - Driving behaviour IV



// "Highway automation" - Driving behaviour V

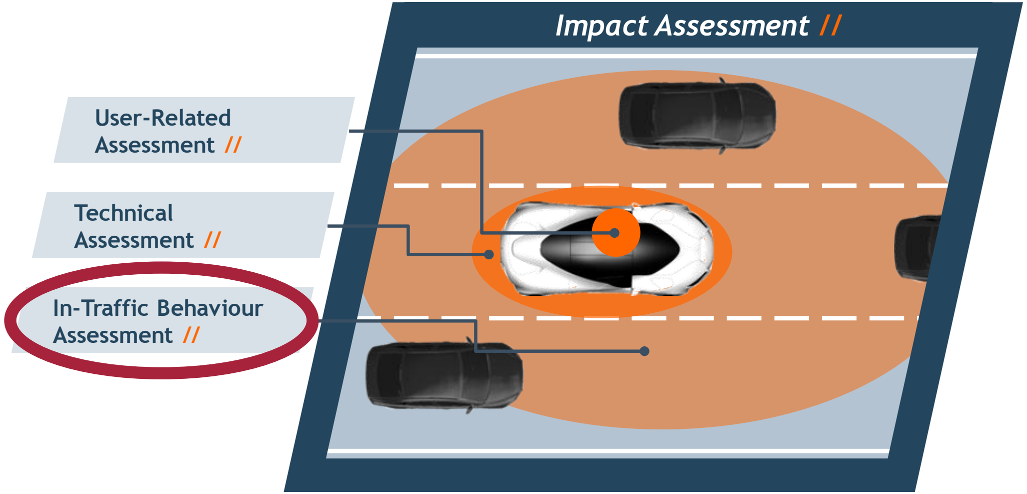
- Negative effects:
  - Not letting other drivers to make a lane change into own lane
  - Longer overtaking due to 130 kph system limit, hindering cars from behind
  - More conflicts due to losing the road markings due the reflection of the sun
  - Sudden braking manoeuvres due to not correctly recognising the surroundings

// "Highway automation" - Driver experiences

- Positive driver experiences:
  + Driving comfort
  + Trust
  + Usability - High System Usability Scale (SUS) score: 82 (on a scale 0-100)
  + Usefulness and Satisfactoriness
- No differences with regard to subjective workload
- Negative driver experiences:
  - Self-assessed driving performance decreased

//In-traffic assessment

- What is in-traffic assessment
- General framework
- Method & Example
- Conclusion



//In-traffic Assessment

- How does the vehicle interact with other traffic participants?
- How do other traffic participants react on the (automated) vehicle?

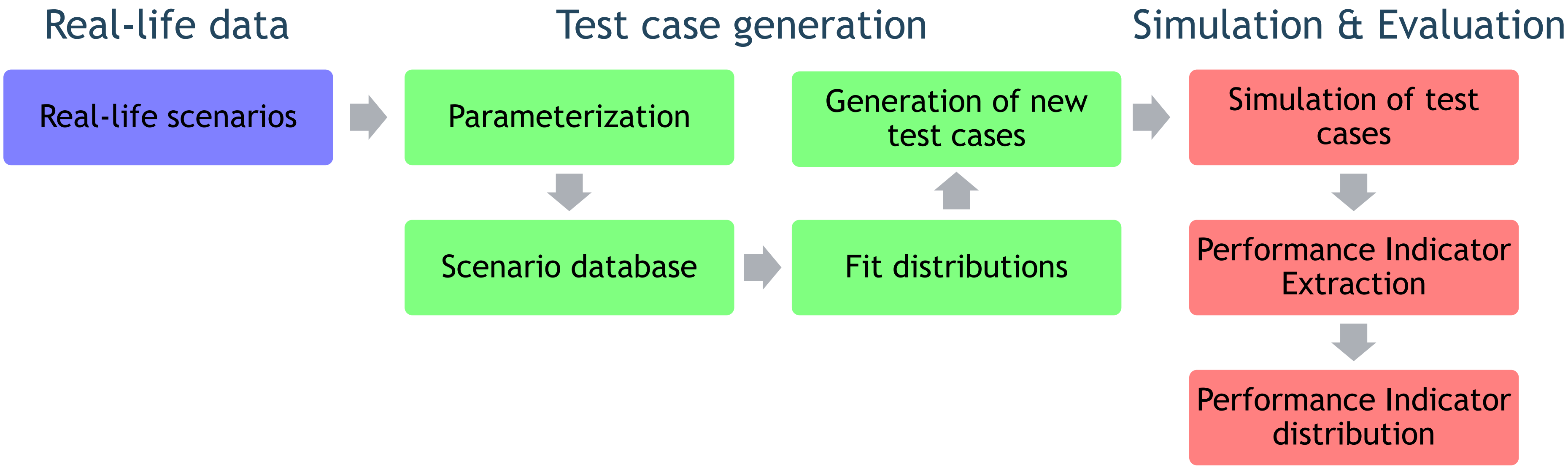
//Solution proposal

- Just go on the road and see what happens.

AdaptIVe

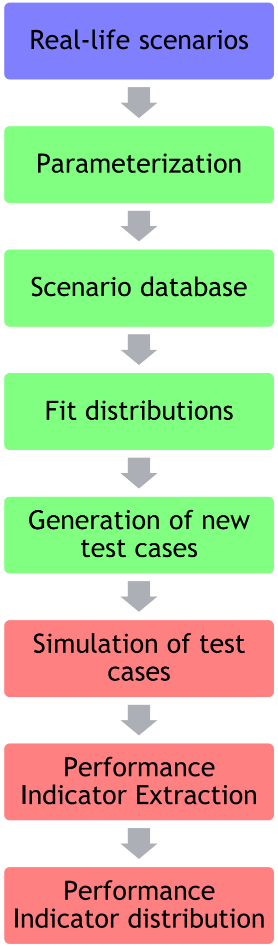
//Method - general framework

- Virtual testing
- Scenarios that resemble real-life traffic



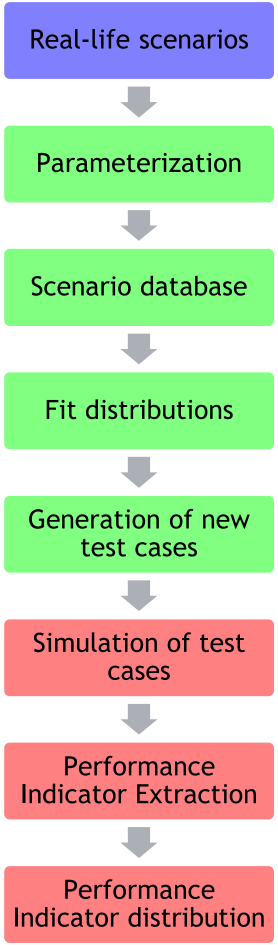
//In-traffic Assessment

- How does the vehicle interact with other traffic participants?
- How do other traffic participants react on the (automated) vehicle?



//In-traffic Assessment

- How does the vehicle interact with other traffic participants?
- How do other traffic participants react on the (automated) vehicle?

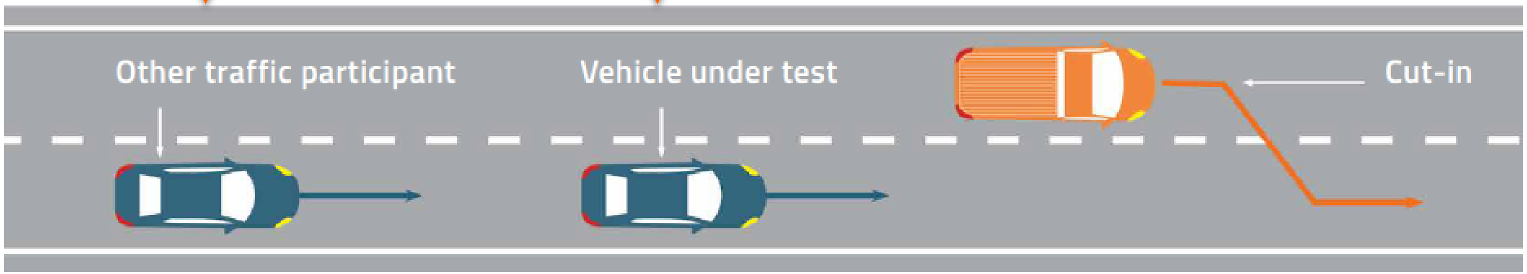


//Real-life scenarios

- Compare performance of third vehicle in two different configurations.

Intelligent Driver Model (IDM) [1]

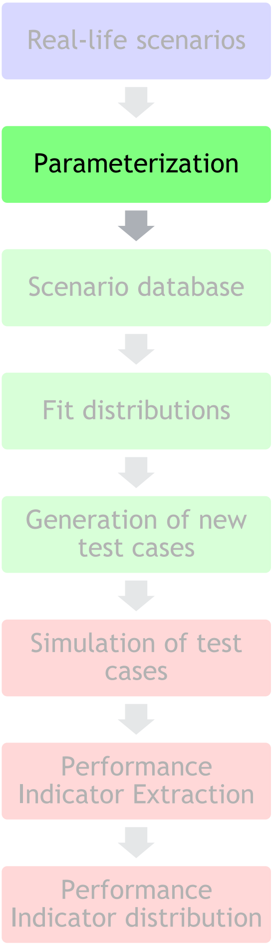
IDM or Traffic Jam Assist (TJA)



Real-life scenarios
↓
Parameterization
↓
Scenario database
↓
Fit distributions
↓
Generation of new test cases
↓
Simulation of test cases
↓
Performance Indicator Extraction
↓
Performance Indicator distribution

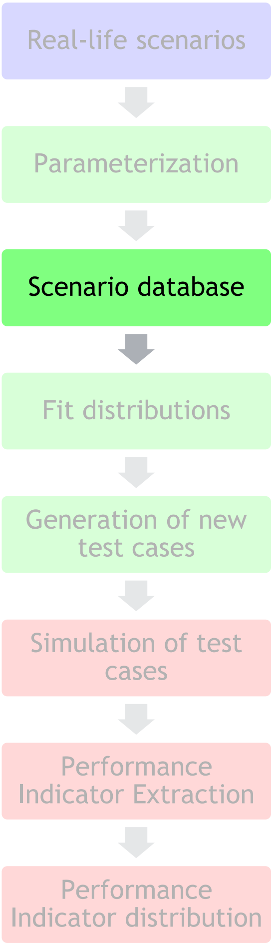
//Test case generation

- Summarizes scenario in only a few parameters.
- Why?
  - Probabilistic results
    - No need to ‘drive’ all kilometres to make claims!
  - Emphasize critical scenarios
    - Without *a-priori* knowledge of what might be critical
  - Prevent repetition
- Cut-in scenario → 5 parameters.
- Some assumptions, e.g. constant velocity



//Test case generation

- Store parameters in database.
- No need to store all data of a scenario.



//Test case generation

- Kernel Density Estimation [2], [3]:

$$f_h(x) = \frac{1}{nh}\sum_{i=1}^{n} K\left(\frac{x - x_i}{h}\right)$$

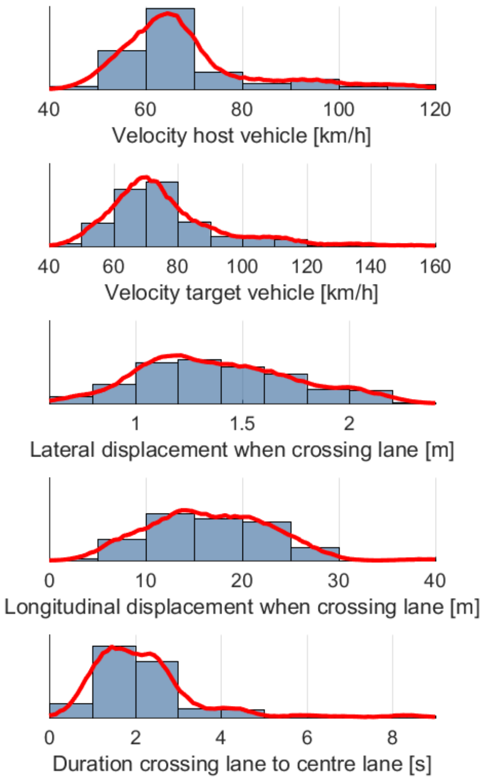
- Bandwidth h → cross-validation
  - Let the data speak for itself!

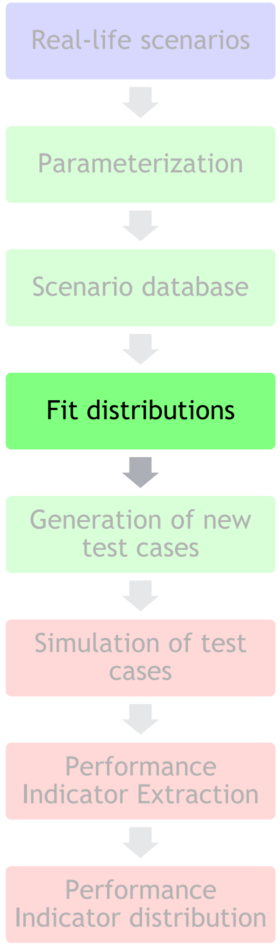
✓ No assumptions
✓ Multivariate data
✓ Easy to draw random samples

- Real-life scenarios
- Parameterization
- Scenario database
- **Fit distributions**
- Generation of new test cases
- Simulation of test cases
- Performance Indicator Extraction
- Performance Indicator distribution

//Test case generation

- Histogram: original data
- Red lines: Kernel Density Estimation

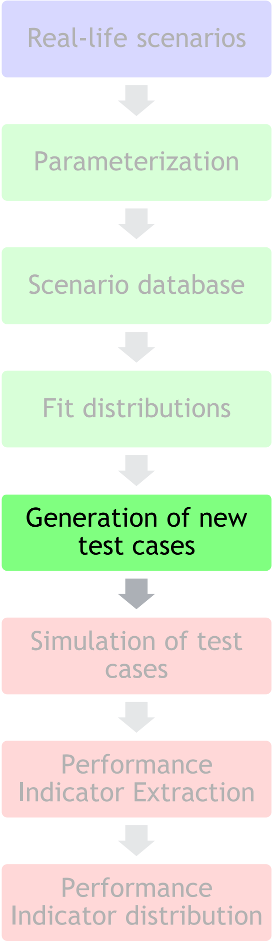




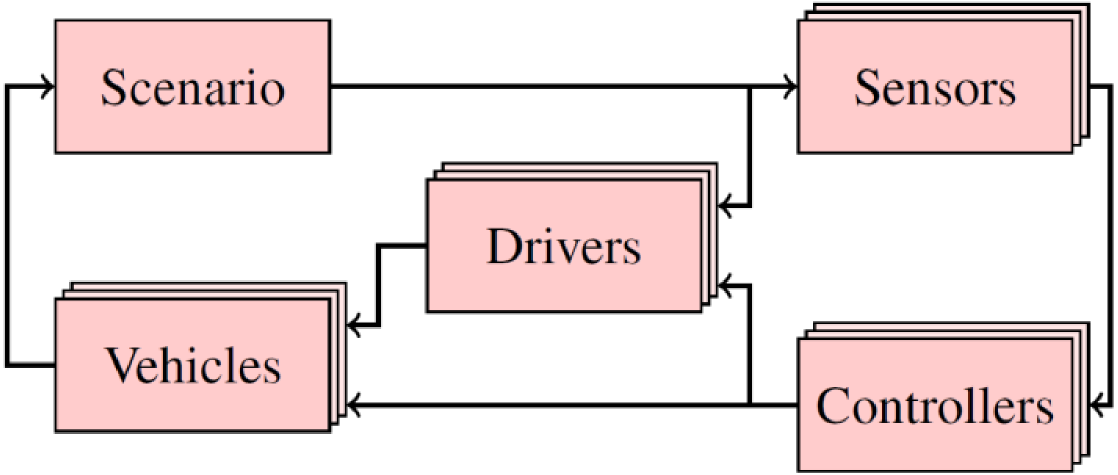
AdaptIVe

//Test case generation

- Generation of new test cases:
  - Draw sample
  - Transform to real-life test case
- Importance sampling → emphasize performance-critical scenarios
  - Ask me for more details
  - See also *Assessment of Automated Driving Systems using real-life scenarios, de Gelder, E. and Paardekooper, J.-P. (2017)*



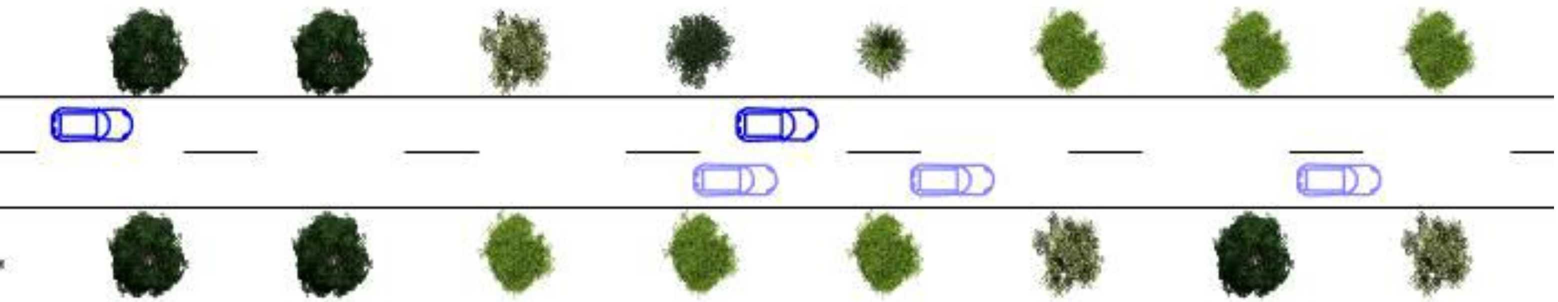
//Method - simulation and evaluation



Real-life scenarios
Parameterization
Scenario database
Fit distributions
Generation of new test cases
Simulation of test cases
Performance Indicator Extraction
Performance Indicator distribution

AdaptIVe

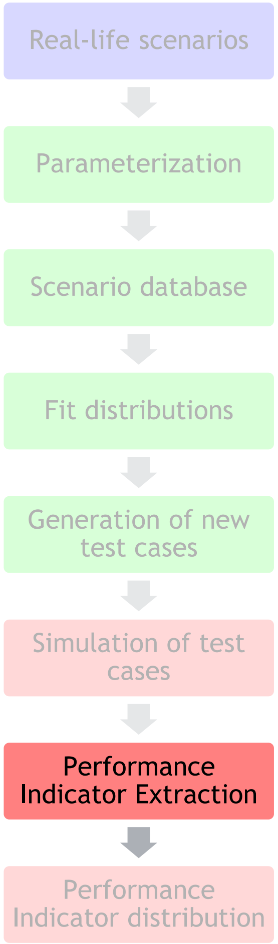
//Example - simulation and evaluation



Real-life scenarios
Parameterization
Scenario database
Fit distributions
Generation of new test cases
Simulation of test cases
Performance Indicator Extraction
Performance Indicator distribution

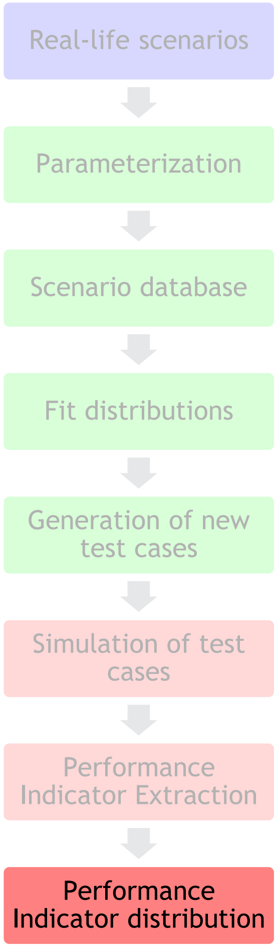
//Method - simulation and evaluation

- Performance Indicators are extracted from a simulation, e.g.
  - Time Headway (THW)
  - Time-To-Collision (TTC)
  - Distance
  - Velocity
  - Acceleration
  - etc.



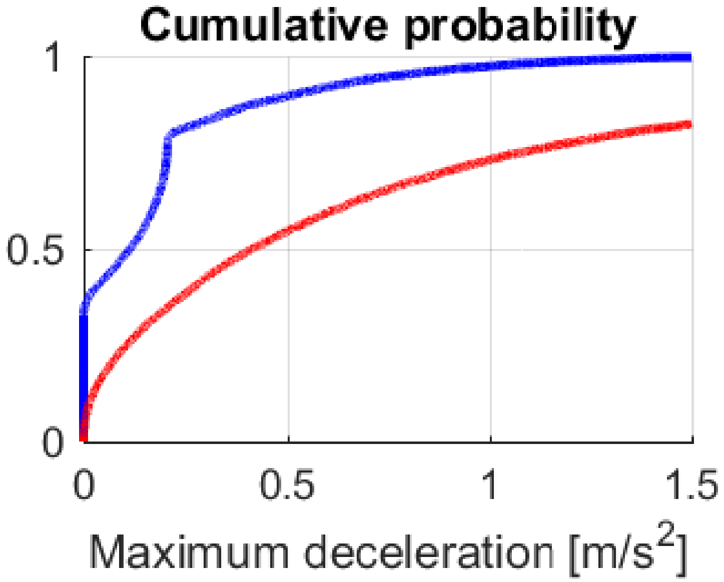
//Method - simulation and evaluation

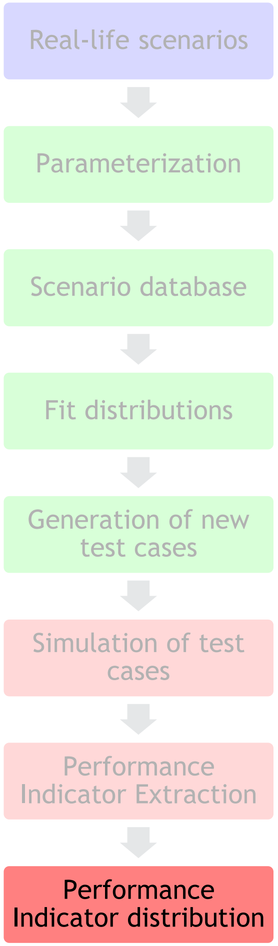
- When a large number of simulations are performed, we can make distributions of the resulting Performance Indicators.



//Example - simulation and evaluation

- Red: both following vehicles are human driven (IDM)
- Blue: second car equipped with Traffic Jam Assist

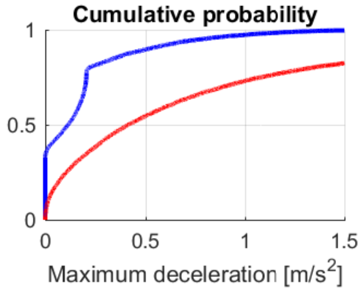


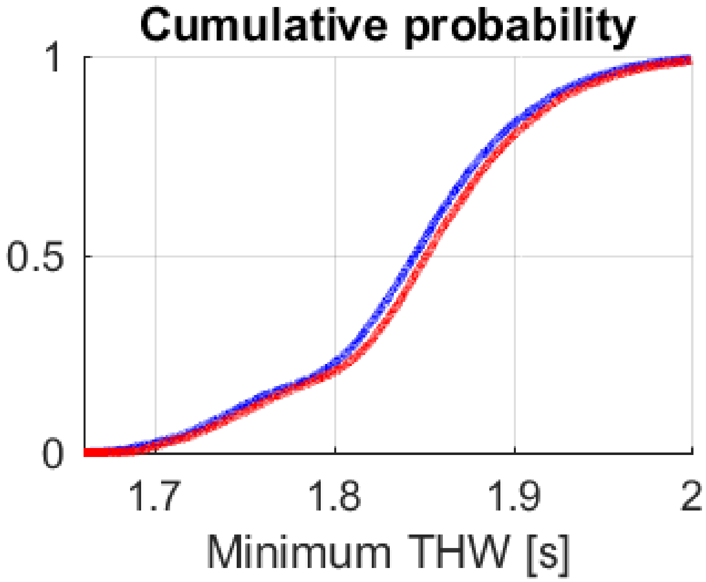


AdaptIVe

//Example - simulation and evaluation

- Red: both following vehicles are human driven (IDM)
- Blue: second car equipped with Traffic Jam Assist





Real-life scenarios

Parameterization

Scenario database

Fit distributions

Generation of new test cases

Simulation of test cases

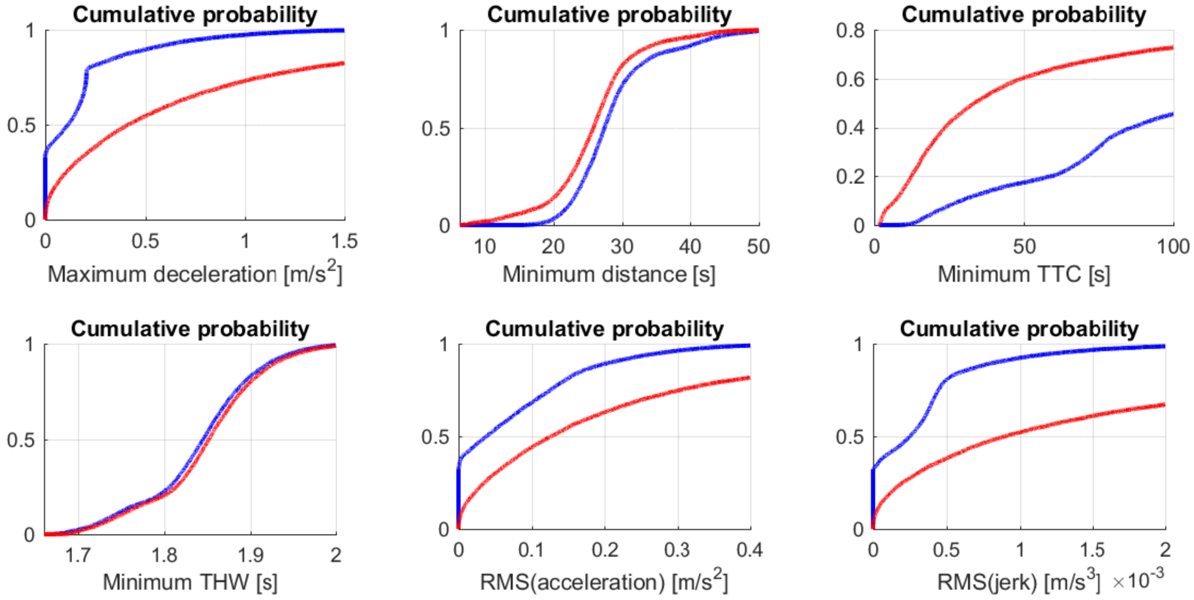
Performance Indicator Extraction

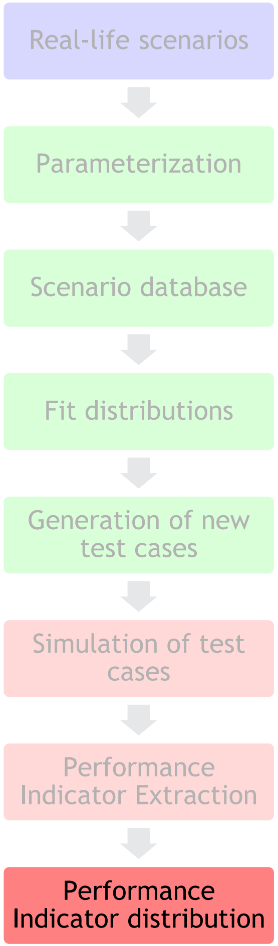
Performance Indicator distribution

AdaptIVe

//Example - simulation and evaluation

- Red: both following vehicles are human driven (IDM)
- Blue: second car equipped with Traffic Jam Assist





//Conclusion

- Methodology to assess the performance of an Automated Driving Function has been developed.
- Through parameterization of the real-life scenarios, test cases are generated.
- The framework is mostly data driven.
- It provides quantitative results on
  - how a system will perform in real-life traffic and
  - how other traffic participants will react on the system.
- More information → check our stand

Co-funded by
the European Union

AdaptIVe

Automated Driving Applications and Technologies for Intelligent Vehicles

Thank you.

András Várhelyi
Andras.varhelyi@tft.lth.se

Erwin de Gelder
erwin.degelder@tno.nl