

Gefördert durch:



Bundesministerium  
für Verkehr

aufgrund eines Beschlusses  
des Deutschen Bundestages

# IMoGer ['imodʒɜ:r]

## SAFETY CASE DEVELOPMENT

André Bolles and IMoGer-Team



# Project Information



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- **Funded by**

- Bundesministerium für Verkehr (BMV)

- Total budget **39,2 Mio. €**, thereof **35,5 Mio. €** funding

- **Duration:** 12.2024 – 12.2027

- **Project Participants**

- Deutsches Zentrum für Luft- und Raumfahrt (**Verbundkoordinator**)
- Braunschweiger Verkehrs-GmbH BSVG (Anwendungsfall ÖPNV)
- DiMOS Operations GmbH (Betriebsbereichsanalyse und -monitoring)
- MOTOR Ai GmbH (Automation und Technische Aufsicht)
- UPS Deutschland S.à.r.l.&Co.OHG (Anwendungsfall KEP-Logistik)
- VITRONIC Machine Vision GmbH (Infrastrukturgestütztes Fahren)

- **Associated Participants**

- Stadt Braunschweig
- Regionalverband Großraum Braunschweig (ÖPNV-Aufgabenträger und Behörde für Regionalplanung und -entwicklung)



# Challenges for future mobility solutions

*Automation as a chance for highly available mobility*

- Demographic change and missing skilled workers
- Increasing need for flexible and specific transport systems and mobility solutions
- Overcapacity and flexibility in public transport outside peak hours
- Last mile cargo inefficiencies
- High potential for
  - new sector specific operation and business models
  - optimization of specific vehicle functions and transport solutions
- Reduction of traffic

Source: Stadt Braunschweig/Daniela Nielsen

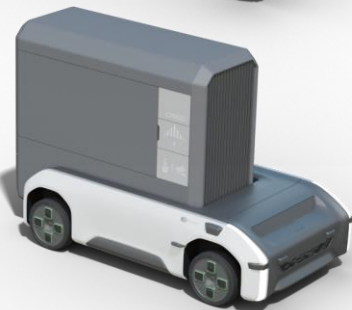
# A modular system for autonomous combined cargo and passenger transport



source: DLR



source: DLR



source: DLR

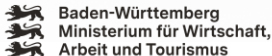
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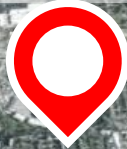
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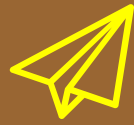


# Schwarzer Berg in Northern Braunschweig

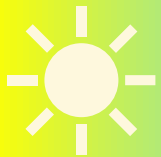


# Combined trial operation under real-world conditions for CEP logistics\* and passenger transport\*\* from mid 2027;

\*Courier, express and parcel logistics; \*\*with test persons only



Traffic Light  
Integration via  
V2X



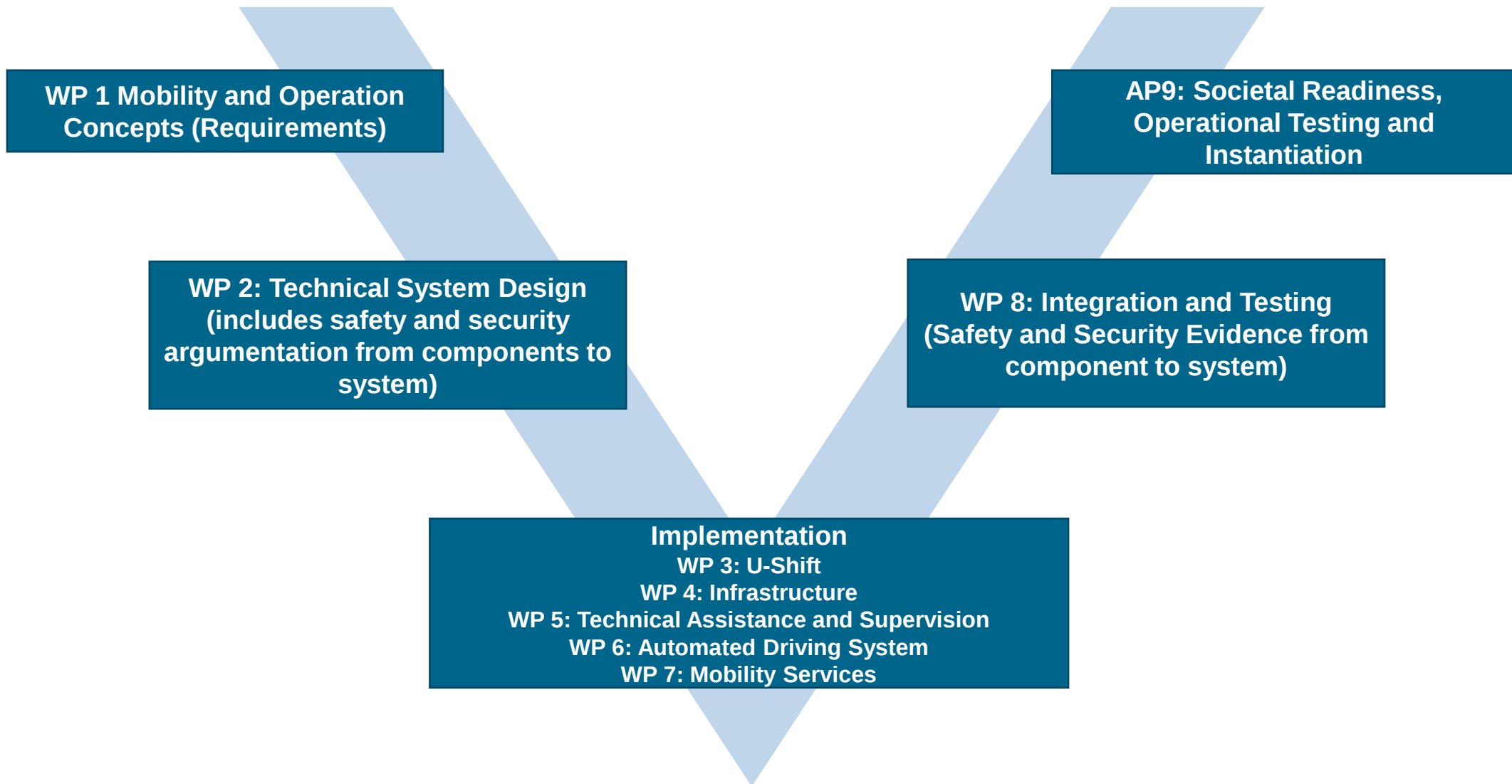
Evaluation of logistical  
hub processes with  
temporal experimental  
hub setup



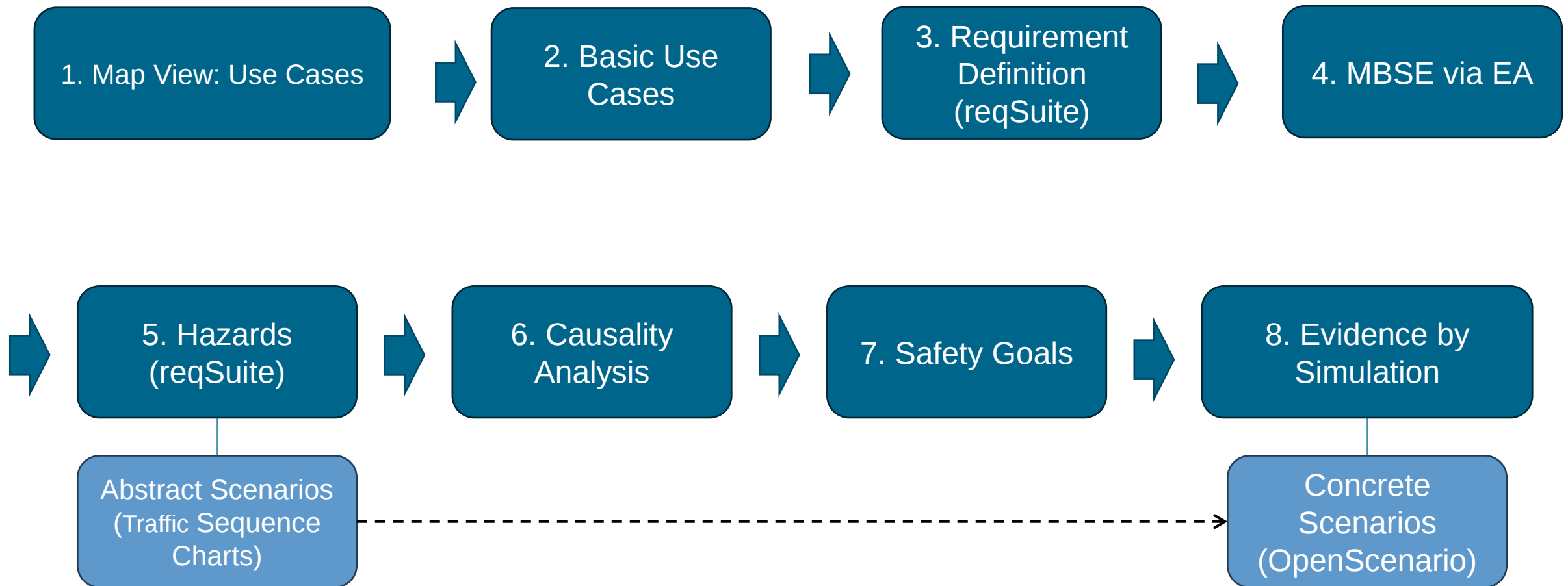
New bus stop  
„Supermarkt Schwarzer  
Berg“ planned for start of  
trial operation from mid  
2027

Infrastructure support  
for autonomous vehicle  
planned

# Safety by Project Design



# Development and Safety Process



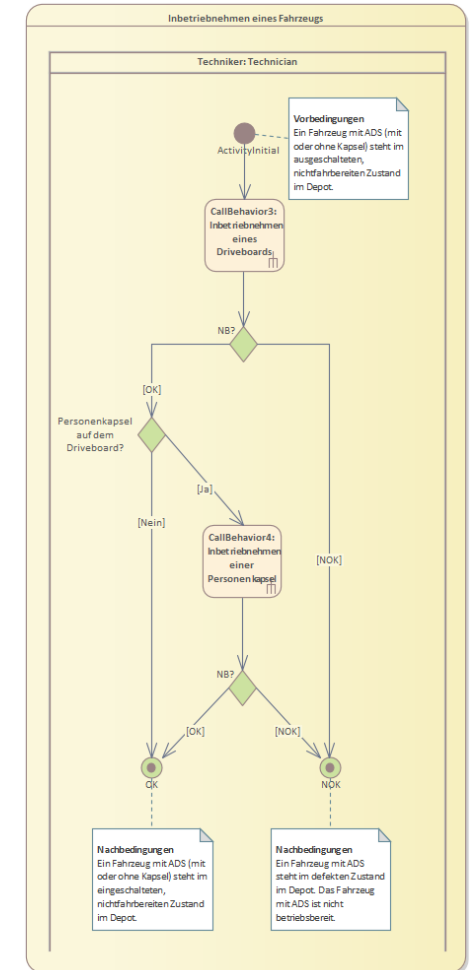
# Use Cases at Schwarzer Berg

- Checking system and environment status before start
- Taking on / releasing capsule
- Driving with cargo capsule / passenger capsule in residential area
- Driving without capsule in residential area
- Driving in depot
- Start/stop at bus station
- Crossing a pedestrian crossing
- Crossing the main intersection at stadium
- ...



Map: VertiGIS WebOffice FRISBI

- Everything in one SysML Model
- Activities (dependencies between use cases)
- System Architecture
- Safety Argumentation
- Linking requirements from reqSuite



source: IMoGer-Team

# Initial Hazard Identification with SWIFT<sup>1</sup>

- Process Step / System Part
  - Step into passenger capsule
  - Driveboard without capsule
  - ...
- Guidewords
  - Timing
  - External factors
  - ...
- What-if
  - What-if someone is doing what we didn't expect?
  - What-if the order of expected process steps is changed?
  - ...
- Consequence
  - What would the system do, if the what-if behavior becomes true?
  - ...
- Hazard
  - What circumstances resulting from the consequence could lead to damage or harm?
  - ...
- Grouping this analysis into different scopes for identification of hazard categories
  - Hazards for VRUs at bus stop
  - Hazards VRUs in public traffic space
  - ...



source: IMoGer-Team

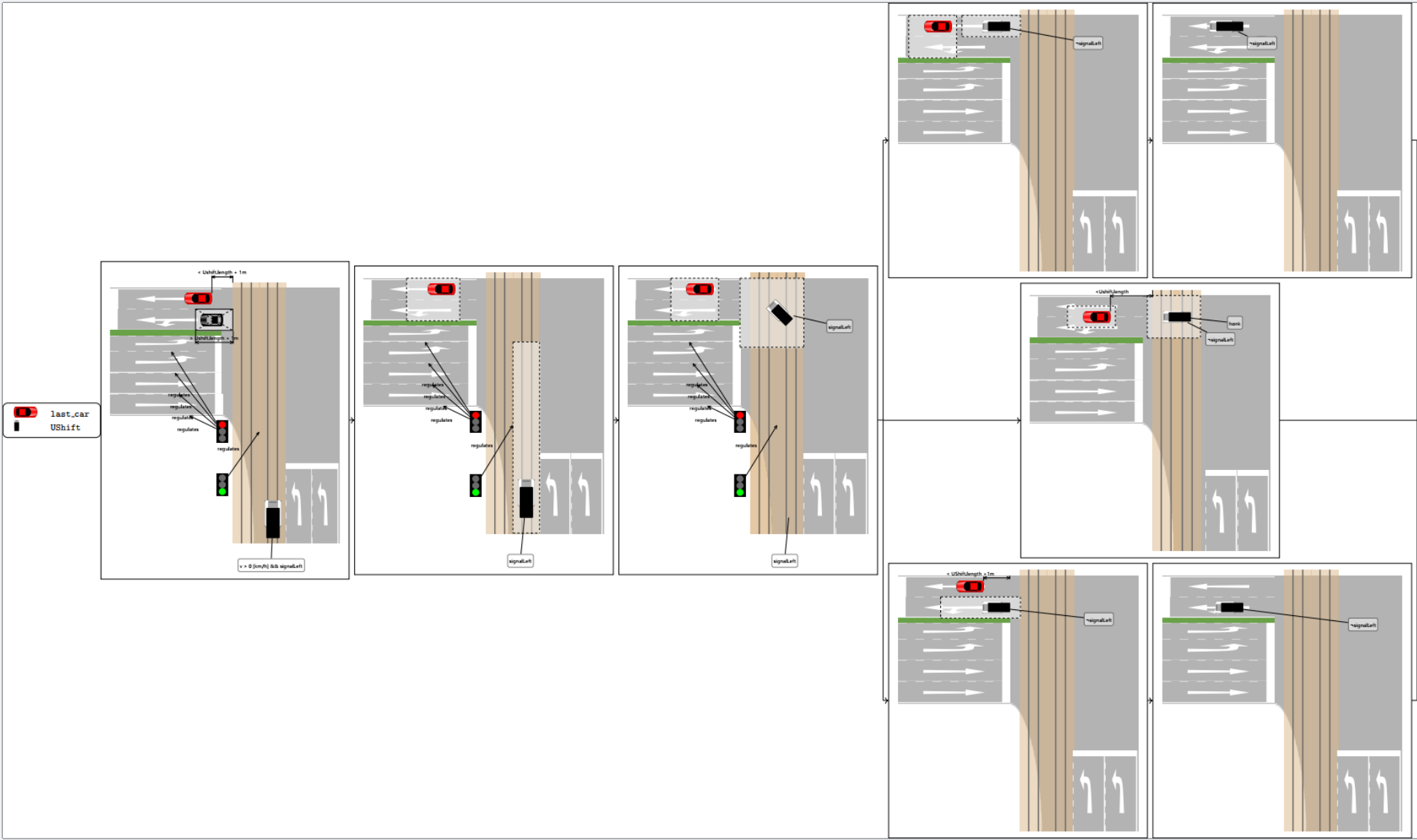
<sup>1</sup>Mentioned in ISO 31010; for details see also:

- <https://onlinelibrary.wiley.com/doi/10.1002/jhrm.20101>; last visit: 2026-05-20;
- Frank Crawley and Brian Tyler; Hazard Identification Methods; Institution of Chemical Engineers (IChemE), ISBN: 0 85295 457 3; 2003

- Collection of criticality phenomenons
  - From Project VVMMethods
  - By criticality analysis for autonomous driving in urban areas
  - fog, wind, conflicting trajectories, ...
- Needed for compliance with ISO 21448
  - Identification of „Triggering Conditions“
  - How can one make them easily usable and accessible for the purpose of generating a safety case?
- Criticality metrics, causal graphs, ...
- Modelling of relations between phenomenons
  - Concretisation/abstraction
  - Synergies
  - Potential causalities

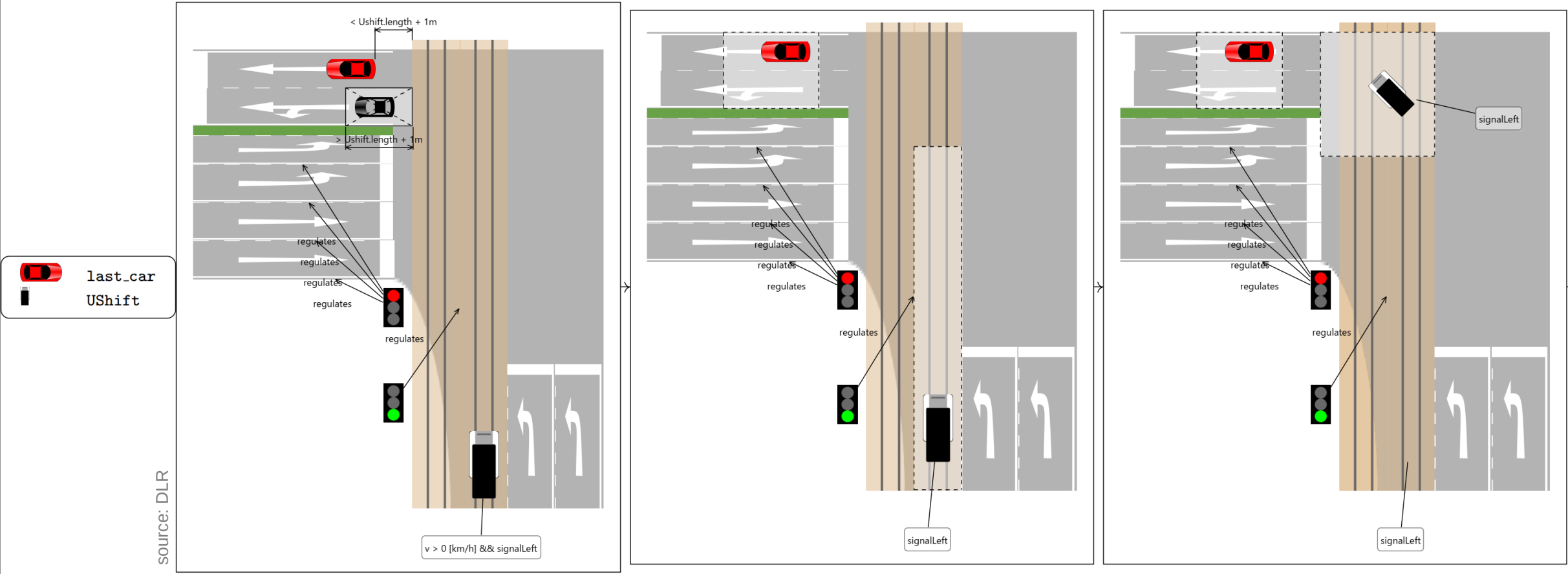


# Abstract Scenarios with Traffic Sequence Charts



source: DLR

# Abstract Scenario – Entering Intersection

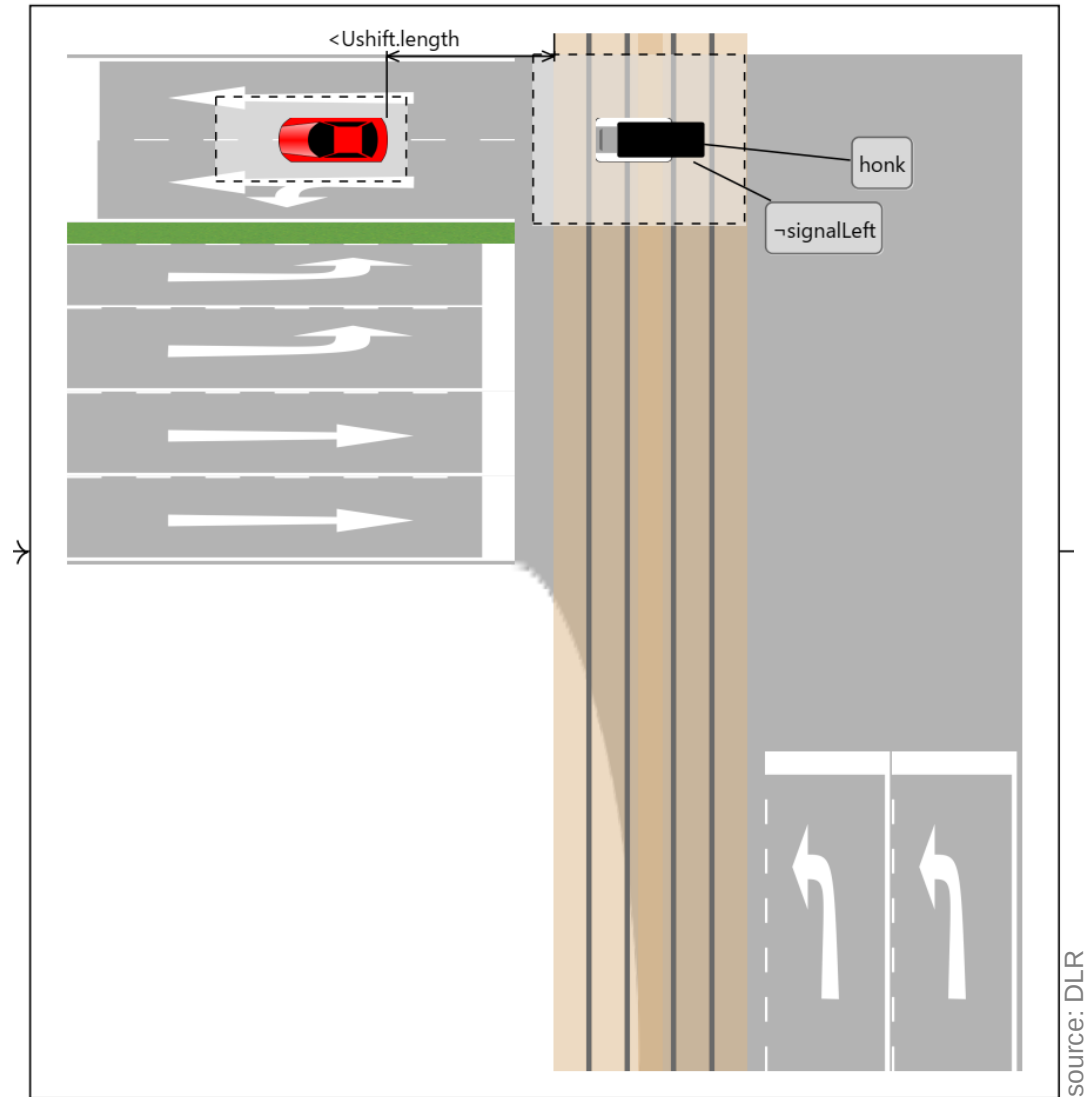


# Abstract Scenario – Left Turn Alternative I

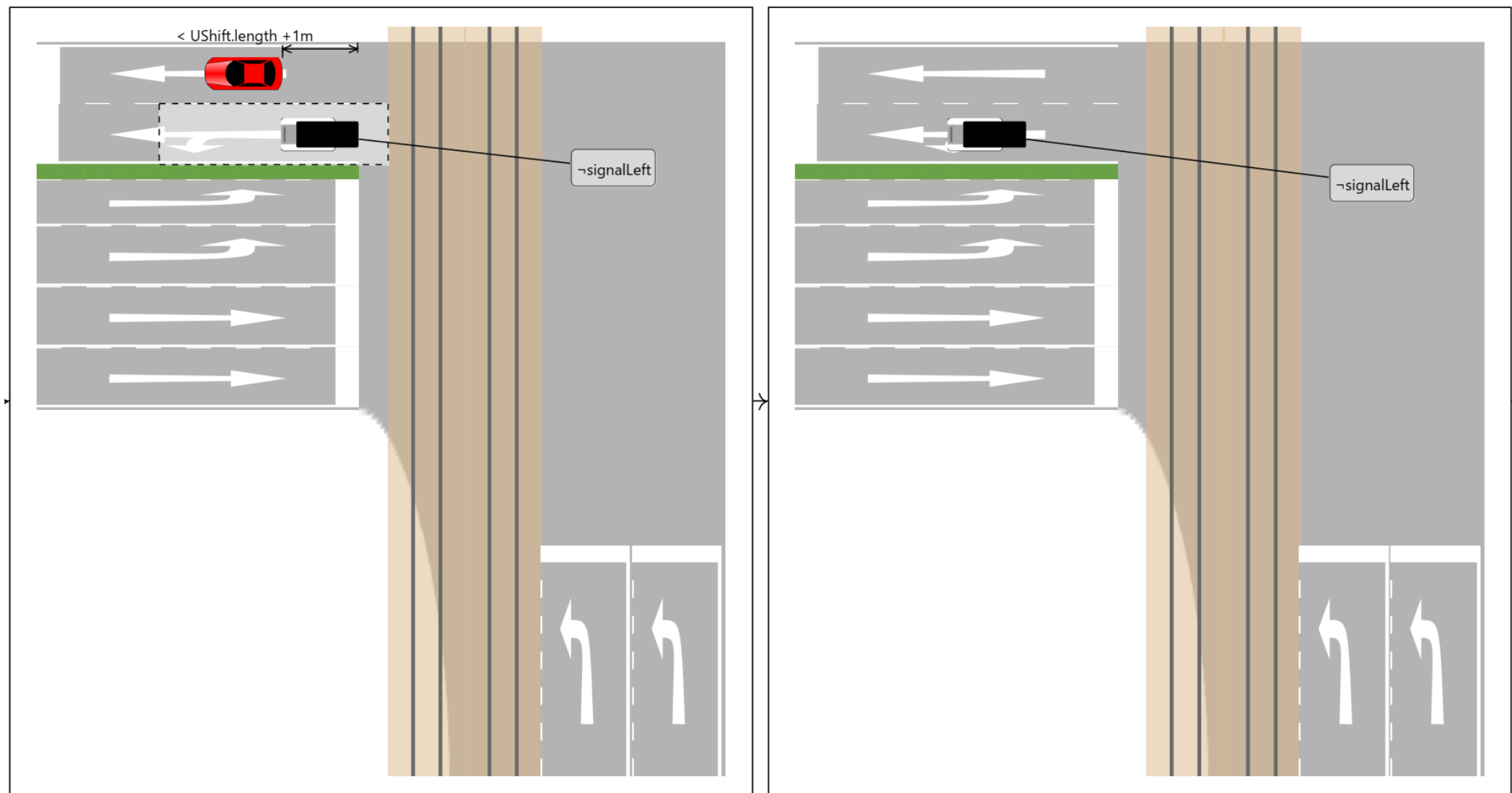


source: DLR

# Abstract Scenario – Left Turn Alternative II



# Abstract Scenario – Left Turn Alternative III



source: DLR

# 3D Modelling for Simulation Based V&V



Source: DLR



Source: DLR



Source: DLR

# Our discussion groups are open

- Discussion Group 1: Industry
  - How to develop and produce modular vehicles in combination with models for operation
- Discussion Group 2: Homologation, Certification, Standardisation
  - Best practices and missing regulatory aspects for safety assurance and certification of (modular) autonomous vehicles
- Discussion Group 3: Public Transport
  - How to integrate autonomous and modular vehicles in existing public transport systems

# Acknowledgements

| Topic                       | Contact Person                                                                                                    |
|-----------------------------|-------------------------------------------------------------------------------------------------------------------|
| Safety Case                 | Ingo Stierand, Björn Koopmann, Lukas Westhofen                                                                    |
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| Simulation                  | Michaela Rehm                                                                                                     |

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