Automotive SPIN ITALIA

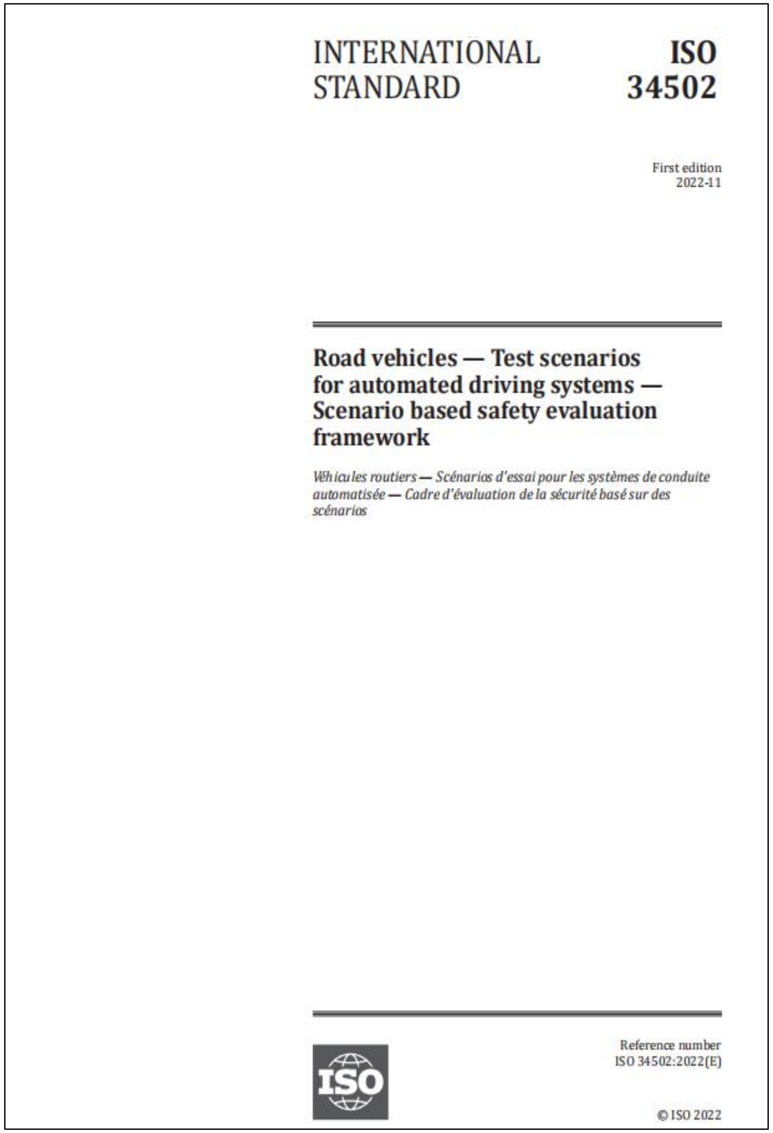
Overview of ISO 34502

Road vehicles — Test scenarios for automated driving systems — Scenario based safety evaluation framework

Fabio Falcini
Giuseppe Lami

2025

Introduction



INTERNATIONAL STANDARD

ISO 34502

First edition
2022-11

Road vehicles — Test scenarios for automated driving systems — Scenario based safety evaluation framework

Véhicules routiers — Scénarios d'essai pour les systèmes de conduite automatisée — Cadre d'évaluation de la sécurité basé sur des scénarios

Reference number
ISO 34502:2022(E)

Part of the ISO 3450x series.

Strong link with SOTIF (ISO 21448) - safety of the intended functionality

ISO 34502 is conformant with SOTIF and adds specificity to its content, by incorporating a scenario-based safety evaluation process.

Function-based approach	Suitable for targeted verification of specific functionalities	May overlook system-level interactions and emergent behavior More suitable for ADAS than fully autonomous AVs
Scenario-based approach	Focuses on critical use cases, verifies specific scenarios Systematic evaluation of key scenarios for SOTIF Targeted approach for V&V	May not cover all edge cases and potential failures Limited in handling unknown scenarios and emergent behavior

ISO 34502 Introduction

Product development process for automated driving systems with Level 3 and above defined in ISO/SAE PAS 22736.

ISO/SAE PAS 22736:2021

Taxonomy and definitions for terms related to driving automation systems for on-road motor vehicles

Published (Edition 1, 2021)

The main target of the norm is an ADS system that operates on motorways.

Its evaluation process that identifies risk factors and related critical scenarios that affect the intended functionality.

ISO 34502 does not address safety-related issues involving

- misuse
- human machine interface
- and cybersecurity.

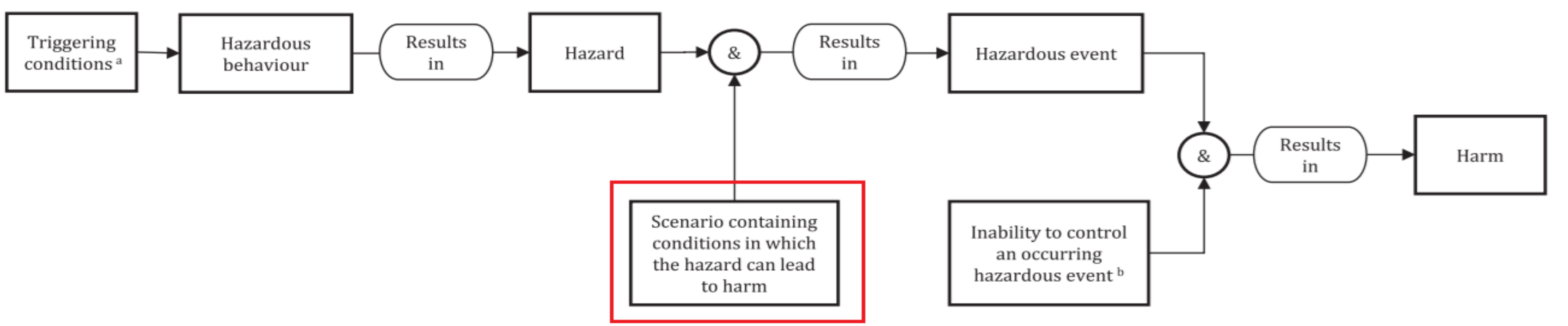
ISO 34502 Introduction

Testing strategies that are sufficient for testing ADAS become insufficient for verifying and validating ADS.

The current Safety of the Intended Functionality (SOTIF) standard (ISO 21448) establishes scenario-based testing as state-of-the-art to test highly automated ADAS/ADS.

A scenario is the basis for a test case definition in the scenario-based testing approach - it describes the environment of a vehicle, including the road infrastructure, actors, and other conditions.

A scenario is hazardous if it contains triggering conditions turning functional insufficiencies of the SUT into hazardous behavior potentially causing harm.



Efforts related to scenario selection

The search for a selection of scenarios for the validation of automated driving systems has been the subject of various international works. The following references can be noted in particular:

Basis and reference	Nature of prescriptions	Typology of scenarios
EU 2022/1426	Regulatory	Functional to logical
UN R 157	Regulatory	Concrete
NHTSA 2018	Guidance	Functional to logical
NHTSA 2007 (pre-crash)	Guidance	Functional to logical
EuroNCAP		
SafetyPool Database		

UN Regulation No. 157 - Automated Lane Keeping Systems (ALKS)

VDA 702June 2015

Situation catalog E-parameters according to ISO 26262-3	VDA 702

Lots of Data from NHTSA

U.S. Department of Transportation
National Highway Traffic Safety Administration

NHTSA

DOT HS 812 745

August 2019

Statistics of Light-Vehicle Pre-Crash Scenarios Based on 2011-2015 National Crash Data

Pre-Crash Scenarios
Running Red Light
Running Stop Sign
Turning/Same Direction
Changing Lanes/Same Direction
Drifting/Same Direction
Opposite Direction/Maneuver
Opposite Direction/No Maneuver
Rear-End/Striking Maneuver
Rear-End/Lead Vehicle Accelerating (LVA)
Rear-End/Lead Vehicle Moving at Slower Constant Speed (LVM)
Rear-End/Lead Vehicle Decelerating (LVD)
Rear-End/Lead Vehicle Stopped (LVS)
Left Turn Across Path (LTAP)/Opposite Direction (OD) at Signal
Turn Right at Signal
LTAP/OD at Non Signal
Straight Crossing Path (SCP) at Non-Signal
Turn at Non-Signal
Control Loss/No Vehicle Action
Control Loss/Vehicle Action
Parking/Same Direction
Backing Into Vehicle
Other

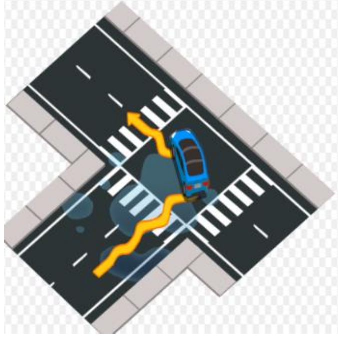
Some definitions from SOTIF

scenario
description of the temporal relationship between several *scenes* (3.27) in a sequence of scenes, with goals and values within a specified situation, influenced by *actions* (3.2) and *events* (3.7)

Note 1 to entry: Every scenario starts with an initial scene. Actions and events, as well as goals and values, can be specified to characterise this temporal relationship within a scenario. In contrast to a scene, a scenario spans a certain amount of time.

Note 2 to entry: This definition is adapted from Reference [3].

Note 3 to entry: The referenced "goals and values" are conditional parameters of the *intended functionality* (3.14). A goal could be "staying between the lane markings". A value could be to "prioritize safety of pedestrians over avoiding monetary damage".



operational design domain
ODD
specific conditions under which a given driving automation system is designed to function

Note 1 to entry: Conditions can be spatial, temporal, intrinsic or environmental.

Note 2 to entry: The term "designed" is taken from the definition in SAE J3016[2]. In this document it means "specified".

Note 3 to entry: The conditions of automated driving system itself (e.g. the vehicle speed, computing capabilities, and perception sensing capabilities) are also in the scope of ODD.

Note 4 to entry: The concept was originally defined in SAE J3016[2].

Vehicle capabilities
x
Geographical domain
x
Traffic & situational environment
=
ODD

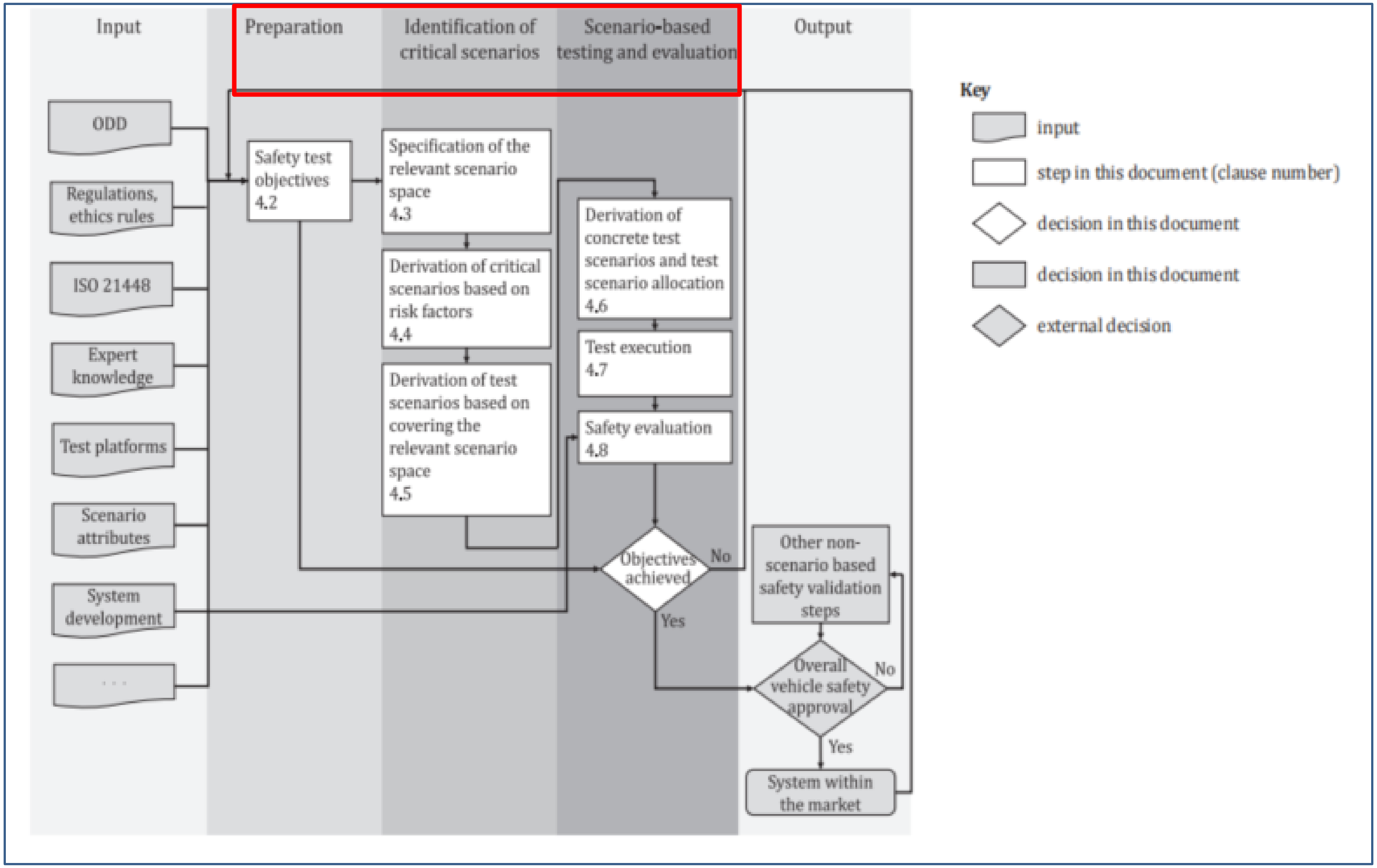
3450x standard family

Standard title		Scope
ISO 34501:2022 Road vehicles — Test scenarios for automated driving systems — Vocabulary		defines terms in the context of test scenarios for automated driving systems (ADS).
ISO 34502:2022 Road vehicles — Test scenarios for automated driving systems — Scenario based safety evaluation framework		provides guidance for a scenario-based safety evaluation framework for automated driving systems (ADSs). The framework elaborates a scenario-based safety evaluation process including identification of trigger conditions and hazards. .
ISO 34503:2023 Road Vehicles — Test scenarios for automated driving systems — Specification for operational design domain		specifies the requirements for the hierarchical taxonomy for specifying operating conditions which enable the definition of an operational design domain (ODD) of an ADS. It also specifies requirements for the definition format of an ODD using the taxonomy.
ISO 34504:2024 Road vehicles — Test scenarios for automated driving systems — Scenario categorization		defines an approach for the categorization of scenarios by providing tags that carry information about the scenarios (qualitative and/or quantitatively).
ISO/DIS 34505: XXXX Road vehicles — Test scenarios for automated driving systems — Scenario evaluation and test case generation		defines a methodology to evaluate scenarios and provides a procedure extending test scenarios to test cases for a given function in a traceable way based on the testability. This Document also defines necessary characteristics of a test case that include but are not limited to unified identifier, test objective, inputs, steps, platform and expected results.

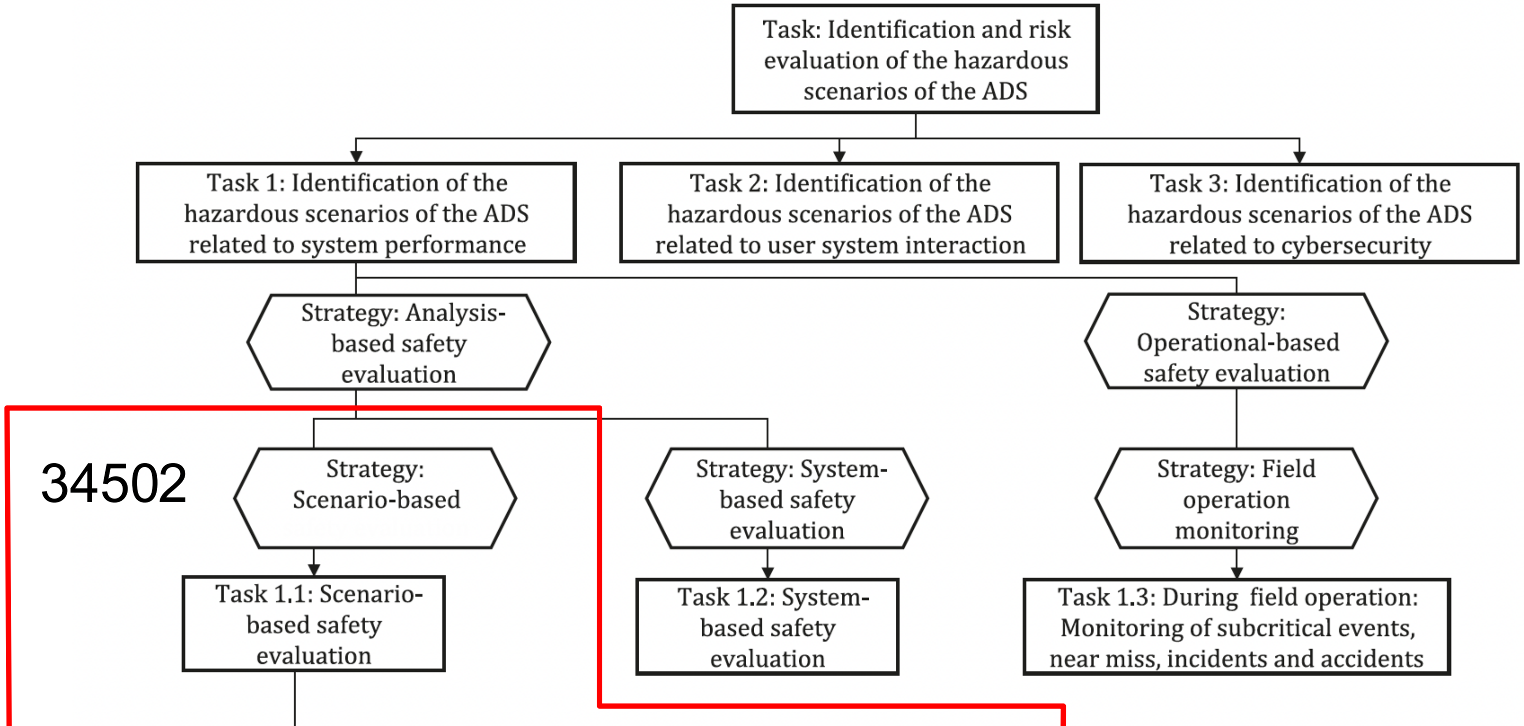
Stepwise process

Evaluation Process Step	Expected output
4.1 Integration into the overall development process: how the framework integrates into existing product development process.	
4.2 Safety test objectives: specification of test objectives that the system needs to fulfil.	Safety test objectives
4.3 Specification of the relevant scenario space: how the relevant scenario space is defined.	Specification of the relevant scenario space
4.4 Derivation of critical scenarios based on risk factors: how to define a set of critical scenarios from which a set of test scenarios are derived.	Set of critical scenarios
4.5 Derivation of test scenarios based on covering the relevant scenario space: identification of critical scenarios to potentially be tested	Set of test scenarios
4.6 Derivation of concrete test scenarios and test scenario allocation: how test scenarios are generated and allocated to different testing platforms	Set of concrete test scenarios Test allocation report Report of the fulfilment of the capability requirements for qualification of used platforms
4.7 Test execution: requirements that need to be fulfilled while running test scenarios	Results report for each test scenario
4.8 Safety evaluation: how the test results are evaluated to achieve an overall result	Safety evaluation report

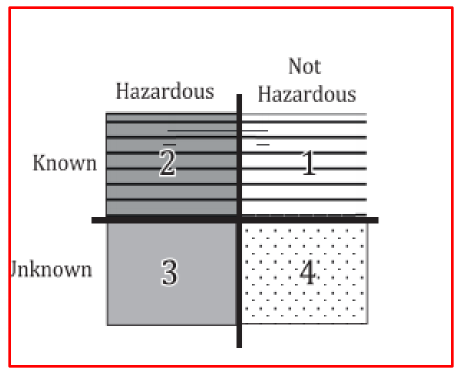
Three stage process



34502 Tasks



Task: Identification and risk evaluation of the hazardous scenarios of the ADS
Task 1: Identification of the hazardous scenarios of the ADS related to system performance
Task 2: Identification of the hazardous scenarios of the ADS related to user system interaction
Task 3: Identification of the hazardous scenarios of the ADS related to cybersecurity
Strategy: Analysis-based safety evaluation
Strategy: Operational-based safety evaluation
34502
Strategy: Scenario-based
Strategy: System-based safety evaluation
Strategy: Field operation monitoring
Task 1.1: Scenario-based safety evaluation
Task 1.2: System-based safety evaluation
Task 1.3: During field operation: Monitoring of subcritical events, near miss, incidents and accidents
Strategy: Identification via analysis and verification via tests
Strategy: Identification via explorative aproach
Task 1.1.1: Identification and risk evaluation of potential hazardous scenarios via analysis of the scenario space
Task 1.1.2: Set of test scenarios cover a relevant part of the scenario space in search for unkown hazardous scenarios. Newly identified hazardous scenarios are evaluated concerning their risk.



Hazardous
Not Hazardous
Known
Unknown
2
1
3
4

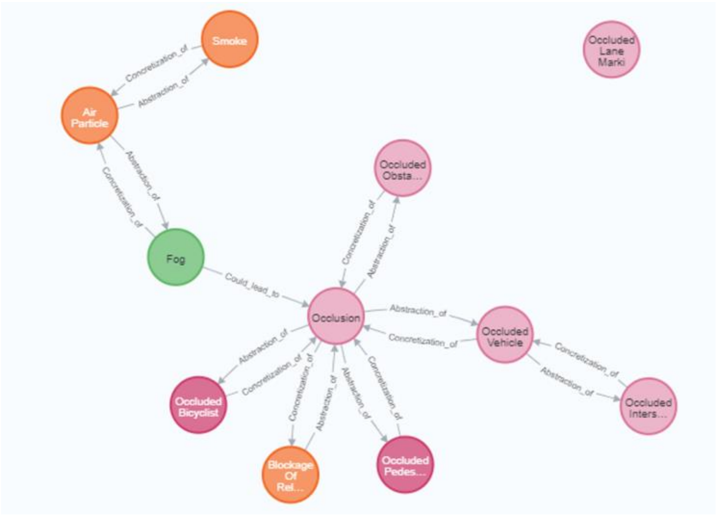
Criticality Analysis

The criticality analysis is a key tool within ISO 34502 and its methodology is designed to **reveal the causes of criticality occurring in traffic situations**.

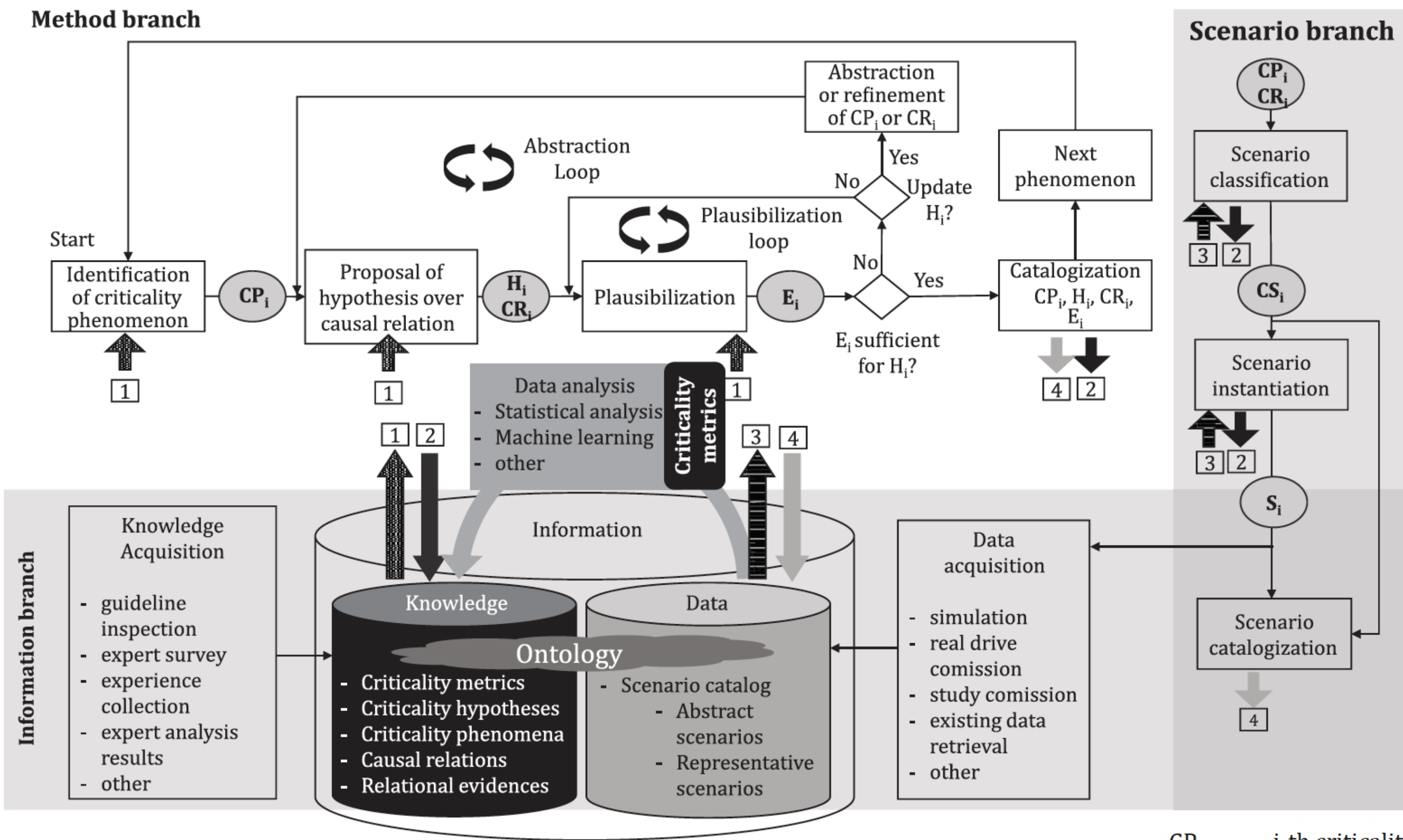
To this end the traffic system itself is studied by **identifying phenomena** (e.g. observable concrete influence factors) **related to an increase in criticality**, when the traffic situation is continued.

These **criticality phenomena** correspond to the **risk factors** relevant for ADS.

Criticality of a traffic situation denotes the combined risk of the involved actors to suffer any harm caused by the traffic.

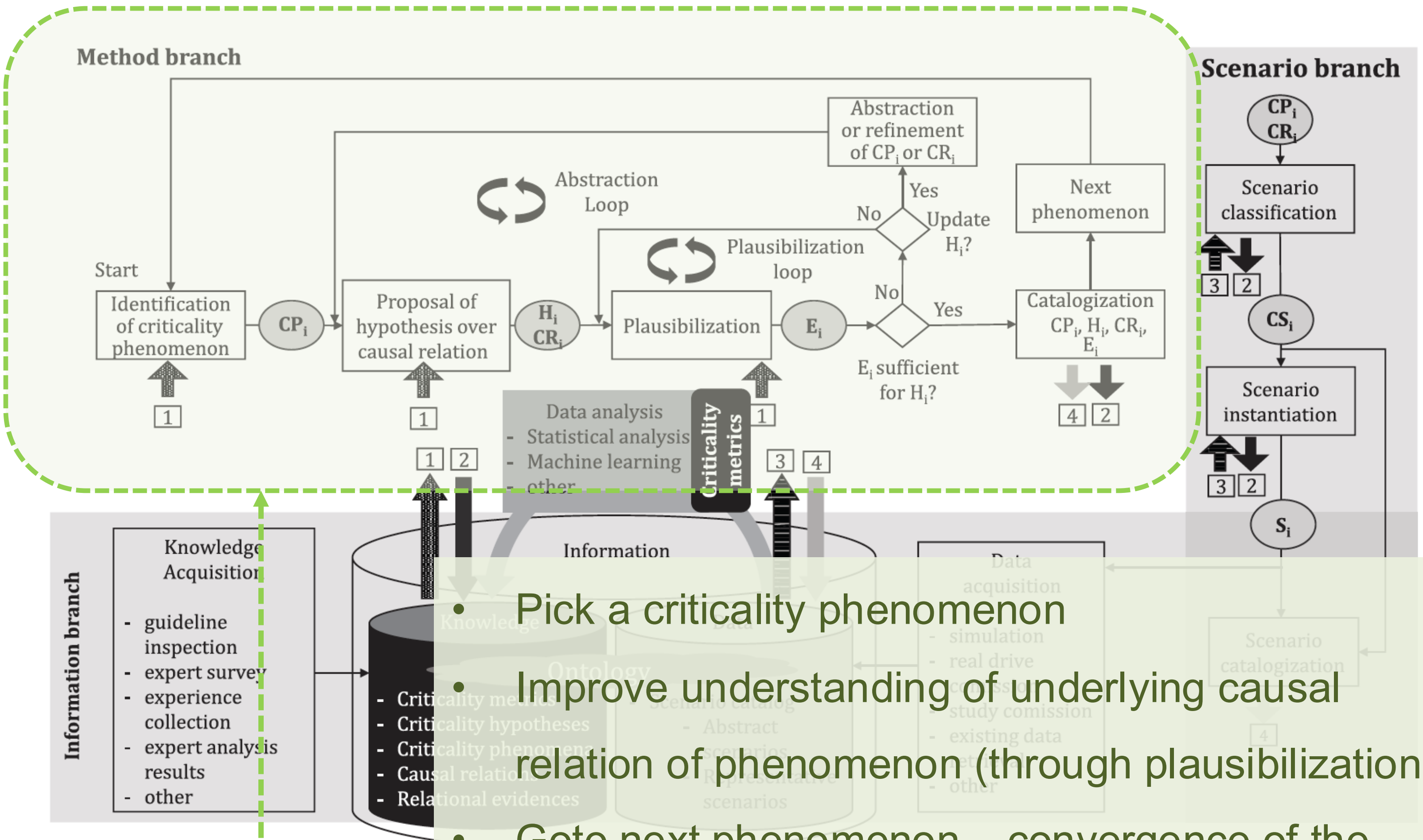


Criticality Analysis to derive and structure scenarios



CP_i	i-th criticality phenomenon
CR_i	causal relation for CP_i
H_i	hypothesis for CR_i
H_i	hypothesis for CR_i
SC_i	scenario class for CP_i
S_i	scenario instance for SC_i

Criticality Analysis: Method Branch

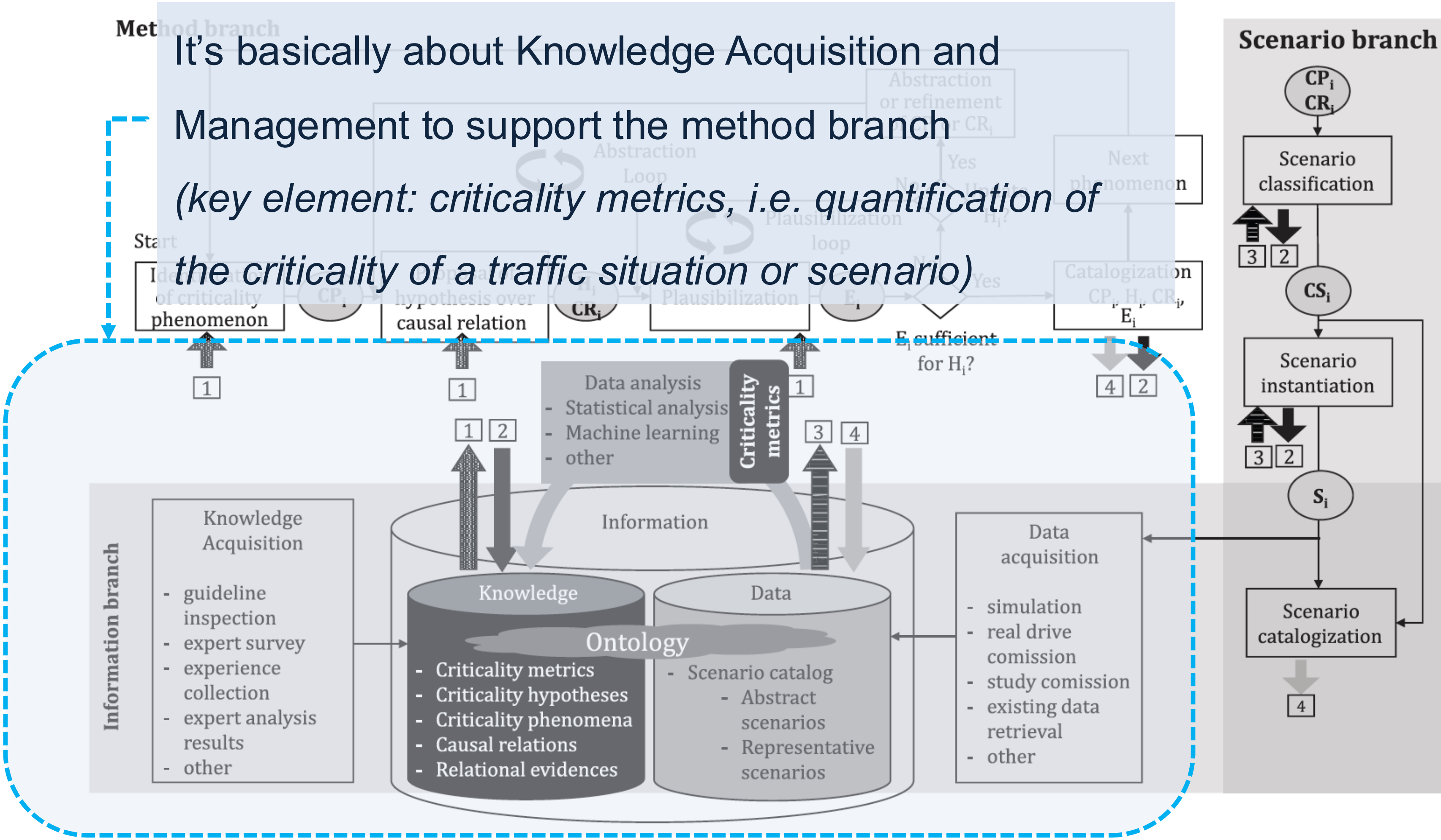


- Pick a criticality phenomenon
- Improve understanding of underlying causal relation of phenomenon (through plausibilization)
- Goto next phenomenon – convergence of the number of identified criticality phenonmena to the number of existing criticality phenomena

Criticality Analysis: Information Branch

It’s basically about Knowledge Acquisition and Management to support the method branch

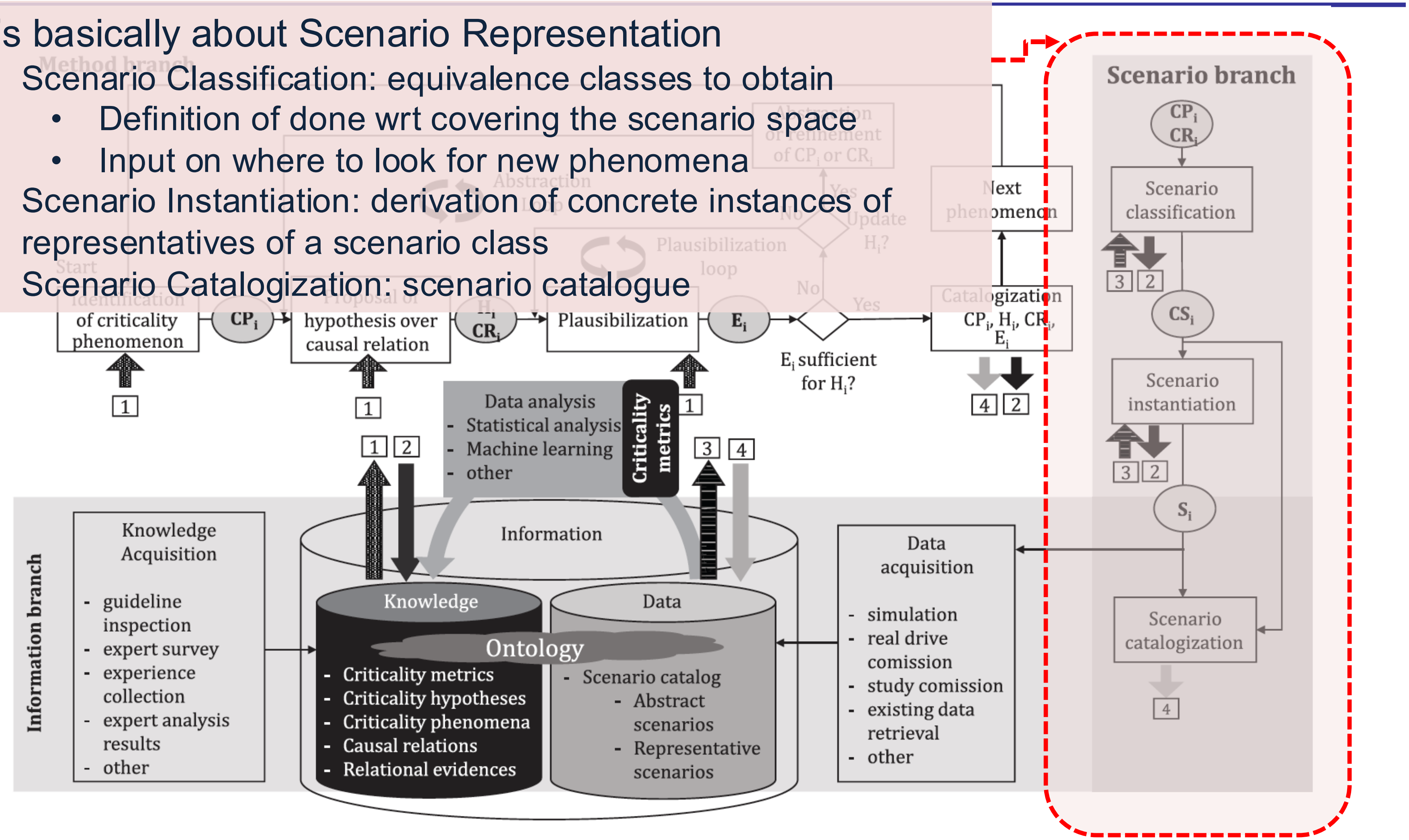
(key element: criticality metrics, i.e. quantification of the criticality of a traffic situation or scenario)



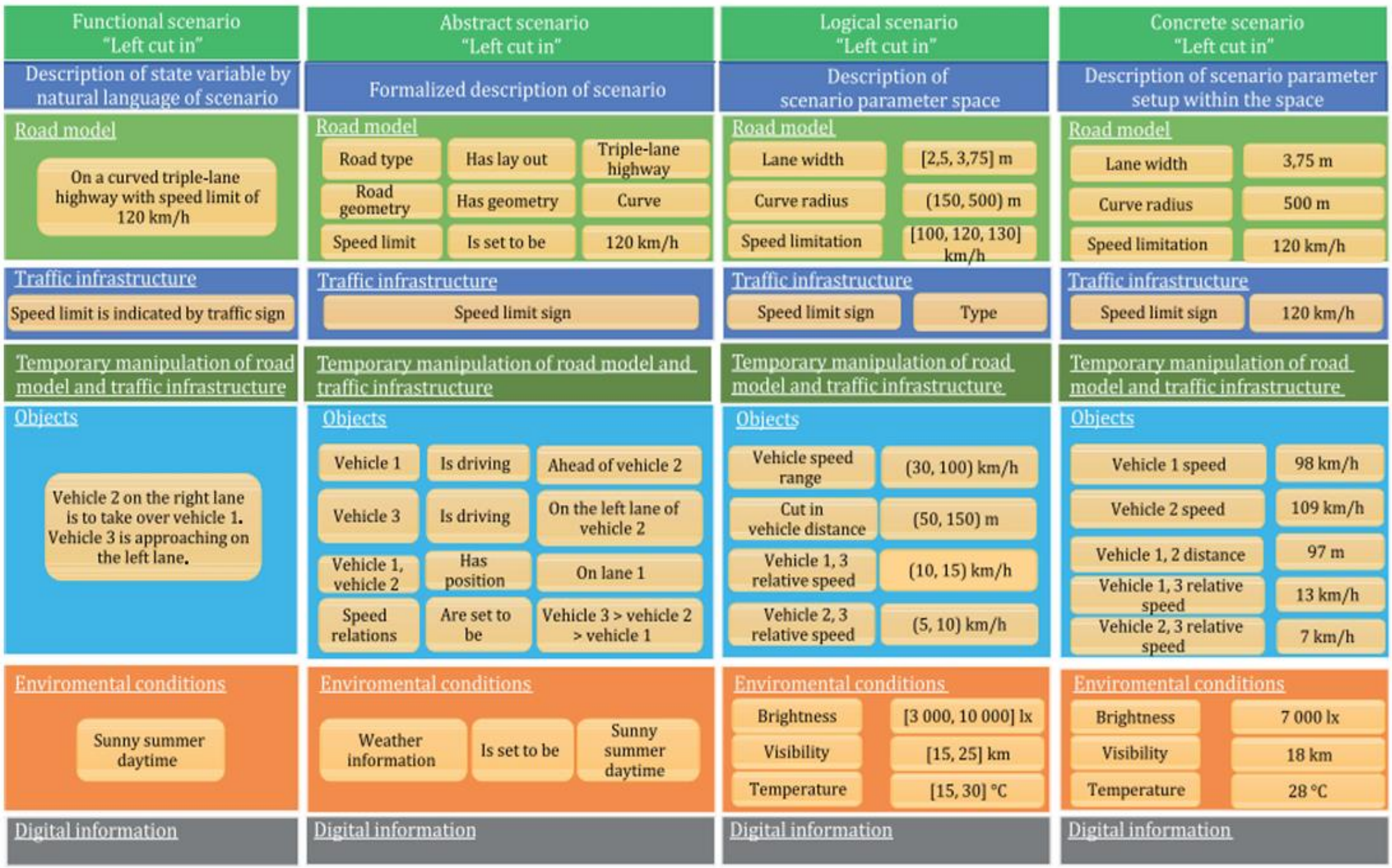
Criticality Analysis: Scenario Branch

It's basically about Scenario Representation

- Scenario Classification: equivalence classes to obtain
  - Definition of done wrt covering the scenario space
  - Input on where to look for new phenomena
- Scenario Instantiation: derivation of concrete instances of representatives of a scenario class
- Scenario Catalogization: scenario catalogue



From logical to concrete

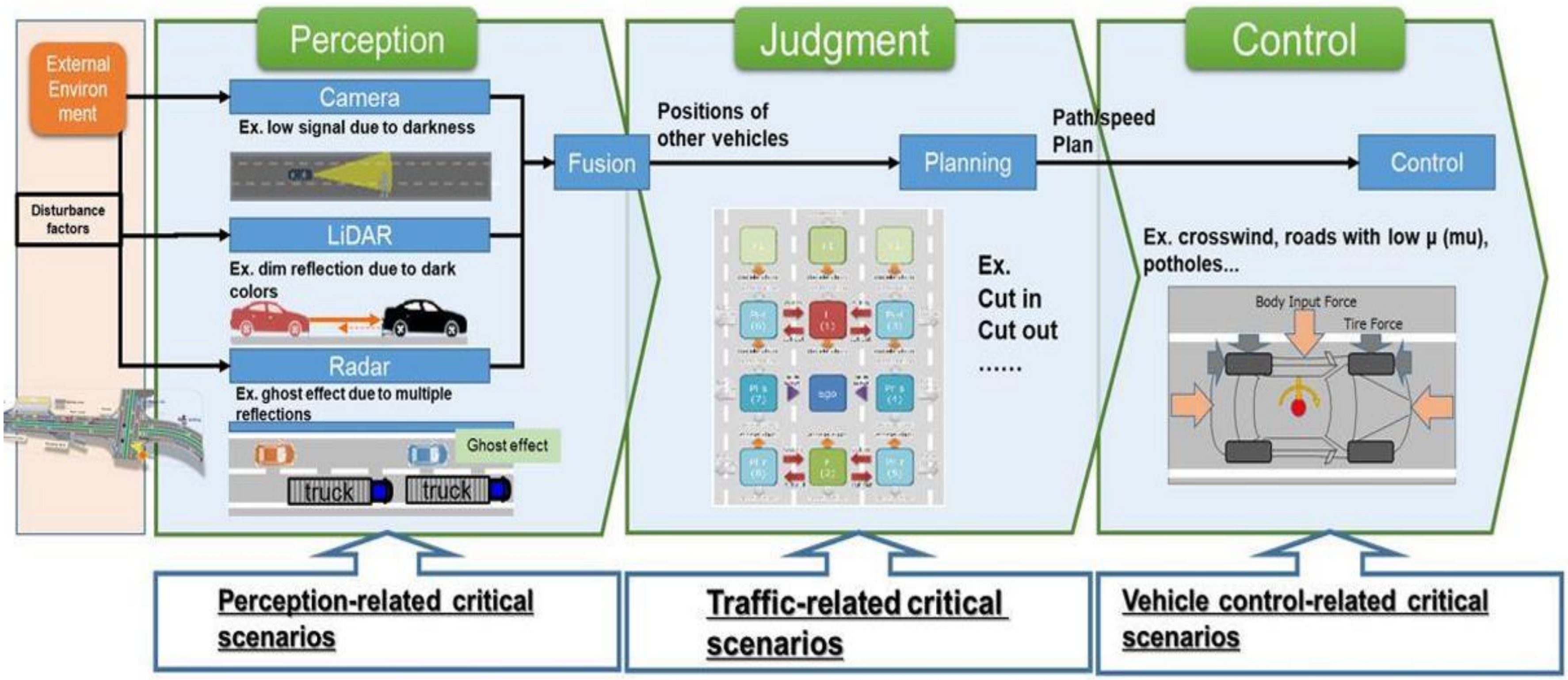


Substantial informative contents in the annexes...

60 of 80 pages of the norm...

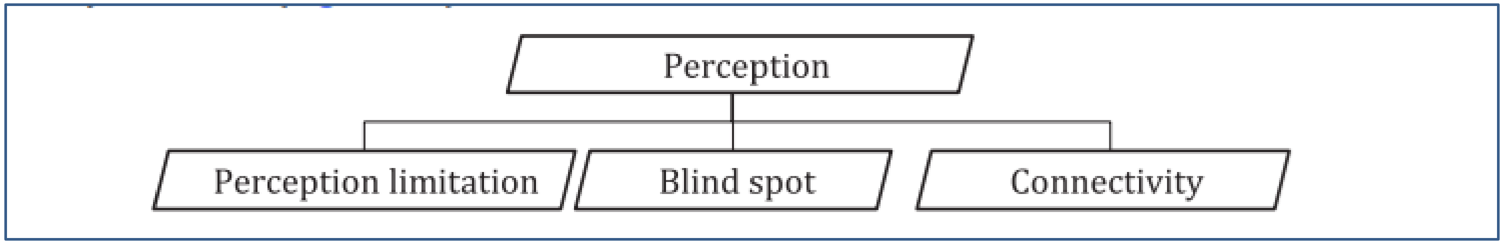
ISO 34502:2022(E)

Annex A



Risk factors and their corresponding critical scenarios are **decomposed and logically structured** in accordance with the **physics of the ADS**, then it is possible to provide a global coverage of all the reasonably foreseeable safety-relevant root causes for a given DDT.

Perception related critical scenarios



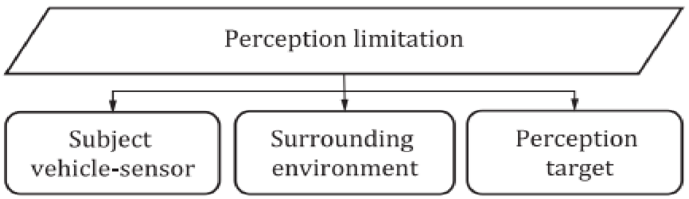
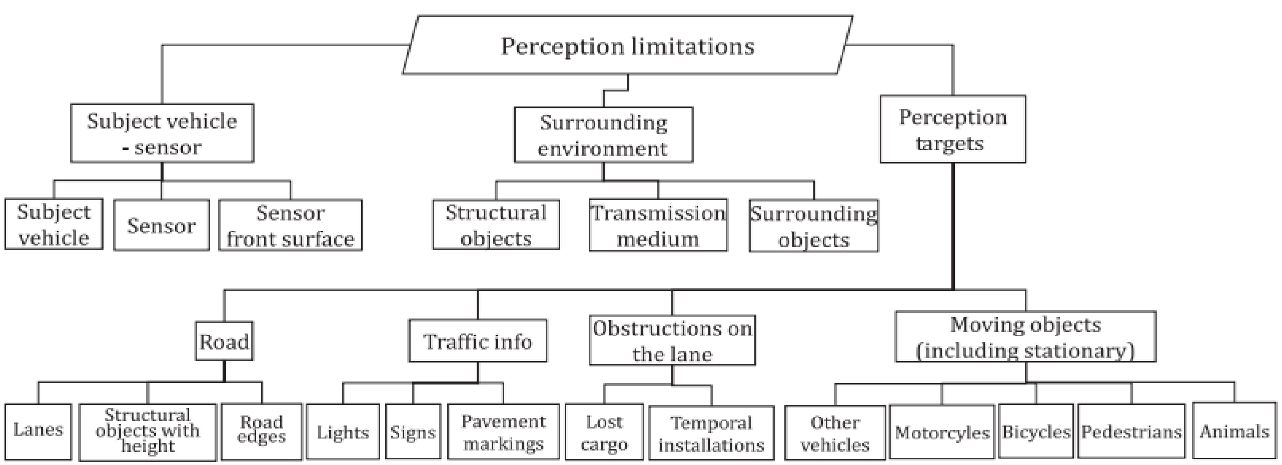


Figure C.3 — Perception limitation related risk factor classification



Perception related critical scenarios

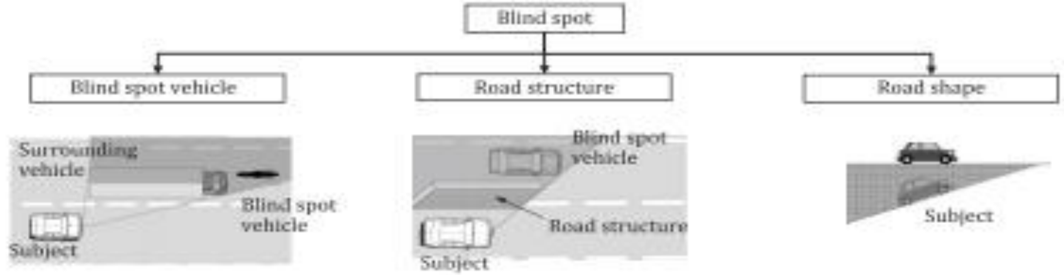


Figure C.12 — Blind spot related risk factor classification

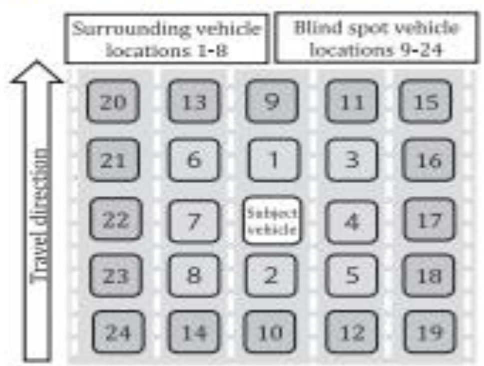


Figure C.13 — Subject, surrounding and blind spot vehicle locations applied to define blind spot vehicle related critical scenarios

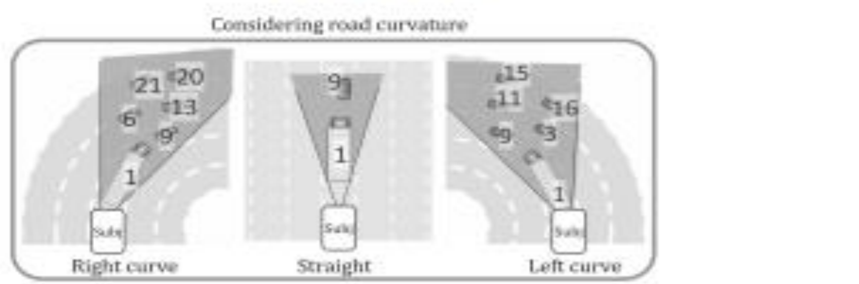
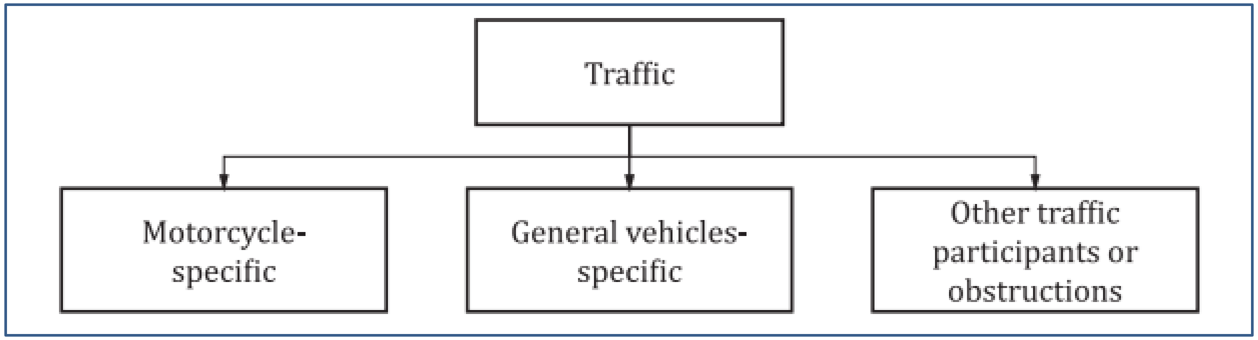
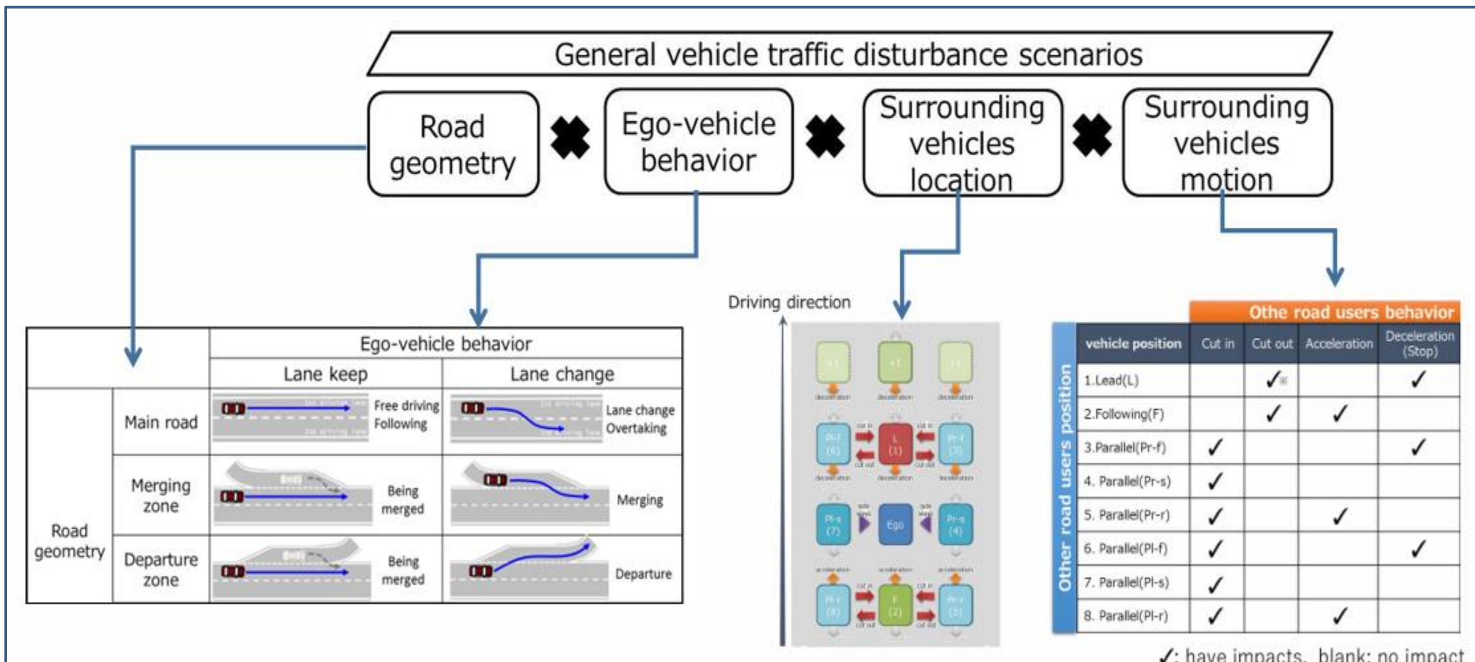


Figure C.14 — Blind spot locations due to a surrounding vehicle in longitudinal location 1 considering road curvature (left rectangle) and a simplified diagram (right rectangle)

Traffic related critical scenarios





Vehicle related critical scenarios

D.2 Vehicle control related critical scenarios

Vehicle control related critical scenarios are classified into body input and tyre input (Figure D.1)

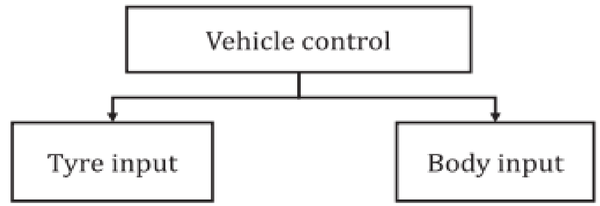


Figure D.1 — Vehicle control related critical scenario classification

D.2.1 Body input related critical scenarios

General body input force related vehicle risk factors are categorized into road geometry and natural phenomena (Figure D.2). Road geometry refers to curve radius, longitudinal gradients and transversal gradients. Natural phenomena refer to naturally occurring crosswind, tailwind and headwinds that exert forces on the body of the vehicle.

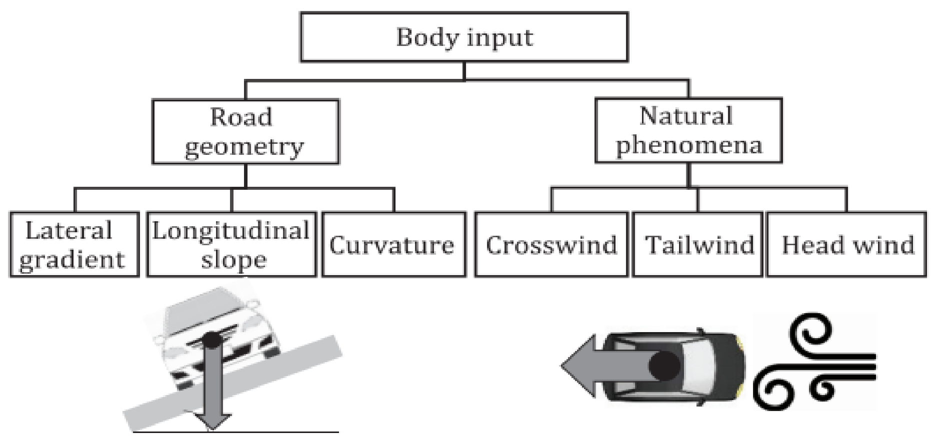


Figure D.2 — Body input related vehicle risk factors

Test platforms

Annex F
(informative)

Qualification of virtual test platforms

F.1 General

Simulation/virtual test platforms (VTPs) such as software-in-the-loop (SIL), hardware-in-the-loop (HIL), vehicle-in-the-loop (VIL), or model-in-the-loop (MIL) are typically used for test scenario evaluations that are not feasible on real-world test platforms (RWTPs), e.g. track testing and real-world testing, due to unacceptably high risks associated to the tests, and/or unreasonable amounts of data requirements and costs associated to the tests. Also, a much more detailed analysis of special scenarios is possible. The VTP includes the whole environment with all necessary tools and models (Figure F.1). The VTP has got a specific configuration, which is dependent on the use case. A VTP can be designed as open loop as well as closed loop and is a safety relevant element within the engineering framework for scenario-based testing of automated driving systems, in case of not purely using RWTPs. Different parameter variation, different scenarios as well as updates in components are extrapolations of the VTP and do not match with the validation points of the VTP, but are extrapolations of the validated area of the VTP.

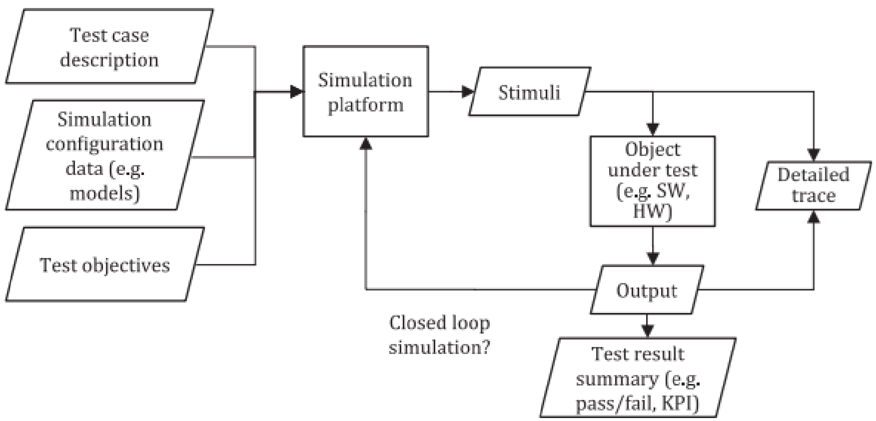


Figure F.1 — Generic VTP description

The validation of VTPs aims at showing that the evaluation result of a certain scenario is similar to that of a RWTP. The VTP is considered as valid for the evaluated scenarios only when the results deviation from RWTP is limited.

Tool qualification required.

Database support

Annex G
(informative)

Scenario database and parameter variation methods

G.1 General

A database to support the overall scenario-based safety evaluation process is envisioned. The fundamental idea is to use this database as a central element in the safety evaluation process to store scenarios for ADS which may originate from different data sources. Within the database, the origin of parameter ranges within logical scenarios should be traceable and distributed in the form of statistics, to allow for bidirectional traceability between the raw traffic monitoring data and the critical parameter ranges of the logical scenarios. Efforts to harmonize the development, maintenance, and accessibility of such a database could lead to a common international database to support a safe and global deployment of ADS.

Divide et impera

Annex H
(informative)

Segmentation of test space

Based on the defined scenario-structure the test space can be reduced by limiting the relevant scenarios, using the ODD and selecting representative test scenarios, which represent subclasses.

While segmenting the scenario and the vehicle components into different segments, possible combinations can be described, in accordance with Figure H.1, thereby representing single test scenario subclasses.

To define subspaces and representative test scenarios, the following steps can be taken:

— divide the test space in subspaces;

— test space may be reduced to dominant effects and to foreseeable scenarios by, e.g. ODD-definition;

— increase the coverage based on extrapolation/variation of the scenario attributes;

— representative test scenarios: each subspace can be tested by a set of suitable test scenarios.

Evaluation

Annex I
(informative)

Evaluation of test scenarios based on behavioural safety assessment

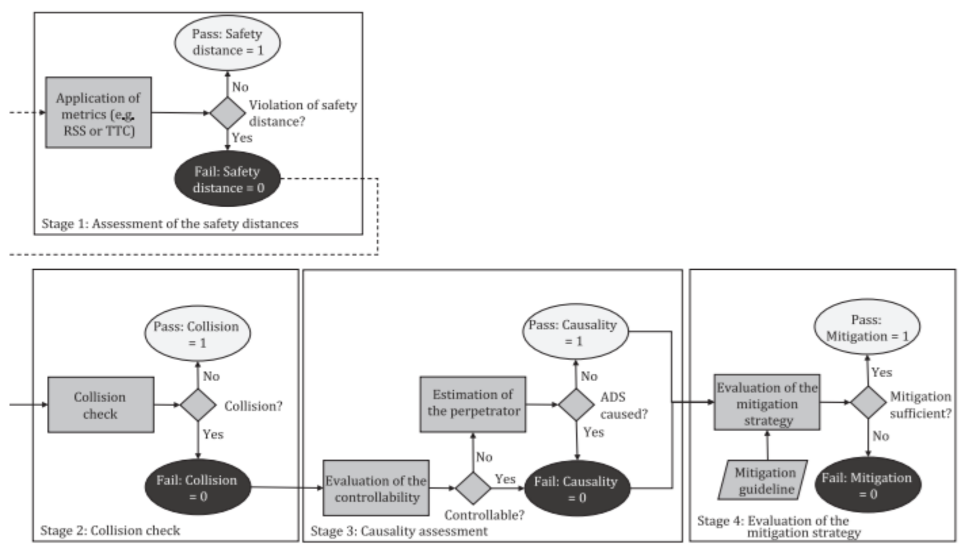
I.1 General

Behavioural safety assessment (BSA) focuses on the assessment of the ADS in individual test scenarios. For each individual test scenario different metrics are applied to confirm the ADSs compliances with pre-defined behavioural criteria. In the specific context these pre-defined criteria are (a) keeping appropriate safety distances, (b) not causing collisions and (c), if possible, mitigating collisions, as they comply with the test concept. During the BSA, for each of these criteria, it is evaluated whether the ADS complies or not. Based on the result for each criterion, a method is proposed to decide if a single test scenario is passed or failed.

Furthermore, the BSA discusses the necessary information needed to extrapolate the result of an individual test scenario to its semi-concrete test scenario and its logical scenario as well as to the overall ODD, to derive more expressive results.

I.2 Multi-stage behavioural safety assessment

The first part of the BSA focuses on the assessment of individual test scenarios. Thereby, it is assumed that the test scenarios from different focus areas (e.g. crash analysis, automation risks, FOT-data, and simulation) are provided in a unified format, as described above. Figure I.1 shows the different stages of the BSA. The first stage assesses if the ADS complies with the required safety distances based on safety metrics (e.g. time-to-collision). In the figure, steps are displayed with rectangles, decisions with squares and results with ovals.



Risk evaluation

Annex J
(informative)

Risk evaluation based on positive risk balance

J.1 General

Based on the results of the assessment of single test scenarios a risk balance assessment over a set of test scenarios can be done. Within the following example a risk assessment is shown, based on the positive risk balance approach.

J.2 Introduction of positive risk balance

A positive risk balance is a major measure of an ethically acceptable level of safety, but by itself is not a socially acceptable criterion. Additional criteria play a role. The evidence used for a positive risk balance can be derived from traffic accidents statistics (reference without ADS) and investigations on the risk resulting by introducing the ADS. Therefore, different safety target values can apply for different markets. On the long term, automated driving systems get reflected in the traffic accident statistics and will continuously increase the safety target values of a new ADS. The avoidance of unreasonable risk is the overall major measure. To complement the positive risk balance, ALARP and other acceptance criteria can also be used. The avoidance of unreasonable risk is typically based on the application of a proactive and reactive driving behaviour, avoidance of accidents as much as "practically possible", an extremely low occurrence rate of accidents, and the avoidance of discrimination on the basis of any road user-related characteristics.

J.3 Definition of risk within ADS

While allocating representative test-results to a risk-class, while using (simplified) crash simulations within the SiL-environment, a probability of accident occurrence (P) can be calculated if the different test scenarios sufficiently cover all aspects of the scenario to be investigated.

$$P = \sum_{i=1}^{n} \left[\prod_{j=1}^{m_{\text{infl,para}}} Pji \right] S_i$$

where

- i is the index of the test scenario;
- n is the total number of test scenarios;
- j is the index of influencing parameters of the test scenario i. Influencing parameters are parameters relevant for the outcome of test scenario i;
- $m_{\text{infl,para}}$ is the total number of influencing parameters within the test scenario i;
- P_{ji} is the probability of occurrence of the influencing parameter j within the test scenario i;
- S_i is the severity rating of the test scenario i. $S_i = 0$ if there is no accident with harm. $S_i = 1$ if there is an accident with the occurrence of harm.

NOTE When determining the P_{ji} the dependencies between different occurrence probabilities of the different influencing parameters are considered. Similar formulae can be applicable in case of other test parameter descriptions.

Unknown ...

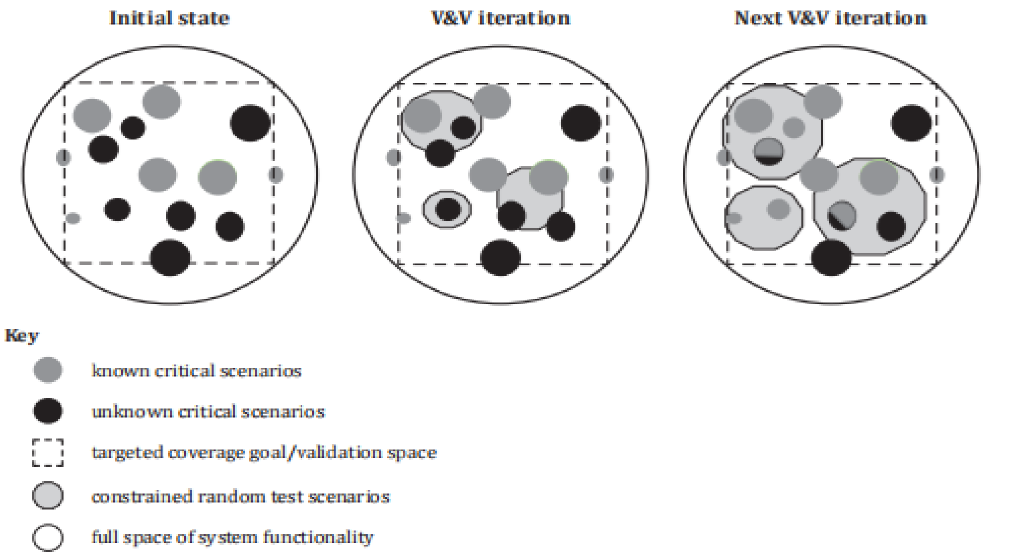
Annex K
(informative)

Constrained random testing to identify unknown critical scenarios

Figure 2 presents the overall flow for scenario-based safety evaluation process. This annex proposes a methodology to leverage this flow and extending it with the intention of reducing the space of unknown critical scenarios. This can be achieved by leveraging on the knowledge developed during the safety evaluation process, and the identification of (known) critical scenarios. The method utilizes constrained random testing to vary the parameter ranges and combinations, with the goal of increasing coverage space. The method is predominantly based on simulation.

Figure K.1 below illustrates a possible model of how iterations combined with coverage requirements and constrained random testing can be used to discover unknown critical scenarios. In the initial state (leftmost circle), several risk factors and critical scenarios are analysed and developed, according to the flow in Figure 2.

As a preparation phase, the test space or the desired coverage space is being determined using the products of the analysis performed in 4.2 and 4.3. This space represents the critical scenarios and their possible parameter spaces. In order to be able to determine coverage percentage, this infinite space should be discretised using expert knowledge and engineering judgement. It may be that the desired coverage space will match the ODD.



Parameter range analysis

Annex L
(informative)

Sufficiency of traffic data to develop parameter ranges

This annex outlines a statistical methodology to estimate the errors in defining parameter ranges as a function of the amount of traffic data applied. This methodology may be applied to establish if the amount of traffic data used to define parameter ranges is enough, or to design data collection campaigns with a specific purpose in mind. The explanations below are based on randomly generated samples and not on real traffic data, for explanation purposes.

Figure L.1 contains four figures corresponding with different numbers of data samples (*N* = 10, 50, 100, 1 000). In each figure, the horizontal axis represents normalized values of a vehicle parameter in a given scenario (e.g. cut-in lateral speed). The vertical axis represents the frequency for each of those values. Each figure includes an ideal true distribution (single black line) and a histogram of randomly generated *N* samples. For each of this sample group, a distribution curve is fitted (single light grey line). This is iterated 100 times resulting 100 light grey lines. This allows to establish a comparison between the parameter range edge values (for example, 95 % confidence ranges at, e.g. 0,3 and 99,7 percentile) obtained from the ideal true distribution and those from the of estimated distributions (light grey lines). The results of applying this approach to different data samples are presented in Table L.1. The results suggest that the estimated 0,3 percentile value may vary ± 0,12 with 10 samples. This error is reduced to ±0,013 with 1 000 samples.

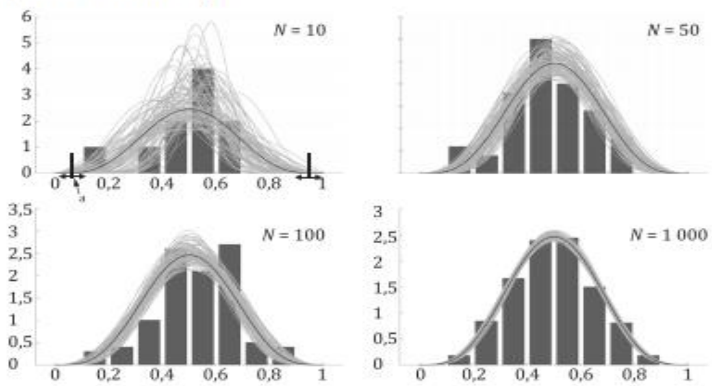


Figure L.1 — Relation between sample size and approximation to a distribution

Table L.1 — Error in estimated parameter range edge values for different numbers of data samples

	Number of data samples			
Error	*N* = 10	*N* = 50	*N* = 100	*N* = 1 000
95 % confidence at 0,3 percentiles	0,121 2	0,054 2	0,038	0,013 2
95 % confidence at 99,7 percentiles	0,132 6	0,054 2	0,037	0,013

Thanks for the attention

Fabio Falcini
fabio.falcini67@gmail.com

Giuseppe Lami
giuseppe.lami@cnr.it