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Automated Driving Applications and Technologies for Intelligent Vehicles

# *Impact Assessment*

Felix Fahrenkrog

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# // Research Question

- How does automated driving influence road traffic?

**Traffic Safety**

**Energy demand**

**Traffic flow**

**Travel time**

// Safety impact assessment

// Enviromental impact assessment

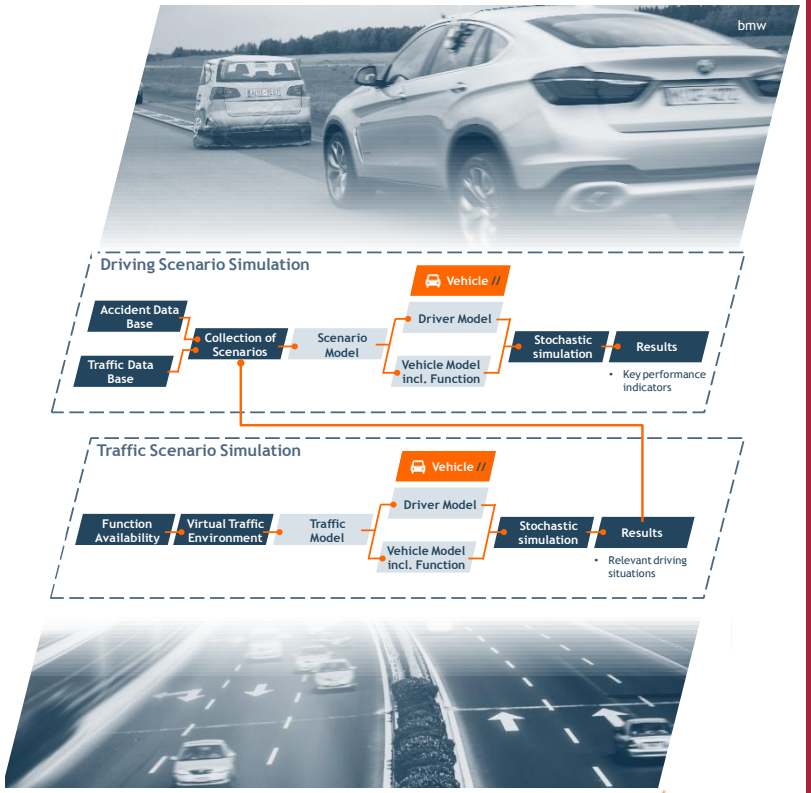
# // Target Areas


| | | | |
|---|---|---|---|
| // Safety impact assessment | | | ✓ |
| // Enviromental impact assessment | ✓ | ✓ | ✓ |

# // Safety Impact Assessment

# // Safety Impact Assessment - Methodology

- Challenges:
  - Continuous intervention by automated driving functions
    - // Simulating reconstructed accidents is not sufficient; instead traffic scenario should be simulated
  - Simulating driver behaviour while manual driving
    - // Adequate driver model is required to consider human errors
  - Implementation of an automated driving function



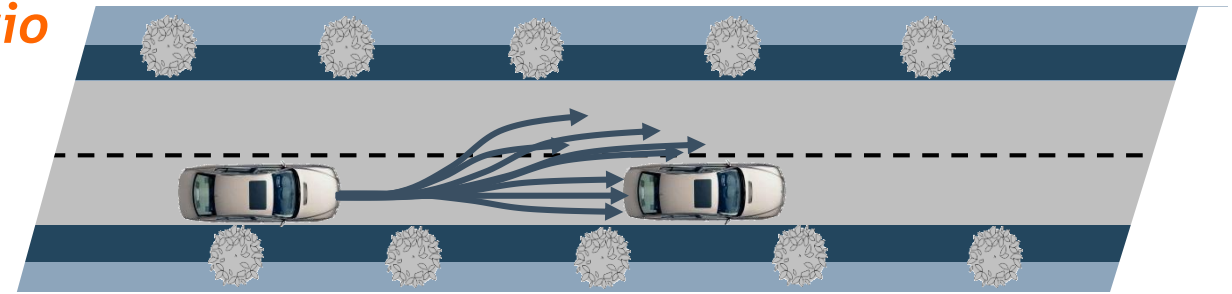
# //Safety Impact Assessment - Methodology

Accident data (e.g. GIDAS) /
Critical situations (FOT)

Description
of function

Simulation of
traffic scenarios

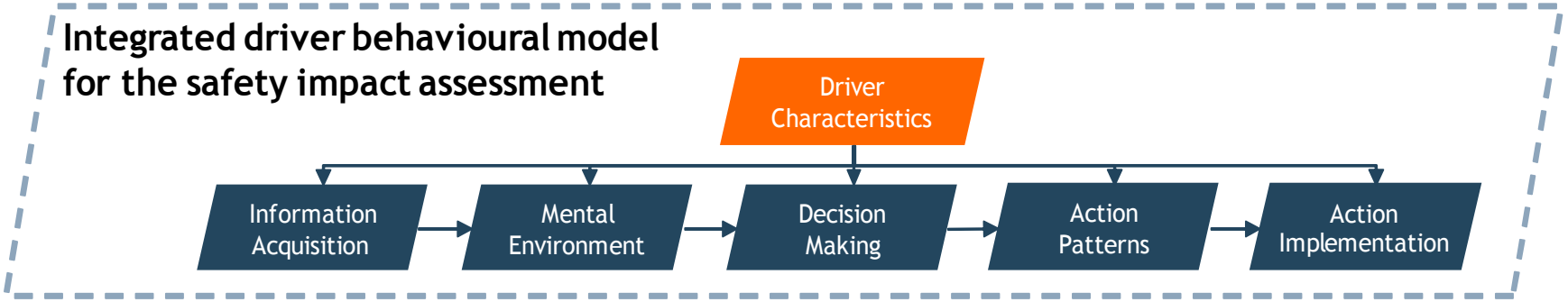
## //Top-Scenario



Simulation of driving
scenarios

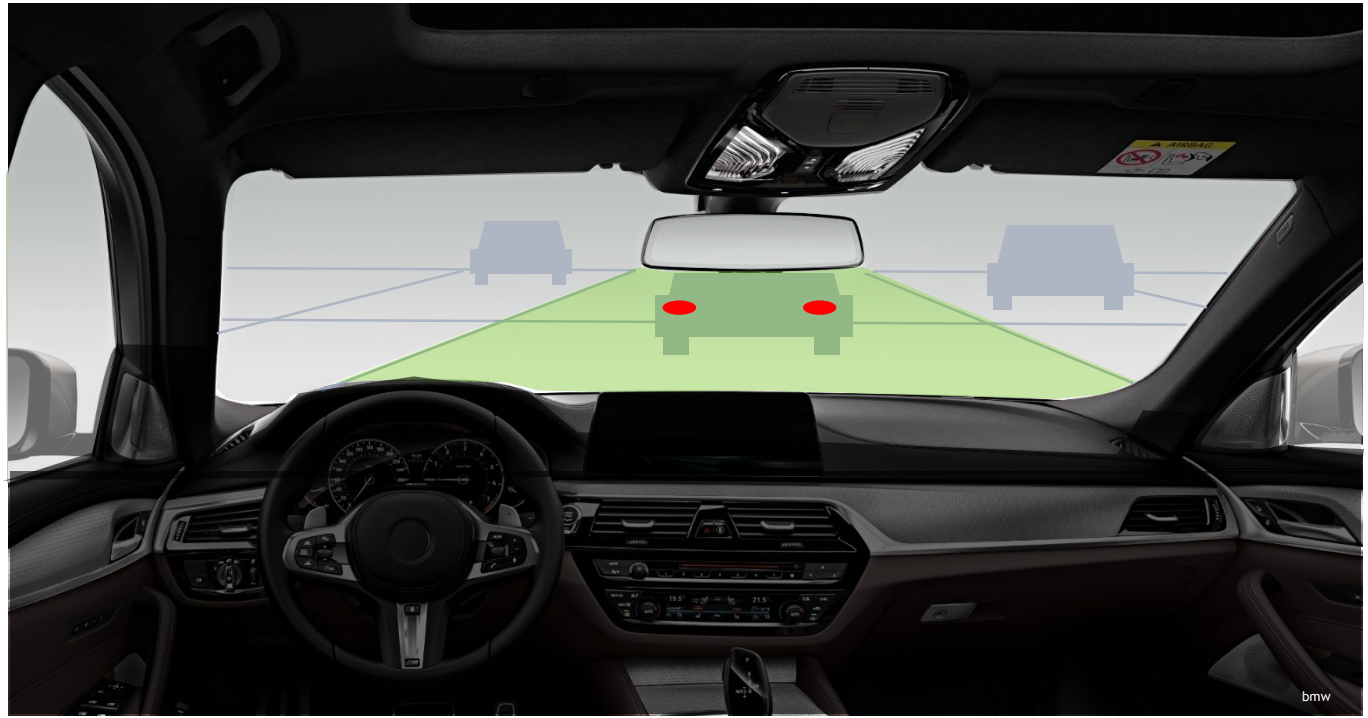
# // Safety Impact Assessment – Driver Model

- Challenge: Simulation of human driving behaviour in the baseline
- **Stochastic Cognitive Model (SCM) is used in the simulation**
- A core aspect of the SCM driver behavioural model is the application of stochastically methods in order to represent the behaviour of different drivers (e.g. gaze control)

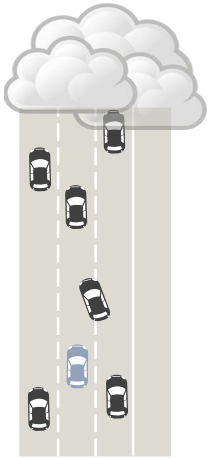
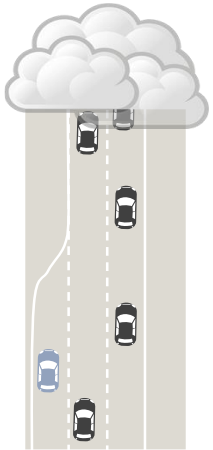
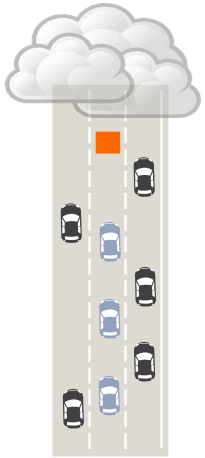
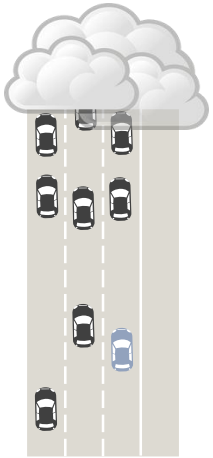
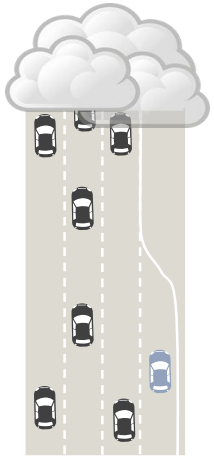
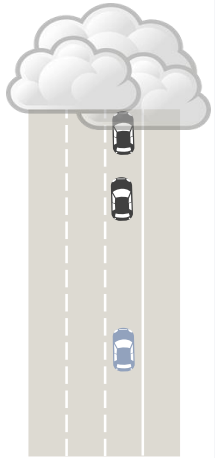
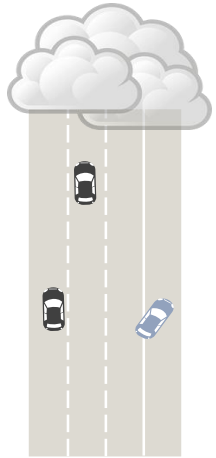


# // Safety Impact Assessment – Driver Model

- **Objective:** realistic implementation of visual perception.
- Definition of different view areas (Areas of Interest – AOI).
- Stochastic view control based on scientifically founded distribution matrix.



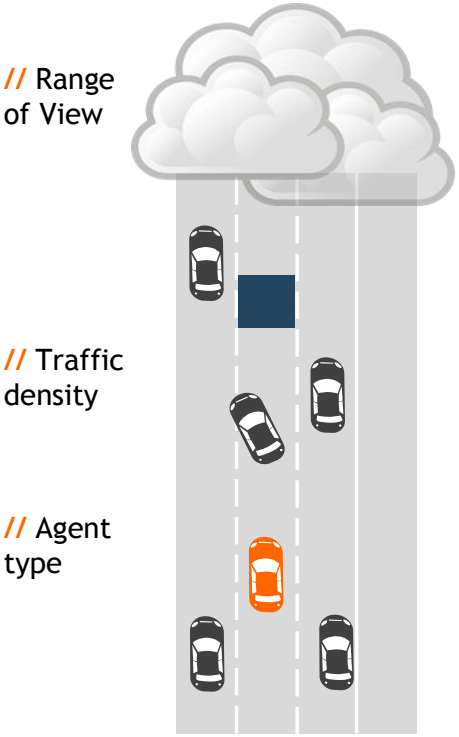
# // Safety Impact Assessment – Top Scenarios

| // Top 1 | // Top 2 | // Top 3 | // Top 4 | // Top 5 | // Top 6 | // Top 7 |
|---|---|---|---|---|---|---|
| Cut-In | End of Lane | Obstacle in the lane | Traffic jam | Highway entrance | Rear-end accident | Single driving accident |
|  |  |  |  |  |  |  |

# // Safety Impact Assessment – Example Obstacle in lane

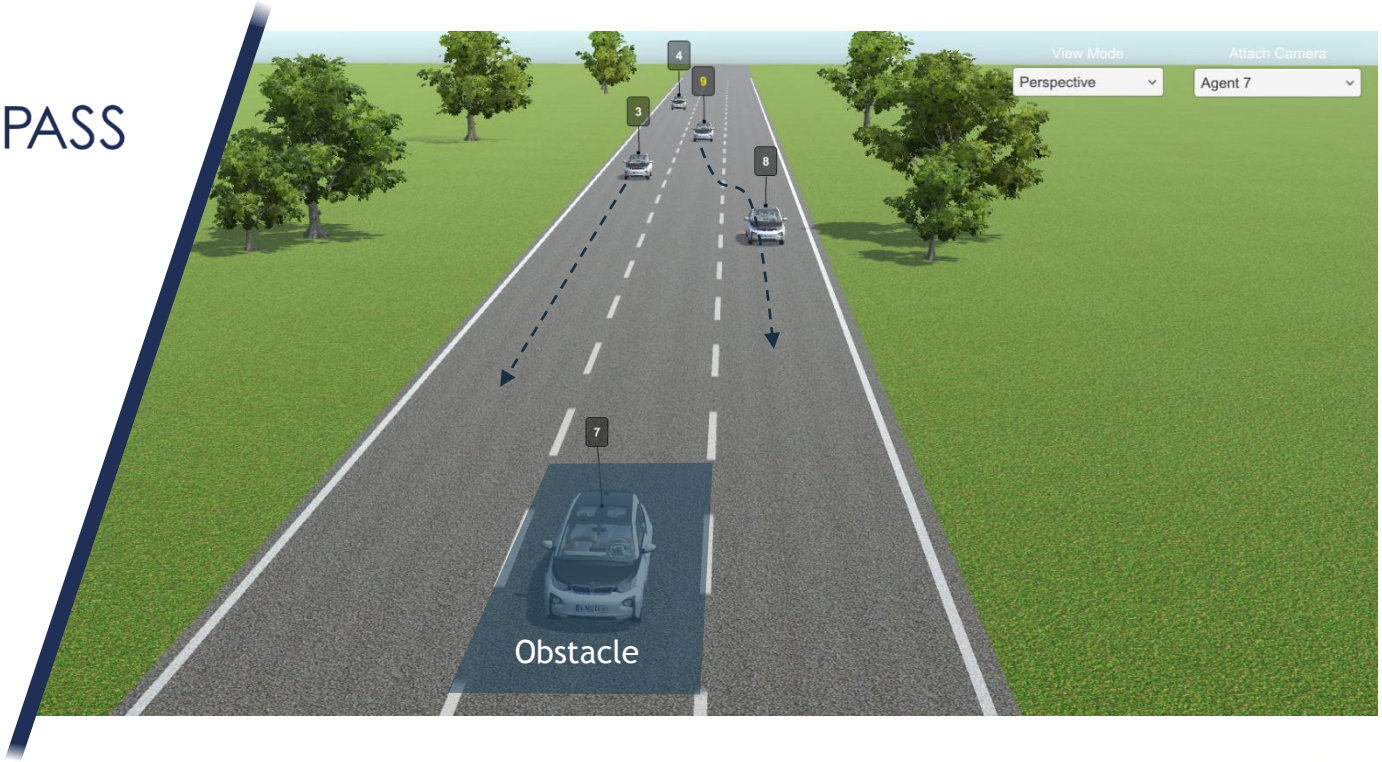
**Setup of the scenario:**

- Three lane motorway of 4 km
- The obstacle is placed in the central driving lane at a position of $s_x$ = 350 m. Positon can be adjusted
- The surrounding traffic is generated by means of stochastic approaches (start position & characteristics of the driver)
- The relevant vehicles are either driven by the automated driving function or manually (SCM-driver model)



# // Safety Impact Assessment – Simulation tool

openPASS



# // Safety Impact Assessment – Results per Top Scenario

- Results per top scenario of an exemplary automated driving function:

| | // Top 1 Cut-In | // Top 2 End of Lane | // Top 3 Obstacle in the lane | // Top 4 Traffic jam | // Top 5 Highway entrance | // Top 6 Rear-end accident | // Top 7 Single driving accident[2] |
|---|---|---|---|---|---|---|---|
| Mean determined effect in the simulation | -83% | -14% | -40% | -40% | -49% | -73% | -100% |
| Accidents within the operation conditions[1] | 72% (92%) | 67% (83%) | 78% (97%) | 80% (89%) | 95% (95%) | 69% (96%) | 67% (93%) |
| Expected change in the accident risk per scenario | -60% (-76%) | -9% (-12%) | -31% (-39%) | -32% (-36%) | -47% (-47%) | -51% (-70%) | -67% (-93%) |

1: Accidents within the operation conditions including accidents at speeds outside operation conditions
2: Determined based on the assumption

# // Safety Impact Assessment – Results per Top Scenario

- Results per top scenario of an exemplary automated driving function:

| | // Top 1 | // Top 2 | // Top 3 | // Top 4 | // Top 5 | // Top 6 | // Top 7 | // Not Considered |
|---|---|---|---|---|---|---|---|---|
| Accident proportion (Motorway - Germany) | 14.5% | 1.2% | 3.4% | 19.7% | 1.4% | 22.7% | 21.8% | 15.2% |
| Determined effect per scenario | -60% (-76%) | -9% (-12%) | -31% (-39%) | -32% (-36%) | -47% (-47%) | -51% (-70%) | -67% (-93%) | 0% |
| Weighted Effect per scenario | -8.7% (-11.1%) | -0.1% (-0.1%) | -1.3% (-1.6%) | -6.3% (-7.0%) | -0.7% (-0.7%) | -11.5% (-16.0%) | -14.6% (-20.3%) | 0% |
| Overall change of the accident risk (Motorway -Germany) | -43% (-57%)[1] | | | | | | | |

[1]: Note: Limitation and assumptions of the study (see report) must always be taken into account!

# // Safety Impact Assessment – Limitation of study

Open Issues for the assessment:

- Situations (→ transition of control) with potentially negative effects are not considered
- Effects along the penetration rate are not considered → limitation of overall effect
- Usage is not considered → although the function is available, it will not necessarily used
- Available data → currently, the relevant and available data set (detailed accident data & NDS and FOT data) is quite limited

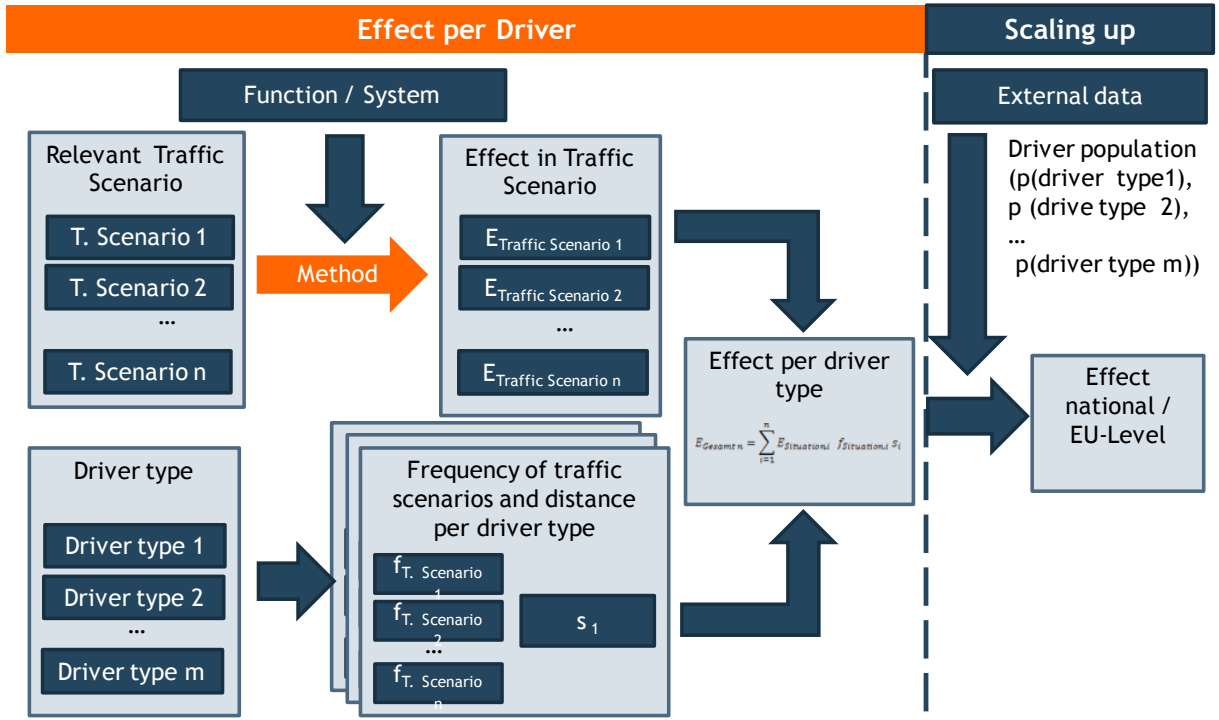
# // Environmental Impact Assessment

# // Environmental Impact Assessment - Methodology

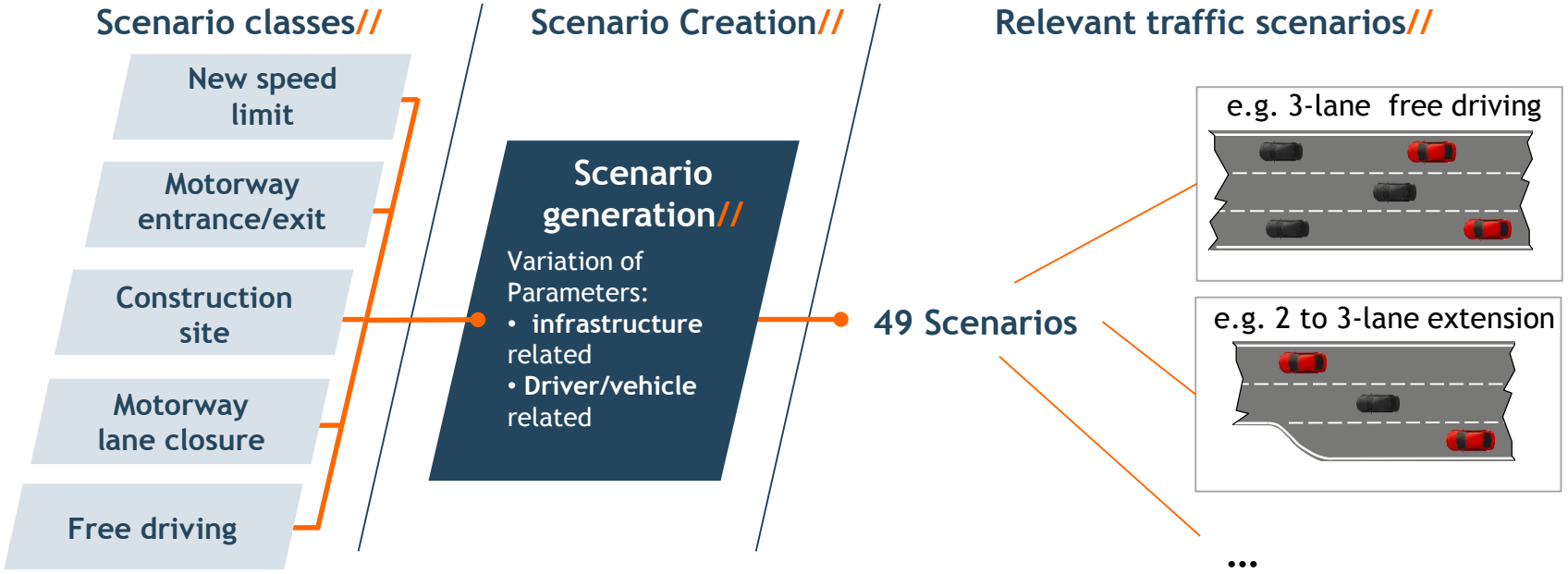
Analysis of the environmental impact with respect to

- Energy demand
- Traffic flow
- Travel time

Consider different driver types



# //Environmental Impact Assessment - Methodology



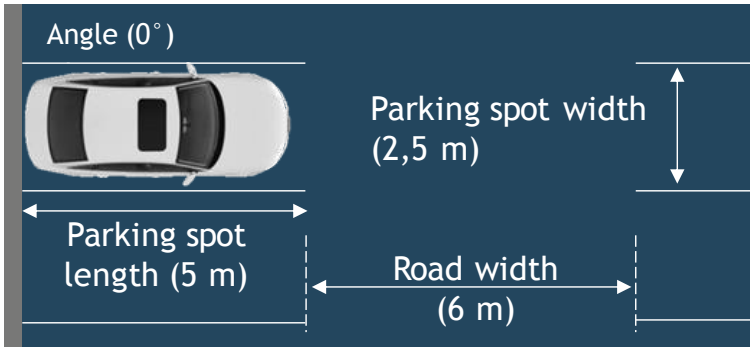
# // Environmental Impact Assessment – Methodology (Parking)

- Analysis of the required parking space for automated vehicle
  - Assumption: If the driver is not in the car, it is possible to park narrower
- Approach: Analysis of parking manoeuver in order to find the optimal trajectory

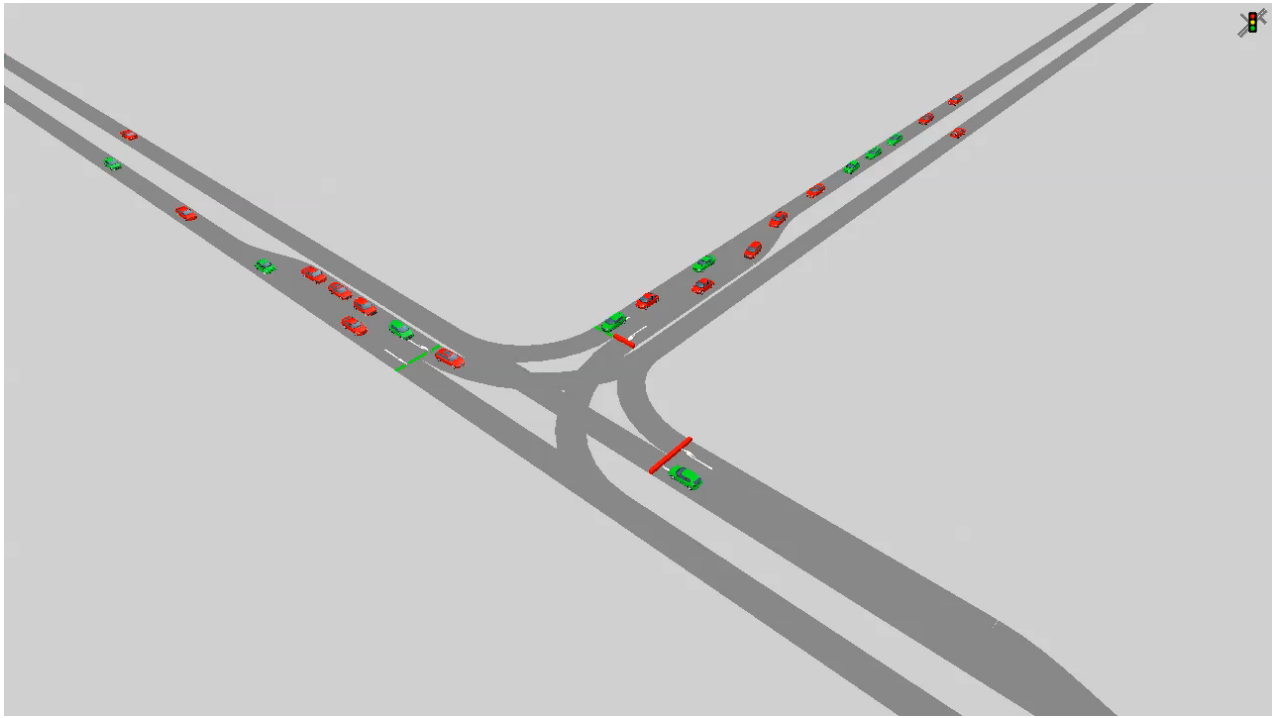
  → calculated required parking lot and road width

  → determine additional parking space

| Vehicle type | Ø Length [mm] | Ø Width w mirrors [mm] | Ø Width w/o mirrors [mm] |
|---|---|---|---|
| Minis | 3409 | 1872 | 1622 |
| Small car | 4042 | 1938 | 1715 |
| … | … | … | … |
| Family vans | 4648 | 2105 | 1866 |
| Utilities | 4561 | 2183 | 1827 |
| Average | 4329 | 2019 | 1785 |



# // Environmental Impact Assessment - Simulation



# // Environmental Impact Assessment - Results

## // Motorway

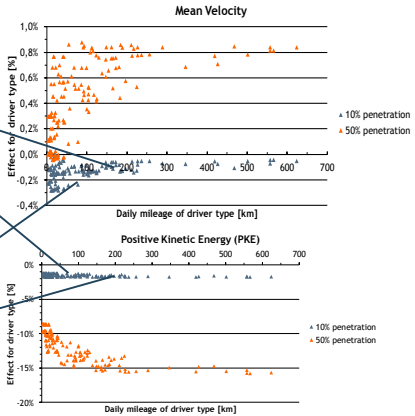
| | | 10% penetration | | 50% penetration | |
|---|---|---|---|---|---|
| Scenario | Lanes | PKE | Mean velocity | PKE | Mean velocity |
| Highway entry | 2 | -1.45% | -0.06% | -20.98% | 0.61% |
| Highway exit | 2 | -1.47% | 0.05% | -17.85% | 0.87% |
| New speed limit, 100-120 | 3 | -2.62% | 0.17% | -13.44% | 0.51% |
| New speed limit, 120-80 | 3 | -2.18% | 0.02% | -12.71% | 0.24% |
| Construction site | 2 | -3.56% | 0.73% | -24.36% | 6.30% |
| Construction site | 3 | -2.56% | 0.71% | -13.55% | 3.00% |
| Free driving, 130 km/h | 2 | -2.28% | -0.11% | -17.40% | 0.51% |
| Free driving, 130 km/h | 3 | -2.07% | -0.05% | -16.73% | 0.83% |

## // Urban

| | 10% penetration | | 50% penetration | |
|---|---|---|---|---|
| Scenario | PKE | Mean velocity | PKE | Mean velocity |
| 4-way-intersection with traffic lights | -6.59% | -2.92% | -27.75% | -3.32% |
| T-intersection with traffic lights | -5.24% | -1.43% | -21.97% | -1.30% |
| New Speed Limit, 30-50 | -1.66% | 0.04% | -10.80% | 0.42% |
| New Speed Limit, 50-70 | -1.50% | 0.03% | -11.36% | 0.40% |
| New Speed Limit, 70-50 | -1.50% | 0.02% | -11.66% | 0.36% |
| New Speed Limit, 50-30 | -1.55% | 0.03% | -11.13% | 0.42% |
| Free Driving, 30 km/h | -1.19% | 0.14% | -17.25% | 1.57% |
| Free Driving, 50 km/h | -1.07% | 0.12% | -18.88% | 1.45% |
| Free Driving, 70 km/h | -1.25% | 0.10% | -20.10% | 1.31% |
| … | … | … | … | … |

# // Environmental Impact Assessment - Overall Results

| | | 10% penetration | |
|---|---|---|---|
| Scenario | Lanes | PKE | Mean velocity |
| Highway entry | 2 | -1.45% | -0.06% |
| Highway exit | 2 | -1.47% | 0.05% |
| New speed limit, 100-120 | 3 | -2.62% | 0.17% |
| New speed limit, 120-80 | 3 | -2.18% | 0.02% |
| Construction site | 2 | -3.56% | 0.73% |
| Construction site | 3 | -2.56% | 0.71% |
| Free driving, 130 km/h | 2 | -2.28% | -0.11% |
| Free driving, 130 km/h | 3 | -2.07% | -0.05% |



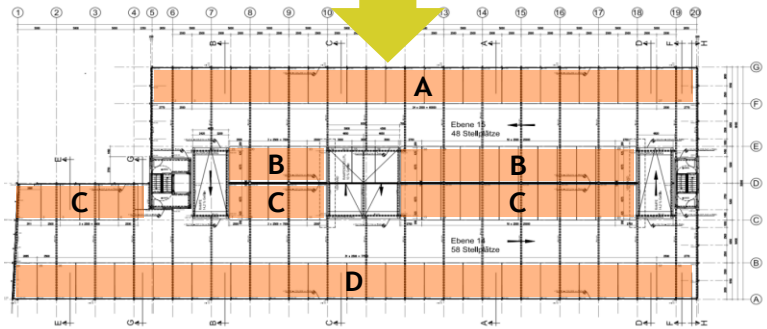

Effect per scenario → Defined driver types → Results per single driver

$$\sum \text{driver}_i \cdot w_i$$

| | Mean Velocity | PKE |
|---|---|---|
| 10% penetration | -0.12% | -1.54% |
| 50% penetration | 0.53% | -12.77% |

# // Environmental Impact Assessment – Results (Parking)

| Angle of parking spot | 0° | 9° | 18° | 27° | 36° | 45° |
|---|---|---|---|---|---|---|
| Minis | 17% | 17% | 17% | 17% | 17% | 17% |
| Small car | 14% | 14% | 14% | 13% | 14% | 14% |
| ... | | | | | | |
| Utilities | 6% | 6% | 6% | 6% | 6% | 6% |
| Average | 10% | 10% | 10% | 10% | 10% | 10% |




- Example RWTH Aachen University parking garage
- Average scenario: each 22.0 m one additional parking spot
- Overall 9 additional parking spots (+8.7% parking spots)
  - Row A: +3 parking spaces
  - Row B: +1 parking spaces
  - Row C: +1 parking spaces
  - Row D: +4 parking spaces
- Limitations must be taken into account

# //Conclusion

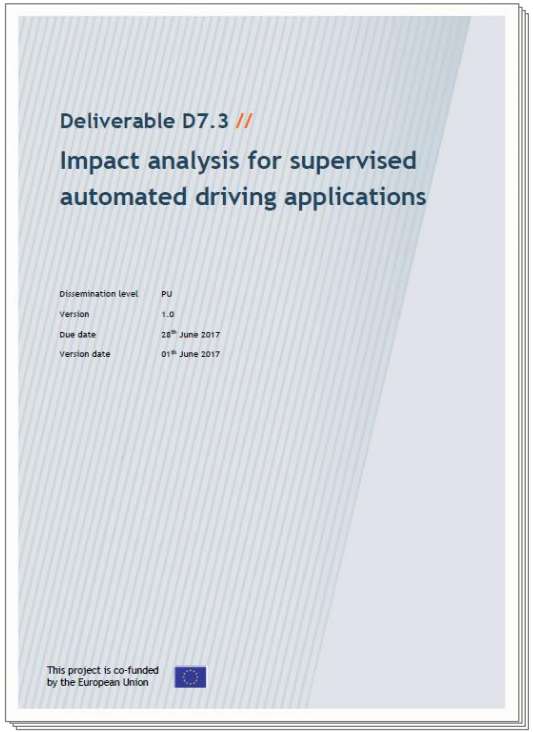
# //Conclusion

- The shown results are first results for the impact of automated driving based on the available information and knowledge.
- In general the impact of automated driving functions need to be investigated further and in more detail (data, more accurate functions).
- Automated driving functions can provide a benefit in terms of traffic safety and the energy demand.
- Changes in the traffic flow will depend on the penetration rate as well as the applied regulation (→ distance behaviour).
- Penetration has a significant influence on the achievable benefits.
- Further important factors, like usage of the functions, need also to be addressed in the future.
- **The mentioned results are only valid under the given limitations and assumptions, which must always be considered when referring to it.**

# // Deliverable D7.3

- Methodology and Results are provided in Deliverable D7.3 „Impact analysis for supervised automated driving applications“

- Many thanks to all, who have contributed to the impact assessment:
  - Christian Rösener, Felix Fahrenkrog Jan Sauerbier, Lei Wang, Sandra Breunig.



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*Thank you.*