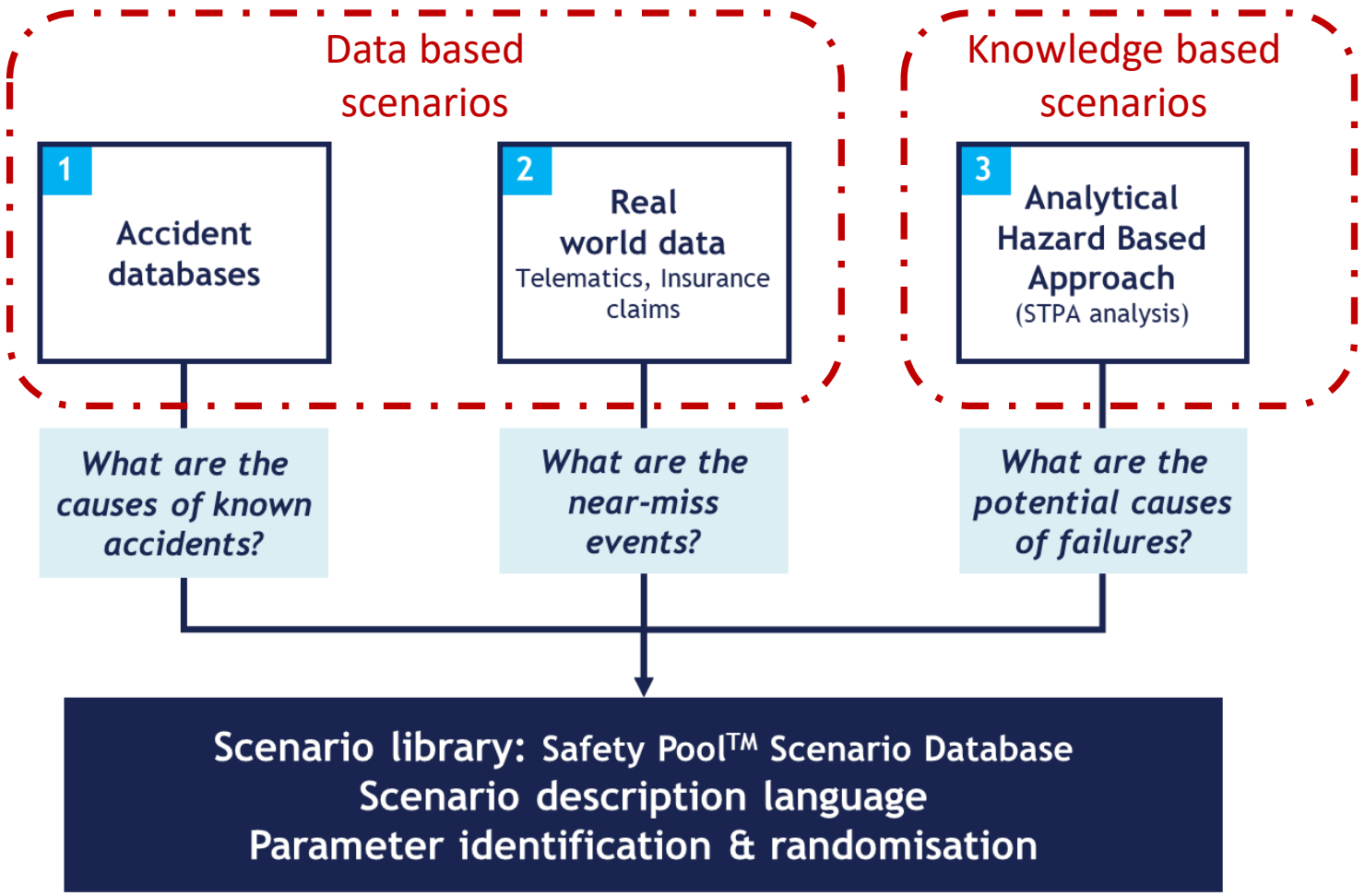
Input to FRAV/VMAD

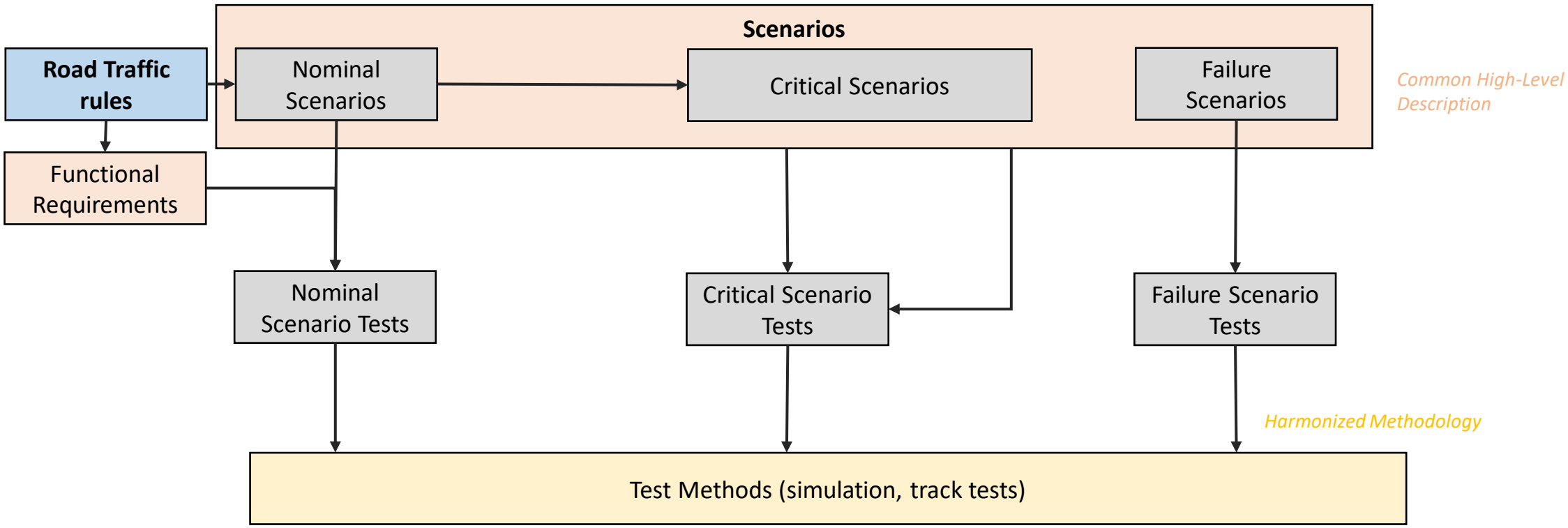
ODD Based Scenario Framework

Determining Traffic Scenarios and Functional Requirements

Scenario Generation Methods



Overall Summary



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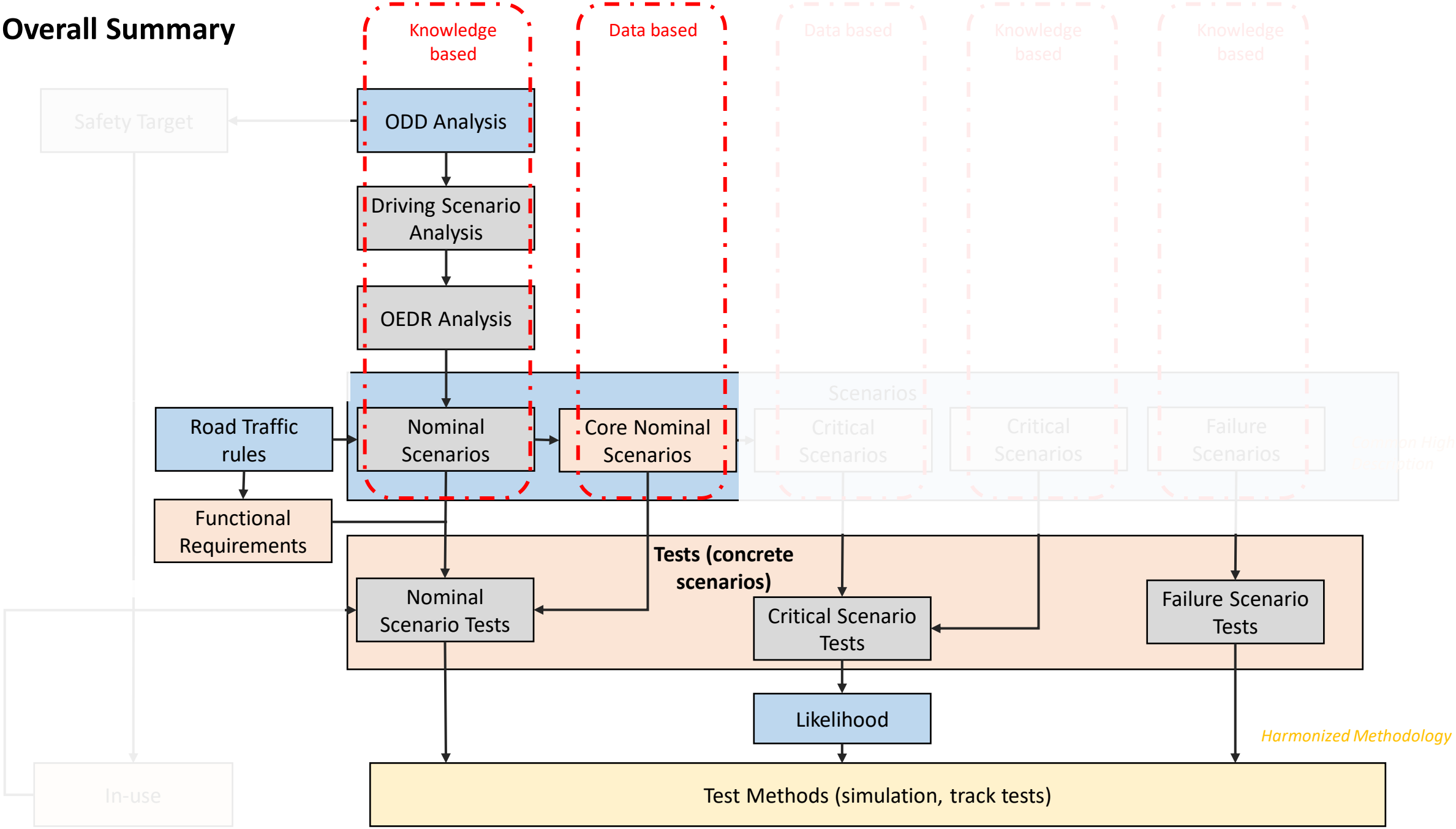

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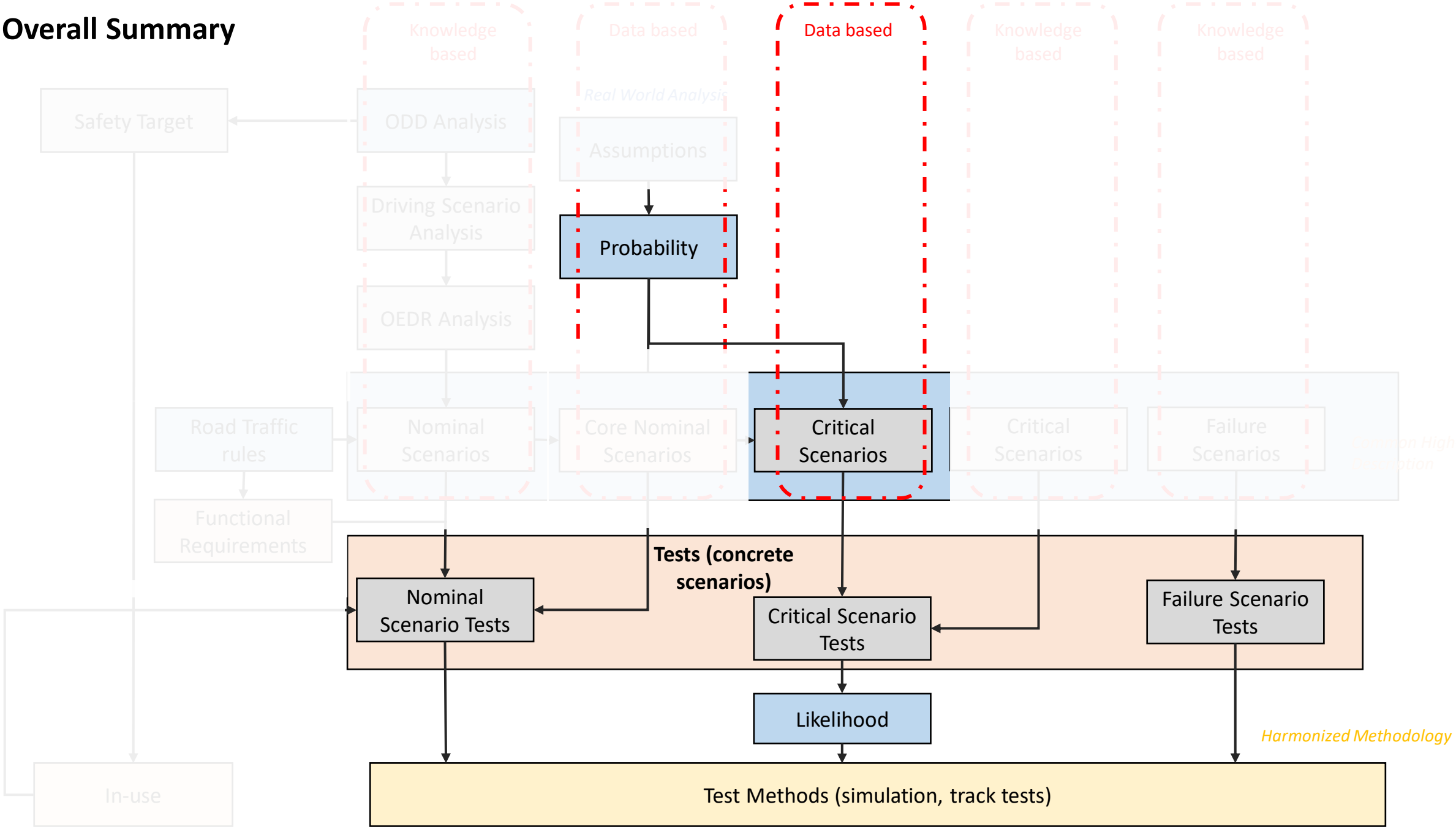

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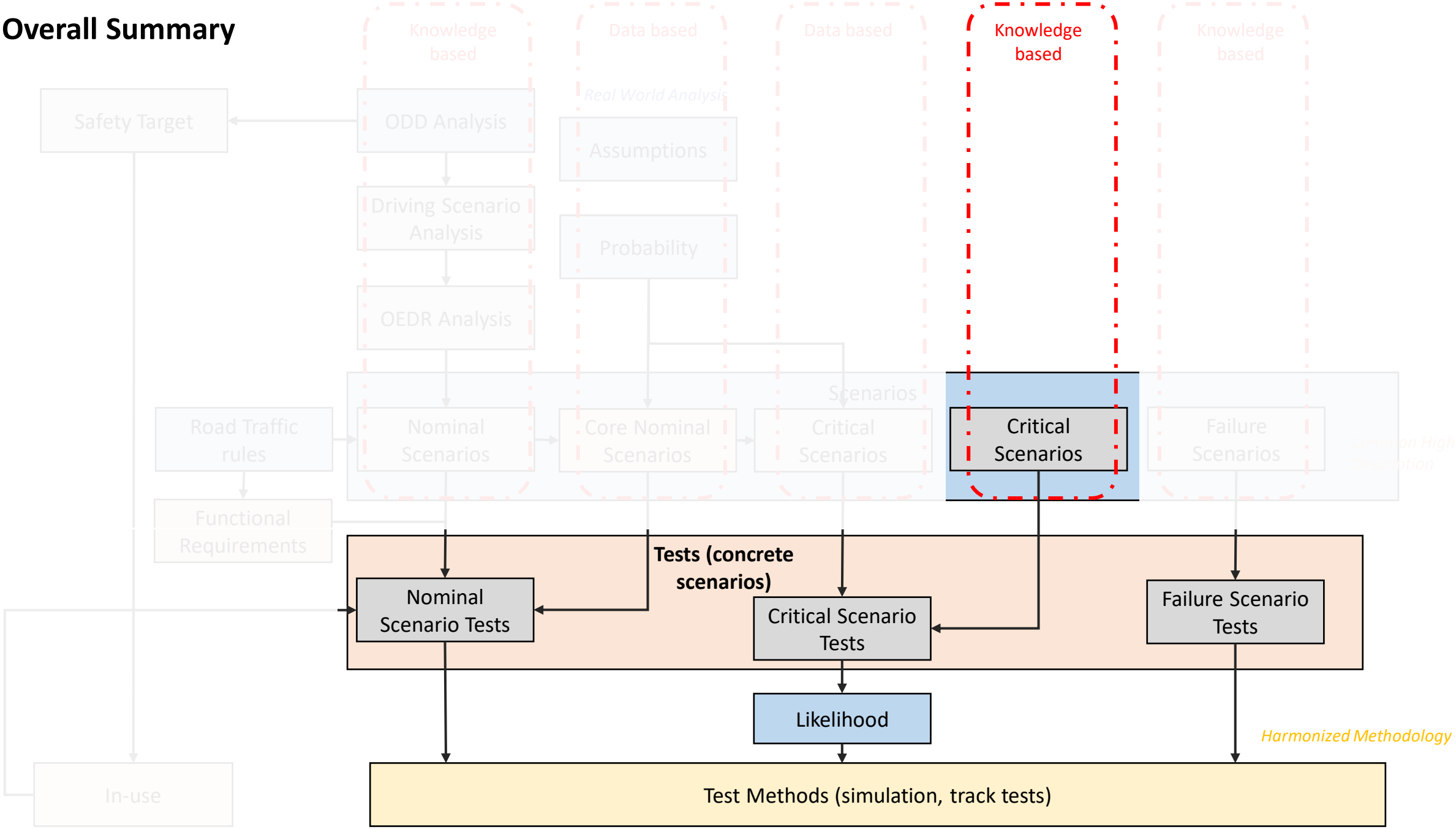

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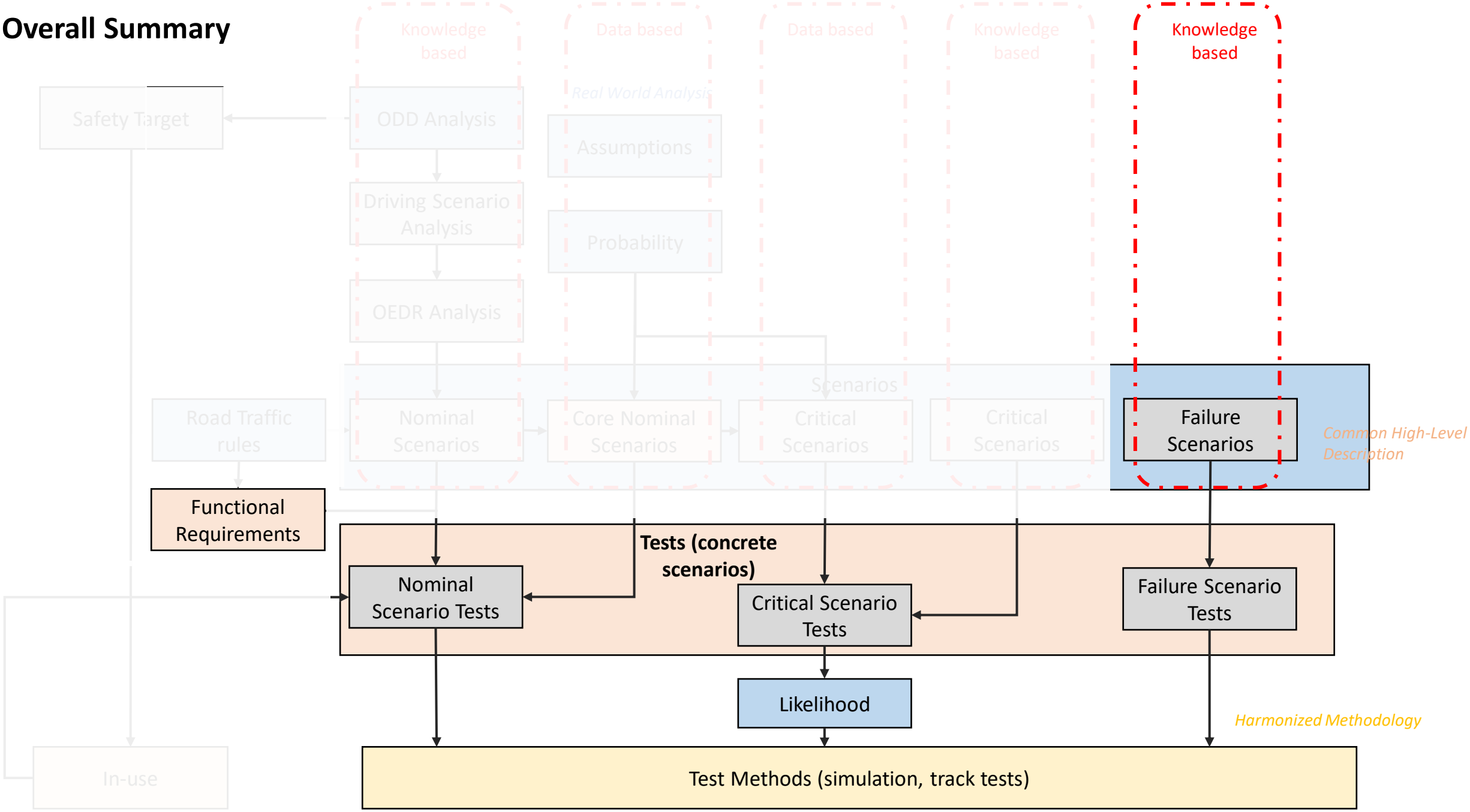
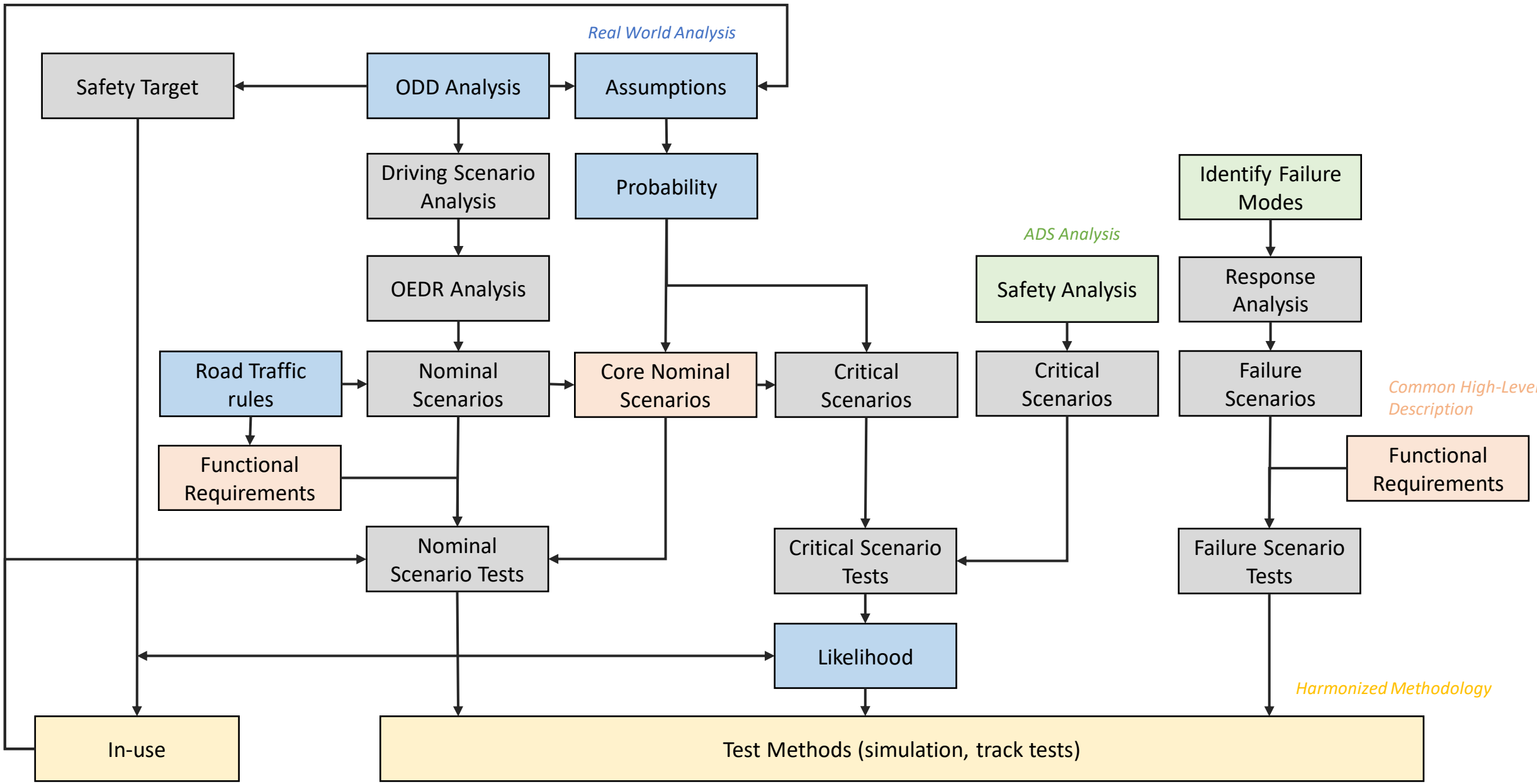
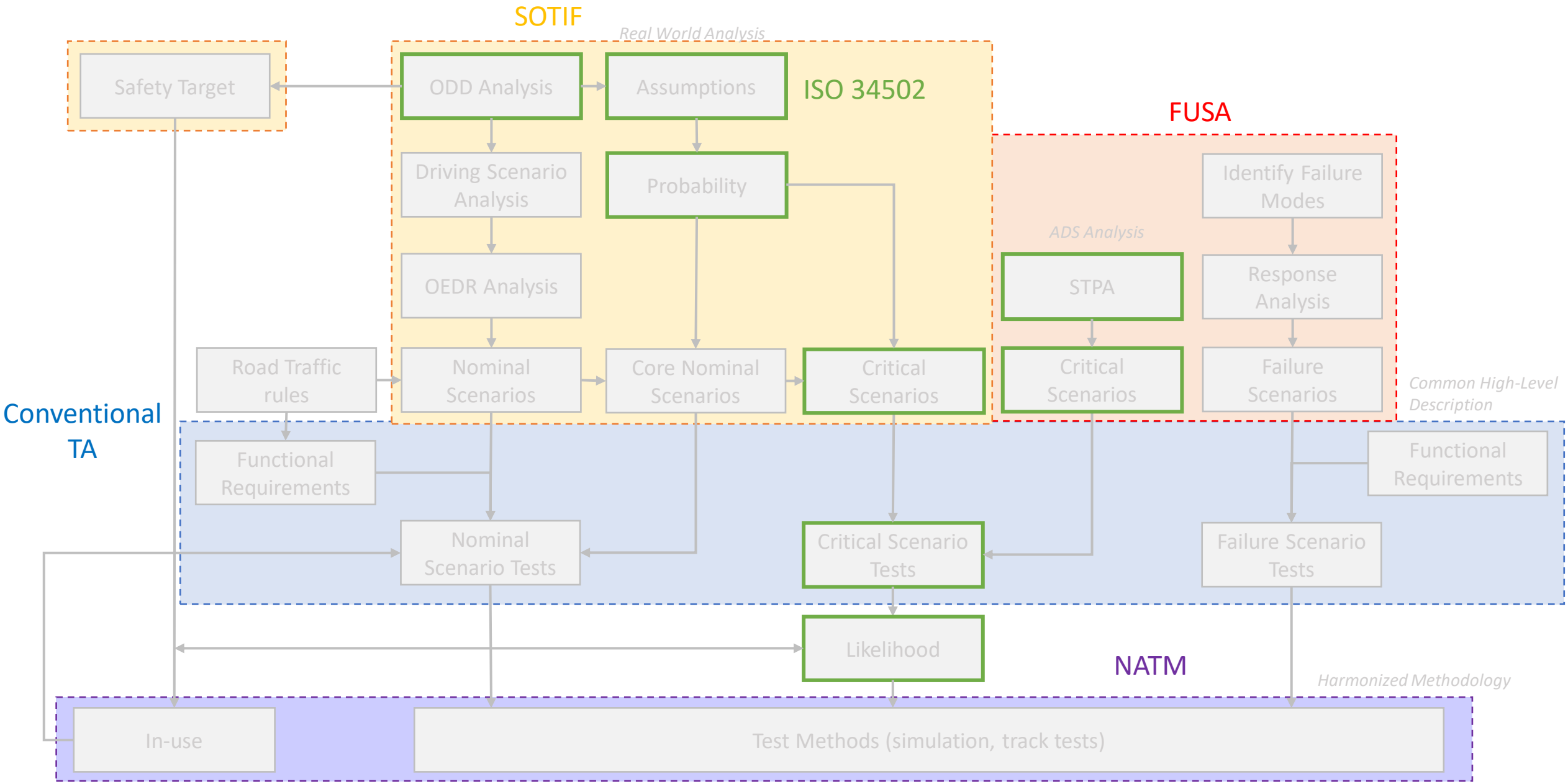


Overall Summary - Full




SOTIF
Real World Analysis
Safety Target
ODD Analysis
Assumptions
ISO 34502
Driving Scenario Analysis
Probability
OEDR Analysis
FUSA
Identify Failure Modes
ADS Analysis
STPA
Response Analysis
Road Traffic rules
Nominal Scenarios
Core Nominal Scenarios
Critical Scenarios
Critical Scenarios
Failure Scenarios
Common High-Level Description
Conventional TA
Functional Requirements
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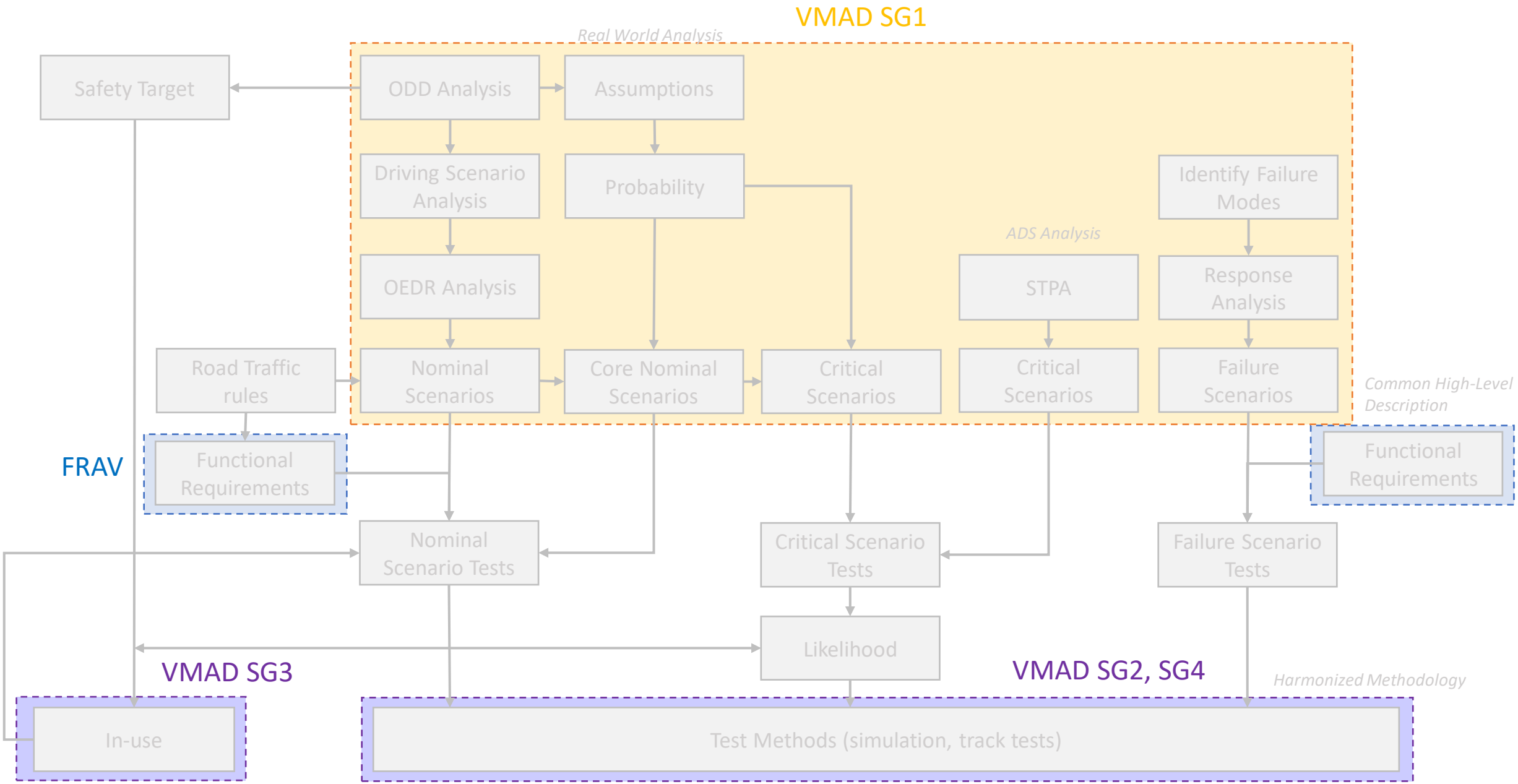
Nominal Scenario Tests
Critical Scenario Tests
Failure Scenario Tests
Likelihood
NATM
Harmonized Methodology
In-use
Test Methods (simulation, track tests)


VMAD SG1
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VMAD SG2, SG4
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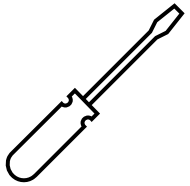
ODD Framework Toolbox



Scenario Categorization	Natural Language scenarios description	Scenarios description	Scenario Database	Core Scenarios
ISO 34502	StiEF, WMG-SDL	ASAM OpenDRIVE, ASAM OpenSCENARIO, M-SDL, H-SDL, ADSL, WMG-SDL	Safety Pool, TNO, CATARC, SAKURA, *France*	NHTSA Test Cases, Safety Pool, ISO 34502, Japan, Foretellix, Germany, Netherlands/Singapore, Waymo, M-CITY

Assumptions	Likelihood	ODD Taxonomy	Virtual Testing	Logical to Concrete
IEEE P2846, Accident Data, SPMD	TNO, HEADSTART	PAS 1883, ISO 34503	CARLA, DriveSIM, LGSVL, PreScan, RFPro	Constrained random, pseudo random, AI/ML, Bayesian Optimization

Safety Analysis
STPA, FTA, FMEA

- A Number of tools are needed to support the ODD based framework. FRAV/VMAD framework should define what tools are needed but shouldn't specify which tool is most appropriate.
- Core scenario list may be Harmonized after review of existing tools.
- With more real world experience, and when ADS is to be regulated then specific tools may be harmonized where needed.

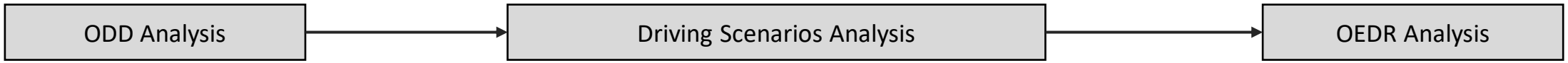
Summary

- ADS certification consists of a scenario-based assessment
- The ODD description by the Manufacturer will support determination of applicable requirements and scenarios generation
- Nominal scenario are derived from ODD and OEDR analysis
  - The ADS is expected to comply with all requirements in these scenarios
- Critical scenarios are derived from STPA and real world data / Assumption of other road users (IEEE P2846)
  - The performance threshold in critical scenarios is compared to accident data
- Failure scenario derived from FMEA and STPA
  - The ADS is expected to comply with all requirements in these scenarios

BACKUP

Nominal Scenarios

- Regulation should provide a framework that allows manufacturers to derive requirements for nominal behaviour.
- Nominal scenarios and requirements can be derived from the ODD and the expected behaviour competency (Analysis of Highway code and ADS functional requirements)
- The EU's implementing act should define a common categories of behaviour competencies that are applicable to all EU members states. The type approval should focus on assessing the ADS ability to perform these behaviours in the ODD.
- Behaviour competencies may be different between: highway, interurban, urban and parking.



Perform analysis to identify the characteristics of the ODD.

Perform driving scenario analysis.

- Expected hazards (e.g., vehicles, pedestrians, etc.);
- Unspecified/unexpected events (e.g., construction zones, emergency vehicles, etc.); and
- Key infrastructure elements (e.g., traffic signs and signals, road markings, etc.).

Perform analysis to identify OEDR behaviors and corresponding responses.

Nominal Scenarios – ODD Analysis

- ODD Analysis
  - Is used to identify the characteristics of the ODD
  - Characteristics may consist of: physical infrastructure, operational constraints, environmental conditions, connectivity etc
  - PAS 1883 may be used as a reference

Nominal Scenarios – Driving Scenario Analysis

- The developed baseline ODDs were used to identify important objects and events that ADS could feasibly encounter within those ODDs
- Interactions with obstacles were indicated as occurring in a frontal, side, or rear zone.

Objects	Events/Interactions
Vehicles (e.g., cars, light trucks, heavy trucks, buses, motorcycles)	**Lead vehicle decelerating (frontal), lead vehicle stopped (frontal), lead vehicle accelerating (frontal), changing lanes (frontal/side), cutting in (adjacent), turning (frontal), encroaching opposing vehicle (frontal/side), encroaching adjacent vehicle (frontal/side), entering roadway (frontal/side), cutting out (frontal)**
Pedestrians	**Crossing road – inside crosswalk (frontal), crossing road – outside crosswalk (frontal)**, walking on sidewalk/shoulder
Pedalcyclists	**Riding in lane (frontal)**, riding in adjacent lane (frontal/side), riding in dedicated lane (frontal/side), riding on sidewalk/shoulder, **crossing road – inside crosswalk (frontal/side), crossing road – outside crosswalk (frontal/side)**

Objects	Events/Interactions
Animals[5]	Static in lane (frontal), moving into/out of lane (frontal/side), static/moving in adjacent lane (frontal), static/moving on shoulder
Debris[6]	**Static in lane (frontal)**
Other dynamic objects (e.g., shopping carts)	**Static in lane (frontal/side), moving into/out of lane (frontal/side)**

Objects	Events/Interactions
Traffic signs[7]	Stop, yield, speed limit, crosswalk, railroad crossing, school zone
Traffic signals[7]	Intersection, railroad crossing, school zone
Vehicle signals	Turn signals

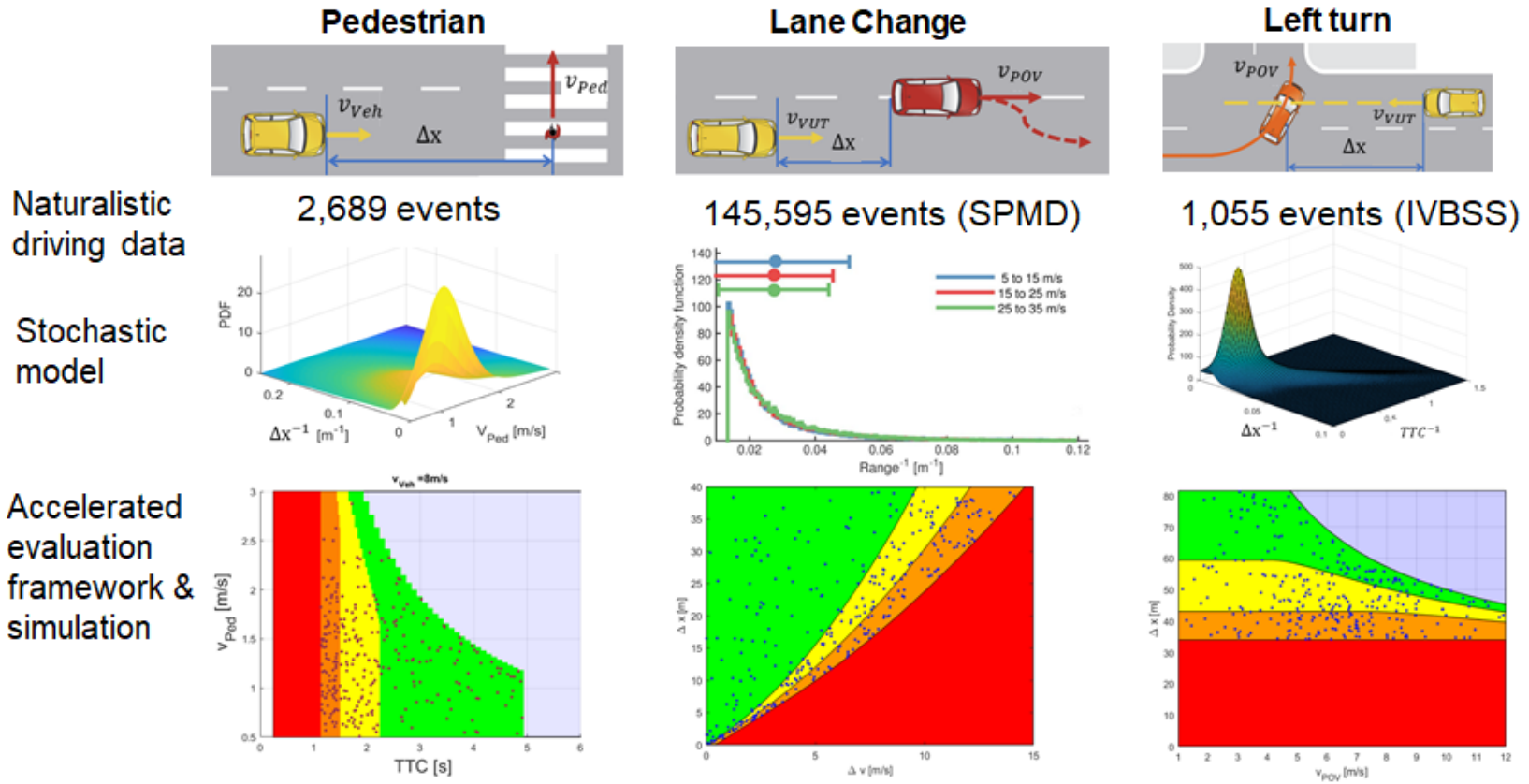
Nominal Scenarios – OEDR Analysis

- Based on the objects and events identified it is possible to map the appropriate response of the ADS
- Align the response with the functional requirements set for the ADS:
  - The ADS should adapt its behaviour in line with safety risks
  - The ADS should comply with road traffic rules.
  - The ADS behaviour should not disrupt the flow of traffic
  - The ADS should interact safely with other road users
  - etc

Event	Response
Lead vehicle decelerating	Follow vehicle, decelerate, stop
Lead vehicle stopped	Decelerate, stop
Lead vehicle accelerating	Accelerate, follow vehicle
Lead vehicle turning	Decelerate, stop
Vehicle changing lanes	Yield, decelerate, follow vehicle
Vehicle cutting in	Yield, decelerate, stop, follow vehicle
Vehicle entering roadway	Follow vehicle, decelerate, stop
Opposing vehicle encroaching	Decelerate, stop, shift within lane, shift outside of lane
Adjacent vehicle encroaching	Yield, decelerate, stop
Lead vehicle cutting out	Accelerate, decelerate, stop
Pedestrian crossing road – inside crosswalk	Yield, decelerate, stop
Pedestrian crossing road – outside of crosswalk	Yield, decelerate, stop
Pedalcyclist riding in lane	Yield, follow
Pedalcyclist riding in dedicated lane	Shift within lane[9]
Pedalcyclist crossing road – inside crosswalk	Yield, decelerate, stop
Pedalcyclist crossing road – outside crosswalk	Yield, decelerate, stop
Lead vehicle decelerating	Follow vehicle, decelerate, stop
Lead vehicle stopped	Decelerate, stop
Lead vehicle accelerating	Accelerate, follow vehicle

Critical Scenarios - Assumptions

- Critical scenarios can be derived from the nominal scenarios and STPA. Test scenario parameters can be defined from:
  - Accident database
  - Real world data
  - Assumptions of real driving behaviour

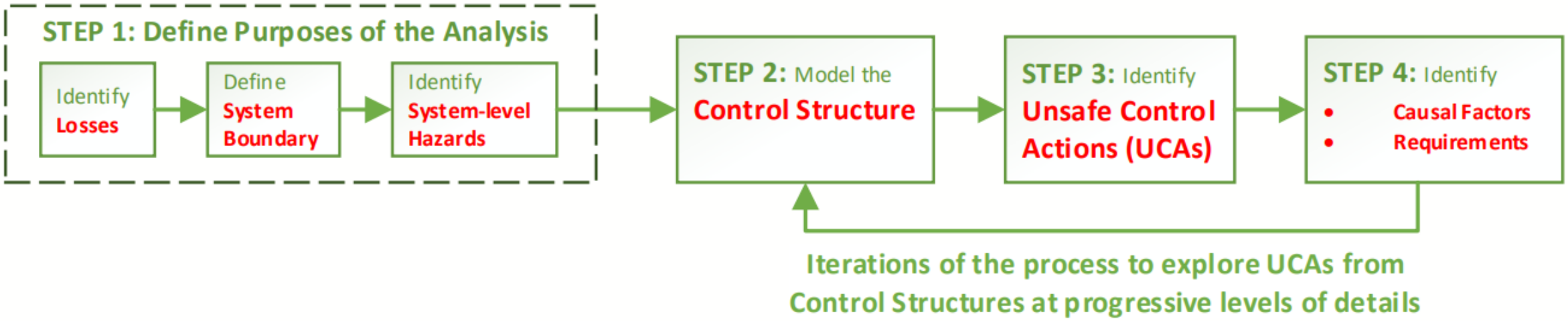


Critical Scenarios - STPA

STAMP/STPA is based on Systems Engineering and considers system safety as a control problem

- Safety is a control problem (property of a system as a whole, not individually)
- Breach of control laws (constraints) cause accidents

Should consider ‘recognition limitation’ and ‘ vehicle disturbances’ for casual factors



Failure Scenarios

An FMEA / STPA can generally be broken down into the following steps.

- Identify potential failure modes
- Identify potential causes and effects of those failure modes
- Prioritize the failure modes based upon risk
- Identify an appropriate corrective action or mitigation strategy

The FMEA was broken down by architecture subsystems to identify potential key failures at each step through the ADS “pipeline.”

- Sensing and communication
- Perception
- Navigation and control
- HMI

After completing the FMEA for the ADS architecture, the various failure modes and effects can be summarized and mapped to the relevant tactical maneuver and OEDR behaviors

Failure Response

- Failure modes and effects

Behavior Failure	Effects
Fail to maintain lane	Impact adjacent vehicle or infrastructure
Fail to maintain safe following distance	Impact lead vehicle
Fail to detect and respond to maneuvers by other vehicles	Impact lead or adjacent vehicles
Fail to detect relevant obstacles in or near lane	Impact obstacles
Fail to identify ODD/OEDR boundary	Operate outside of ODD/OEDR capabilities

- Fail safe

  The primary goal of an FS strategy is to rapidly achieve an MRC where the vehicle and occupants are safe. Three candidate FS mechanisms were considered for further evaluation.
  - Transition to fallback-ready user control
  - Safely stop in lane of travel
  - Safely move out of travel lane and stop

- Fail operation

  FO strategies allow the ADS to continue to function, even in the event of one or more failures. It may only be supported for a limited duration, or potentially with a reduced set of capabilities.
  - Hardware/software redundancy
  - Adaptive compensation
  - Degraded operations
    - Reduced top speed
    - Reduced level of automation
    - Reduced ODD
    - Reduced maneuver capabilities
    - Reduced OEDR capabilities