Hi-Drive
Designing Automation

The Hi-Drive Driving Scenario Database

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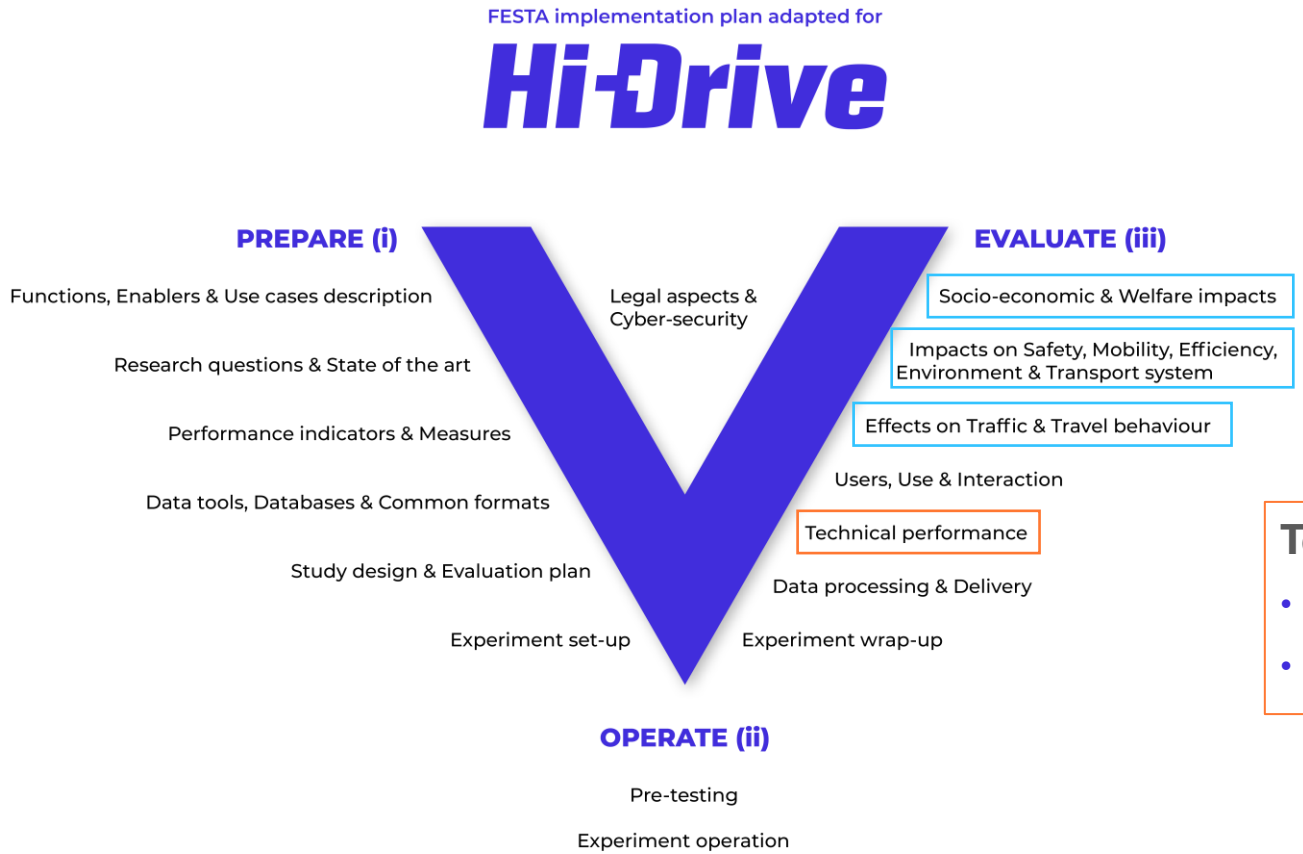
Effects evaluation in the FESTA V



Impact Assessment

- Impact of AD after market introduction

Technical Evaluation

- Availability of AD
- Effect of AD on driving behaviour

References:
Hi-Drive Deliverable D4.5 (2023), https://www.hi-drive.eu/app/uploads/2023/08/Hi-Drive-SP4-D4.5-Effects-evaluation-methods-v1.0_DRAFT_for_website.pdf

Technical Evaluation – Research Questions

Effect on availability of AD
- To what extent do the enablers **extend** the AD **functionality**?
- To what extent do enablers **enhance** AD **robustness**?

Effect on driving behaviour
- What is the effect of AD and its enablers on …
  - **Safe, Comfortable, Efficient** driving behaviour?
  - **Interacting** with other road users?
  - …

We want to **evaluate AD and its enablers**, not just single implementations/systems
→ Joint evaluation of the data

Challenge: Different operations in different environments and use cases with different enablers, different recorded signals with different quality

Concept of the Technical Evaluation

Hi-Drive Operations

ADF w/ Enablers

ADF w/o Enablers

Manual Driving

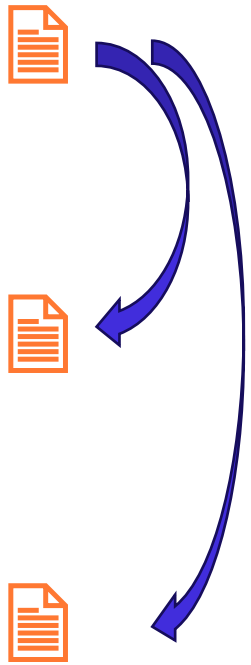
Hi-Drive

Data Conversion

Operation Data (CDF Files)

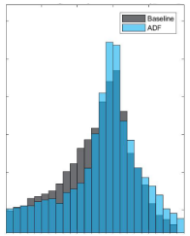
PI Calculation and Pooling (by Evaluation Partners)

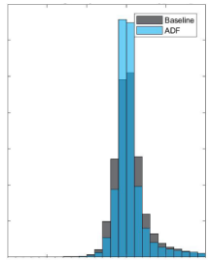
Performance Indicators (PIs)



Comparison and Creation of Results (by Evaluation Partners)

Results / Answers to RQs





Using the data directly

Impact Assessment – Research Questions

Impacts in different impact areas

- What is the impact of AD and its enablers on …
  - **Safety?**
  - **Energy demand**, **emissions, traffic efficiency?**
  - **Personal mobility**, the **transport system**?

Results combined in socio-economic impact assessment

- What is the overall **socio-economic impact** (net welfare effect) of AD and its enablers?
- How does AD affect the **welfare** of different stakeholders in society and **social equity**?

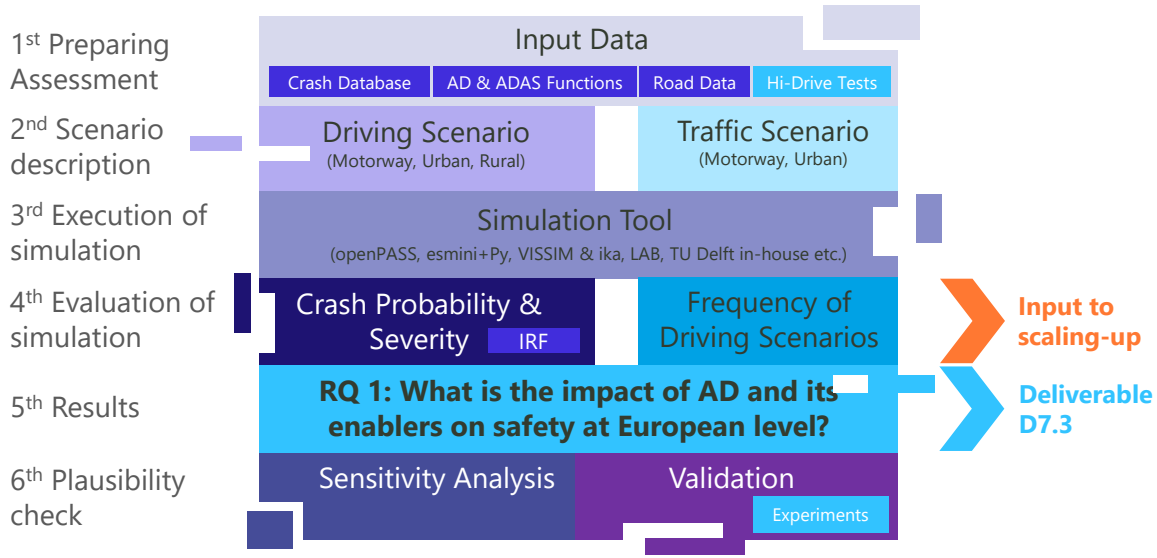
We want to **assess the impacts of AD and its enablers** for the European Union

The assessment is **based on simulations**
→ Operation data is used to calibrate the used models

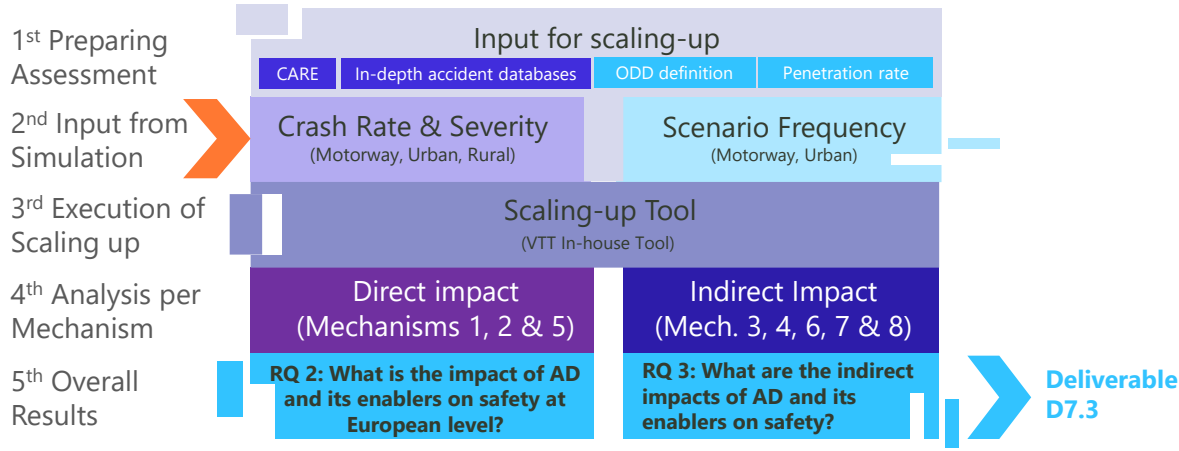
Example: Safety Impact Assessment – RQ and Approaches

1. What is the impact of AD and its enablers on safety **in different driving scenarios**?
2. What are the **indirect** impacts of AD and its enablers on safety?
3. What is the impact of AD and its enablers on safety at **European level**?

1. Effect in the scenario



2. Scaling up



Using the data *indirectly*

To allow a joint evaluation…

…we require harmonized processes

Harmonized data format for data provision

- Common Data Format (CDF) as the mandatory data exchange format between Operation Owners and Evaluation Partner

Harmonised evaluation toolchain

- Collaborative development
- Consistent data evaluation across multiple operations

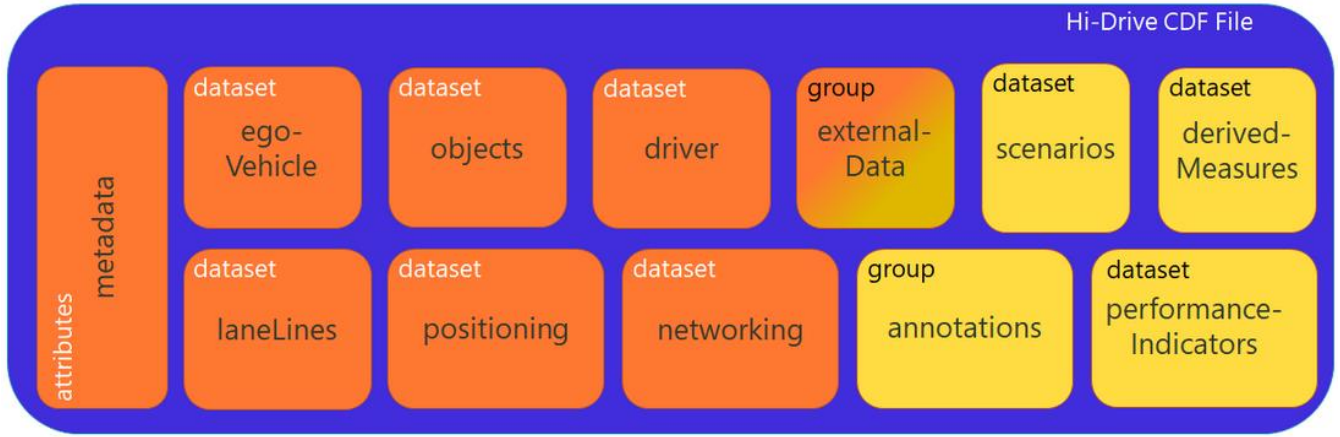
The Hi-Drive Common Data Format (CDF) as a Basis for the Joint Evaluation

Challenges for data harmonisation in Hi-Drive

- Diverse dedicated experiments
  - On-road tests
  - Test track studies
- Differences in system setup and data logging
- Additional signals from enablers
  - V2X
  - High precision positioning
- Enabler-focused research questions

  → Dedicated performance indicators

  → More complex driving scenarios

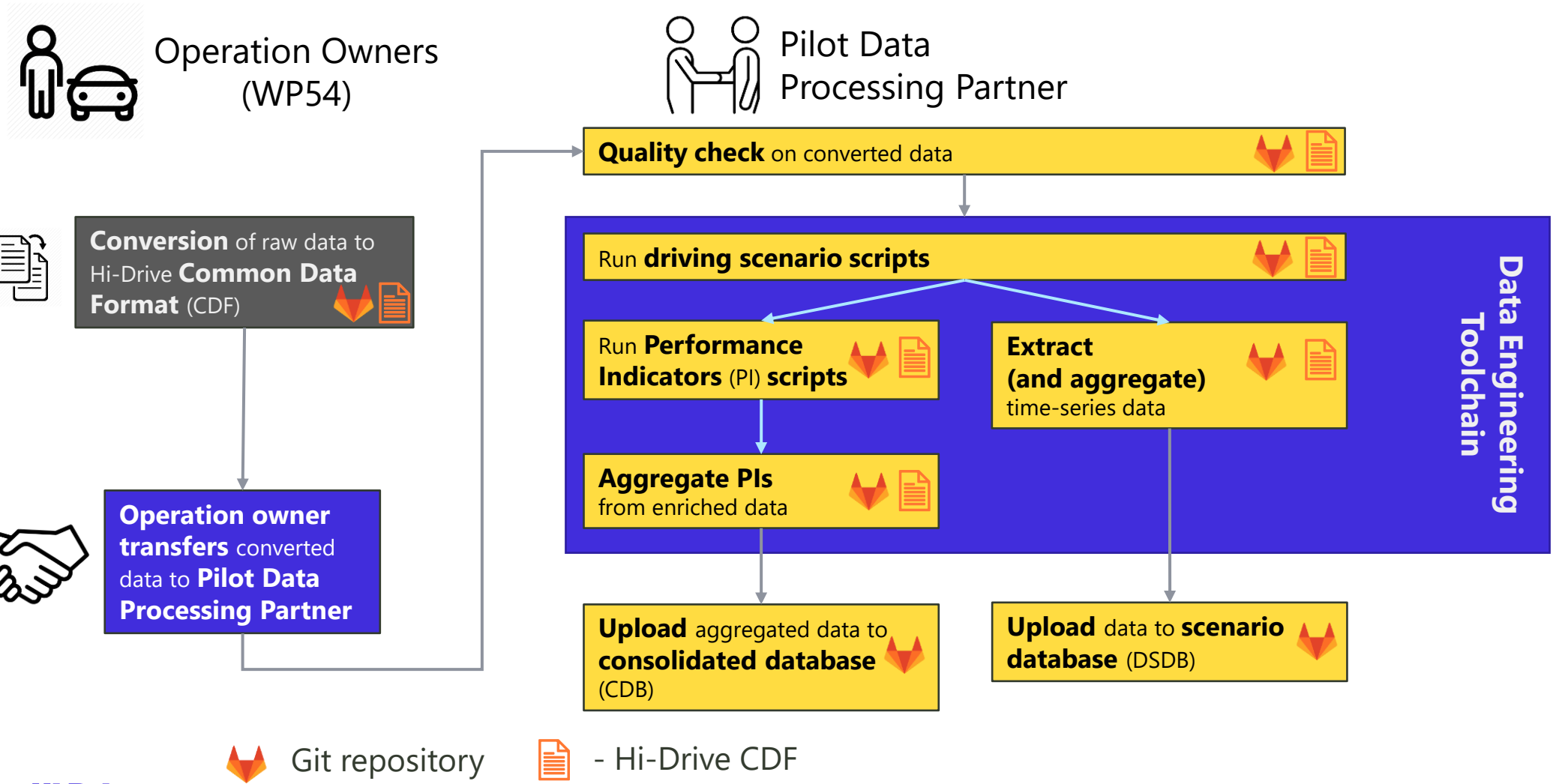


Data delivered by Pilot leaders

Data computed by Pilot data processing partners

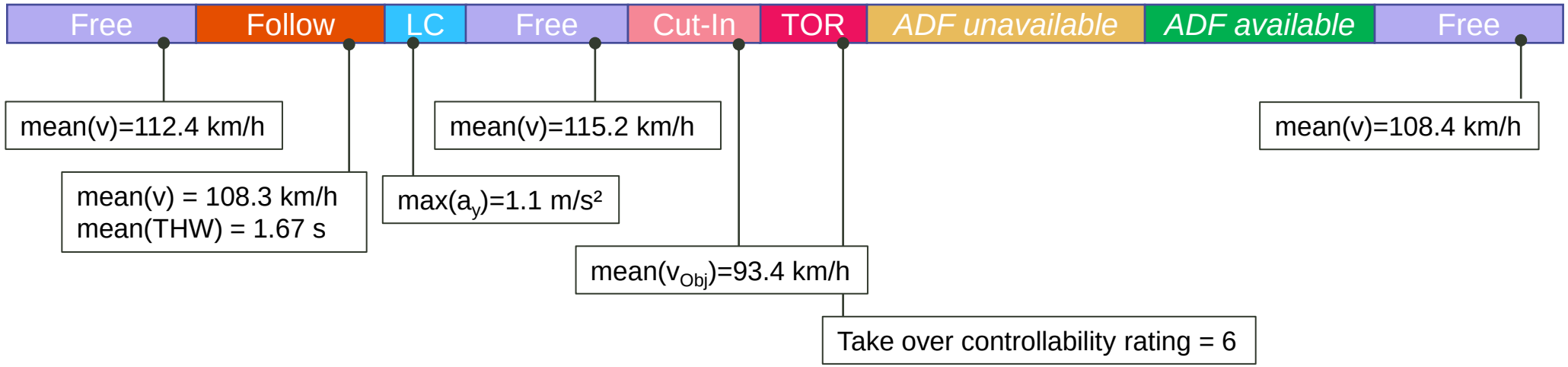
The Common Data Format from L3Pilot is available via Github: *github.com/l3pilot/l3pilot-cdf*

Data Processing Flow



Scenario-based Evaluation of Automated Driving in Hi-Drive

- **Segmenting the trip** into instances of defined driving scenarios
- **Deriving Performance Indicators** per instance of a driving scenario



- **Comparing Performance Indicators** of Treatment with Baseline (Technical Evaluation)
- **Storing the driving scenario instances** in the DSDB and identify Edge Cases
- **Using the DSDB** e.g. for calibration of models for impact assessment

Detailed time series data required!

To allow the scenario-based evaluation…

…we require harmonized concepts

Harmonized driving scenario concept

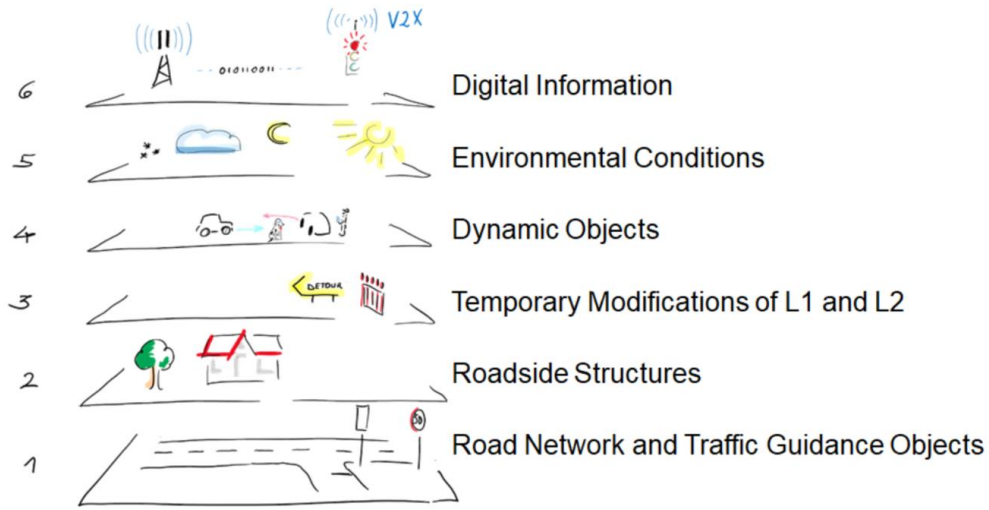
- Hi-Drive driving scenario concept based on 6-layer model

Joint database

- Driving scenario database (DSDB)

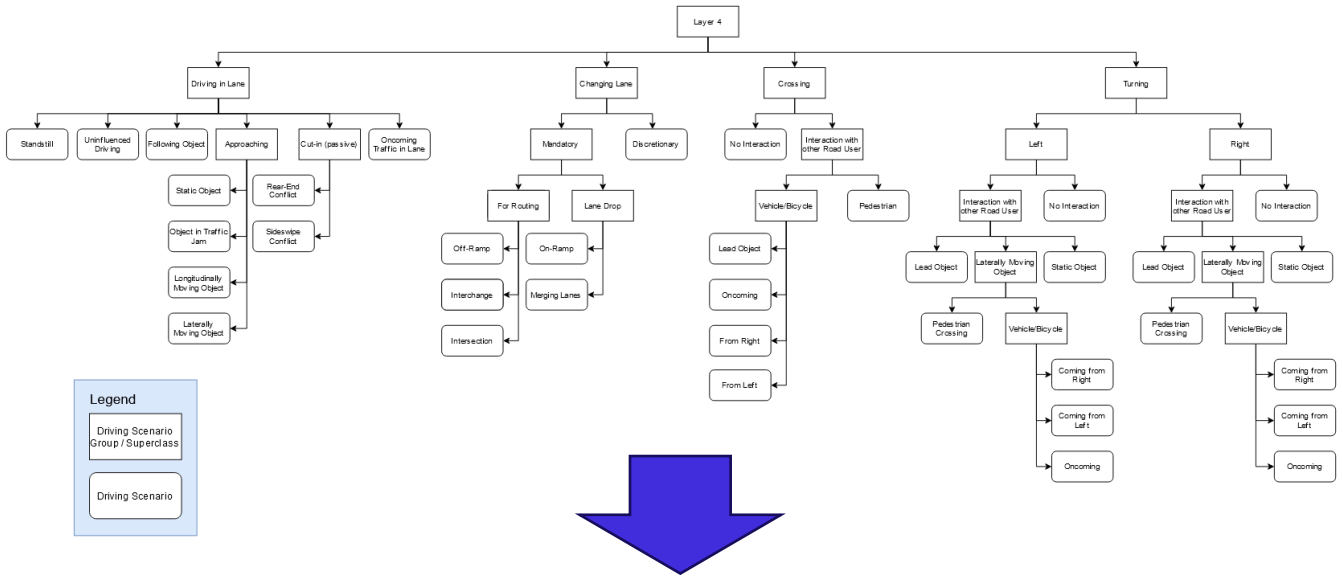
The Hi-Drive Driving Scenario Concept

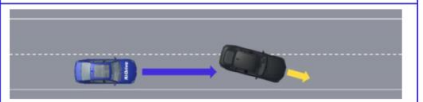
- Main **purpose** is to fulfil the needs of technical evaluation and impact assessment
- The **6-layer model** by Scholtes et al. (2021) was used as a reference
  - **Layer 4** (dynamic objects) defines the driving scenarios
  - The **other layers define situational variables** / tags to further specify the driving scenario instances



References:
Scholtes, M. et al. (2021). 6-Layer Model for a Structured Description and Categorization of Urban Traffic and Environment. IEEE Access, 9, 59131–59147. https://doi.org/10.1109/access.2021.3072739
Illustration taken from Weber, H. et al. (2023). Holistic Driving Scenario Concept for Urban Traffic. 2023 IEEE Intelligent Vehicles Symposium (IV), Anchorage, AK, USA, 2023, pp. 1-8. https://doi.org/10.1109/IV55152.2023.10186385

The Hi-Drive Driving Scenario Structure Defined by Layer 4



Name	Label	Parent	Description	Pictogram
Approaching Longitudinally Moving Object	in_lane_approaching_long_moving	in_lane_approaching	The ego vehicle is following a lane and is approaching an object that is driving in the same lane.	
Approaching Laterally Moving Object	in_lane_approaching_lat_moving	in_lane_approaching	The ego vehicle is following a lane and is approaching a laterally moving object at a road section that is not near a crossing.	
Cut-in with a Rear-End Conflict	in_lane_cut_in_rear_end	in_lane_cut_in	The ego vehicle is following a lane and another object is doing a cut-in that results in a rear-end conflict.	

Initial collection of required driving scenarios for evaluation
→ Harmonization and structuring

First separation based on ego movement relative to infrastructure
→ **Driving in Lane, Changing Lane, Crossing, Turning**

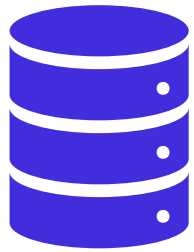
Further separation based on detailed ego behaviour and interaction with other road users
→ **36 specific driving scenarios**

Full concept published on Zenodo:
https://zenodo.org/record/8207762

Challenges Regarding DSDB

Challenges

- **Data sharing**
  - Anonymization of data / avoid being identifiable (avoid benchmarking and reengineering)
  - GDPR compliance
- **Data availability**
  - Many instances per driving scenario from different locations needed to have a representative DB
- **Filtering**
  - Allow easy usage of the high amount of data
- **Interoperability to other solutions**
- **EC detection**
  - Data quality
  - Amount of data



The data are provided via the DSDB…

…but there is more to use the DSDB for

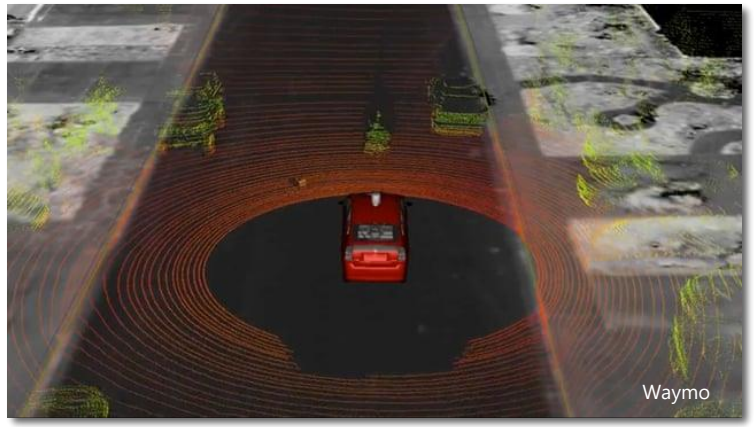
Edge case analysis

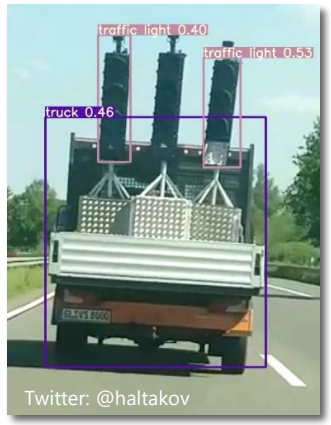
Test case derivation

…

Collecting Driving Scenarios & Edge Cases from Experimental Data

- Apart from evaluating the effects of enablers, we collect driving scenarios in a dedicated database and investigate the data for **edge cases**
- We consider all operations as potentially delivering edge cases
- External data sources serve as additional data
  - Reusing L3Pilot data
  - FOT, NDS & Traffic observation





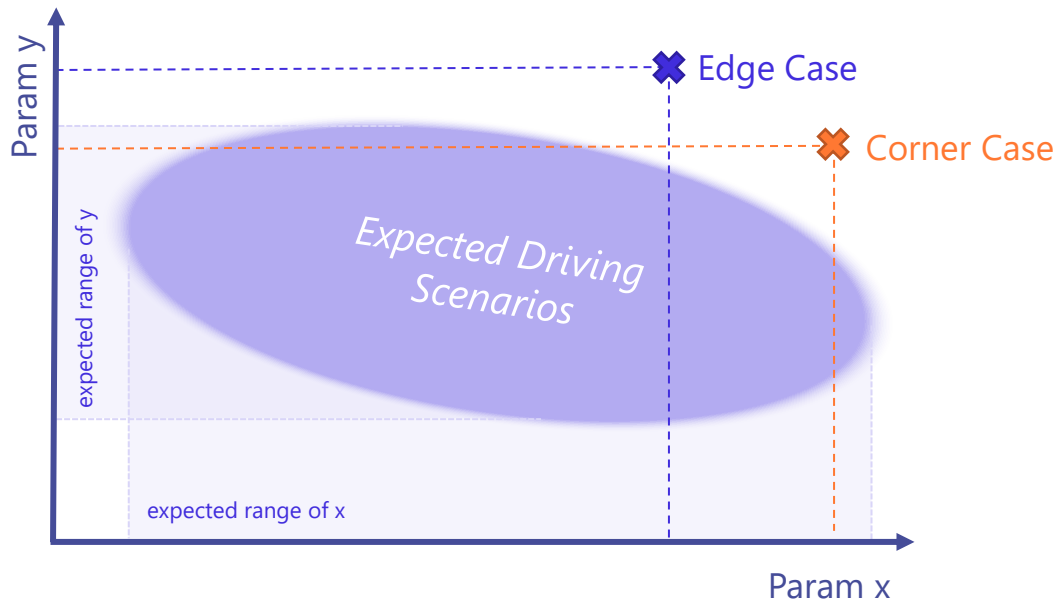
Edge Cases and Corner Cases

Hi-Drive Definition

- An Edge Case is a **driving scenario instance** that is **rare** but still requires **specific design attention** for it to be dealt with by the AV in a reasonable and safe way. The quantification of "rare" is relative, and generally refers to situations or conditions that **will occur often enough in a full-scale deployed fleet** to be a problem if not addressed appropriately.

Edge cases can appear due to extreme parameters:

- **Edge Cases** may arise from **single parameters** taking up values that are out of their expected range.
- **Corner Case: Multiple parameters** may take up values which are close to the boundary of their expected ranges creating a combination that was initially not expected or tested.



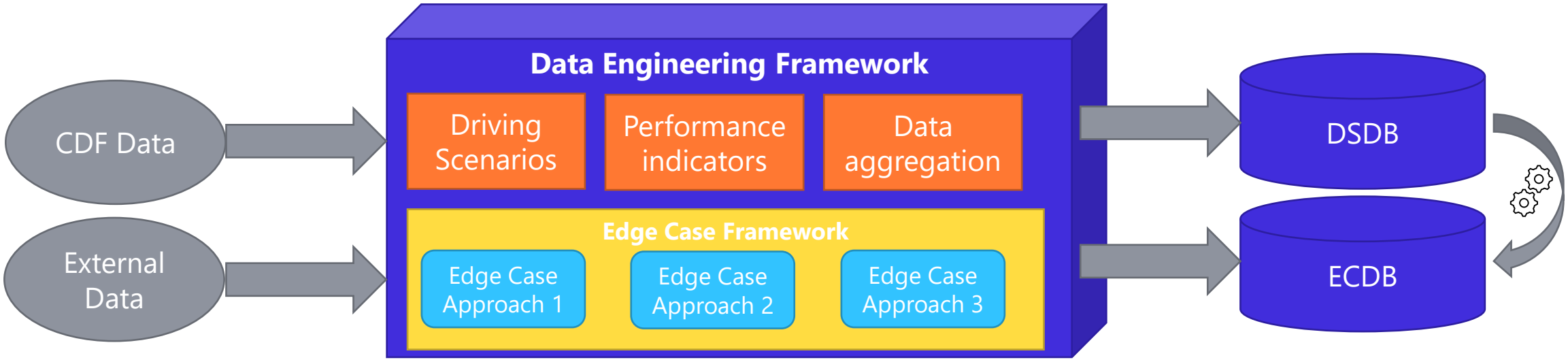
Challenge: No common understanding of what makes a driving scenario instance an edge case due to different understanding and driving functions

Driving Scenario and Edge Case Framework

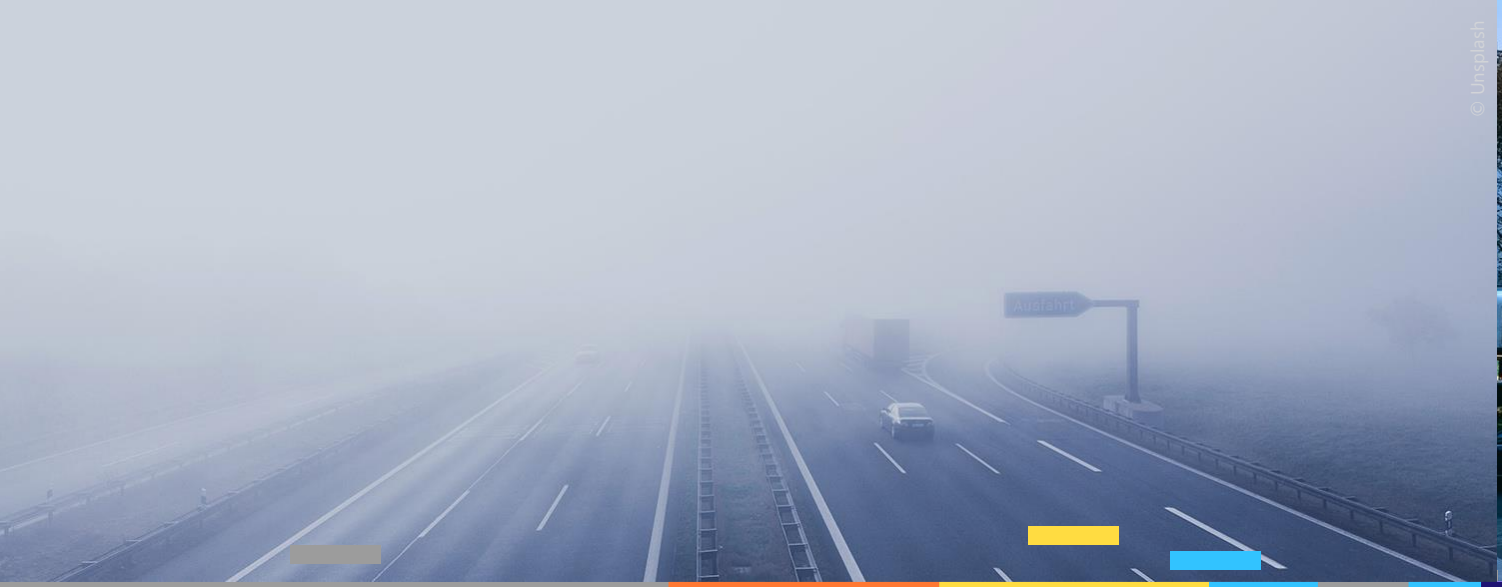
Challenges:

- We probably will not achieve one understanding of Edge Cases
- Due to the nature of edge cases, we might find only a few or none

→ Data engineering toolchain will need to host **different approaches** on how to get to edge cases



…so, we still got some work to do



THANK YOU FOR YOUR KIND ATTENTION.

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Hi-Drive

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