SAFETY ASSURANCE FRAMEWORK FOR CONNECTED, AUTOMATED MOBILITY SYSTEMS

D4.2

Report on mapping of use case requirements to subsystems

Project short name
SUNRISE

Project full name
Safety assUraNce fRamework for connected automated mobIlity SystEms

Horizon Research and Innovation Actions | Project No. 101069573
Call HORIZON-CL5-2021-D6-01

Funded by the European Union

ccam-sunrise-project.eu/

Dissemination level	Public (PU) - fully open
Work package	WP4: CCAM V&V framework
Deliverable number	D4.2: Report on mapping of use case requirements to subsystems
Status - Version	Final – V1.0
Submission date	29/02/2024
Keywords	simulation framework, safety assurance framework, automated driving systems, scenario-based testing, verification and validation, use case requirements

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Peer review 2	Bernhard Hillbrand	VIF	12/02/2024
Peer review 3	Stefan de Vries	IDI	26/02/2024

Version history

Version	Date	Author	Summary of changes
0.1	05/02/2024	Raul Ferreira and Jose Torres (CAF)	First draft.
1	29/02/2024	Raul Ferreira and Jose Torres (CAF)	Addressed comments of all reviews

Legal disclaimer

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GLOSSARY OF TERMS

Term	Description	Source
ADS feature	An automated driving system's (ADS's) design-specific functionality at a given level of driving automation within a particular ODD, if applicable.	SAE J3016:2021 [1]
automated driving system (ADS)	hardware and software that are collectively capable of performing the entire dynamic driving task (DDT) on a sustained basis, regardless of whether it is limited to a specific operational design domain (ODD)	ISO 34501:2022 [2]
dynamic driving task (DDT)	all of the real-time operational and tactical functions required to operate a vehicle in on-road traffic, excluding the strategic functions such as trip scheduling and selection of destinations and waypoints	ISO 34501:2022 [2]
operational design domain (ODD)	The boundaries of the operating environment within which the ADS can operate, performing the DDT safely.	ISO 34501:2022 [2]
safety test objective	safety property of the ADS to be shown via a set of tests	ISO 34502:2022 [3]
scenario	description of a temporal and spatial traffic constellation	
test scenario	scenario intended for testing and assessing automated driving system(s) (ADS)/subject vehicle(s)	ISO 34501:2022 [2]
logical scenario	beginning with an initial scene, a model of the time sequence of scenes whose parameters are defined as ranges; at a defined point in time, the behaviour of	

	the main actor (vehicle under test) is not further specified	
concrete scenario	Parameterised model of the time sequence of scenes (logical scenario) which begins with an initial scene and defined point in time; the behaviour of the main actor (vehicle under test) is not further specified.	
subsystem	part of a system, which is itself, a system	IEC 60050 [4], IEV 192-01-04 (Dependability domain)
subject vehicle	vehicle under observation in the process of testing, evaluation, or demonstration	ISO 34501:2022 [2]
traffic agents	anyone who uses a road including sidewalk and other adjacent spaces	ISO 34503:2023 [5]

ABBREVIATIONS AND ACRONYMS

Abbreviation	Meaning
ACC	Adaptative Cruise Control
AD	Automated Driving
ADAS	Advanced Driving Assistant System
BSM	Basic Safety Message
CAM	Cooperative Awareness Message
CCAM	Connected, Cooperative, and Automated Mobility
CPM	Cooperative Perception Message
C-V2X	Cellular-V2X
DDT	Dynamic Driving Task
DENM	Distributed Environmental Notification Message
DF	Driving Function
DSRC	Dedicated Short-Range Communication
FOV	Field Of View
GLOSA	Green Light Optimised Speed Advisory
GSR	General Safety Regulations
GT	Ground Truth
HWP	HighWay Pilot
IIS	Intersection Information Service
IVI	In-Vehicle Information
KPI	Key Performance Indicator
MAP	MAp-related Message
MRM	Minimum Risk Maneuver
OBU	On Board Unit
OD	Operational Domain

ODD	Operational Design Domain
OEDR	Object and Event Detection and Response
OEM	Original Equipment Manufacturer
OSI	Open Simulation Interface
RSU	Road Side Unit
SAF	Safety Assurance Framework
SIL	Software In the Loop
SOTIF	Safety Of The Intended Function
SPAT	Signal Phase & Timing
SR	Signal Request
sRSU	Smart Road-Side Unit
SS	Signal Status
SuT	System Under Test
TPS	Traffic Probe Service
TTC	Time to Collision
UC	Use Case
V2I	Vehicle-to-Infrastructure
V2V	Vehicle-to-Vehicle
V2X	Vehicle-to-Everything
V&V	Verification and Validation
VIL	Vehicle In the Loop
VRU	Vulnerable Road User
VTP	Verification Test Procedure
XIL	X In the Loop (e.g., Software, Hardware, Vehicle, etc.)

EXECUTIVE SUMMARY

Safety assurance of cooperative, connected, and automated mobility (CCAM) systems is crucial for their successful adoption in society, and it is necessary to demonstrate reliability in their complete operational design domains (ODD). For higher level of automation, it is commonly accepted that validation of these systems by means of real test-drives would be infeasible. Instead, a mixture of physical and virtual testing is seen as a promising approach, with the virtual part bearing more significant weight for cost efficiency reasons. This in turn accelerates the time to market.

The SUNRISE project aims to develop a Safety Assurance Framework (SAF) for scenario-based safety validation of CCAM systems, including a broad portfolio of use cases and comprehensive test and validation tools. Part of this is to develop a harmonised verification and validation (V&V) simulation framework for virtually validation of CCAM systems and overcoming virtual testing and validation limitations by completing the targeted safety assurance framework with hybrid and real-world testing and validation approaches.

This deliverable presents the mapping between the defined requirements for all use cases, as defined in deliverable D7.1, and the identified subsystems in deliverable D4.1. The identified subsystems are (1) test case manager, (2) environment, (3) subject vehicle, (4) traffic agents, and (5) connectivity. In addition, a subsystem for (6) simulation model validation is included to ensure this important part is not missed.

Said mapping will clearly distribute the requirements amongst the subsystems, thus stating which things shall be considered, included, or excluded while implementing each of the components of the safety assurance framework. This will enable the selection of possible tools per subsystem, which will happen in task T4.3.

The presented work is theoretical, so the proposed mapping may need to be updated or refined in further tasks and deliverables of the SUNRISE project. The needs and visions of all the partners in the consortium were considered to detail the description of the requirements, supporting all the tasks and deliverables in need of fine-grained information involving these requirements. In addition, the study focuses on pure virtual simulation, but the framework should be useful also for XiL tests were some of the subsystems in the SuT is replaced with the real functions.

1 INTRODUCTION

1.1 Project Intro

Safety assurance of cooperative, connected, and automated mobility (CCAM) systems is crucial for their successful adoption in society, yet it remains a significant challenge.

CCAM systems need to demonstrate reliability in their complete operational design domains (ODD), requiring robust safety argumentation. It is already acknowledged that for higher levels of automation, the validation of these systems by means of real test-drives would be infeasible. In consequence, a carefully designed mixture of physical and virtual testing has emerged as a promising approach, with the virtual part bearing more significant weight in this mixture for cost efficiency reasons. Several worldwide initiatives have started to develop test and assessment methods for automated driving functions. These initiatives have already moved from conventional validation to a scenario-based approach and combine different test instances (physical and virtual testing) to avoid the million-mile issue.

The initiatives mentioned above provide new approaches to CCAM validation, and many expert groups formed by different stakeholders are already working on CCAM systems' testing and quality assurance. Nevertheless, the fact that there is a lack of a common European validation framework and homogeneity regarding validation procedures to ensure safety of these complex systems, hampers the deployment of CCAM solutions. In this landscape, the role of standards is paramount in establishing common ground and providing technical guidance. However, standardising the whole pipeline of CCAM validation and assurance is in its infancy, as many of the standards are under development or have been very recently published and still need time to be synchronised and established as common practice.

Scenario databases are another issue tackled by several initiatives and projects, which generally tends to silo solutions. A single concrete approach should be used (at least at the European level), dealing with scenarios of any possible variations, including the creation, editing, parameterisation, storing, exporting, importing, etc. in a universally agreed manner.

Furthermore, validation methods and testing procedures still lack appropriate safety assessment criteria to build a robust safety case. These shall be set and valid for the whole parameter space of scenarios. Another level of complexity is added, due to regional differences in traffic rules, signs, actors, and situations.

Evolving from the achievements obtained in predecessor project HEADSTART, and taking other initiatives as a baseline, it becomes necessary to move to the next level in the concrete specification and demonstration of a commonly accepted Safety Assurance Framework (SAF) for the safety validation of CCAM systems, including a broad portfolio of use cases [6] and comprehensive test and validation tools. This will be done in SUNRISE, which stand for **S**afety ass**u**ra**n**ce f**r**amework for connected, automated mobil**i**ty **S**yst**e**ms.

The Safety Assurance Framework is the main element to be developed in the SUNRISE project. This framework takes a central role, fulfilling the needs of different automotive stakeholders that all have their own interests in using it. The overall objective of the SUNRISE project is to accelerate the safe deployment of innovative CCAM technologies and systems for passengers and goods by creating demonstrable and positive impact towards safety, specifically the EU's long-term goal of moving close to zero fatalities and serious injuries by 2050 (Vision Zero), and the resilience of (road) transport systems. The project aims to achieve this by creating and sharing a European federated database framework centralising detailed scenarios for testing of CCAM functions and systems in a multitude of relevant test cases with standardised, open interfaces and quality-controlled data exchange.

1.2 Purpose of the deliverable

Work package 4 in SUNRISE aims to develop a harmonised V&V simulation framework for virtually validation of CCAM systems and overcoming virtual testing and validation limitations by completing the targeted safety assurance framework with hybrid and real-world testing and validation approaches.

This deliverable complements the work done in the task T4.1: Identifying relevant subsystems of a harmonised V&V simulation architecture for virtual validation of CCAM systems. The partner contributions to this deliverable are summarized in Table 1.

Table 1. Partner contributions to D4.2

Partner	Contribution
CAF	CAF is task leader and main editor for the deliverable.
AVL	Contribution for requirements mapping for UC 2 - Traffic Jam AD Validation.
RISE	Mapping sub-UC 4.1 requirement to subsystems
ICCS	Working on the specification of tools needed in virtual and hybrid validation of specific UCs
IDI & IDI DE	Participation on requirements mapping for the use cases 3.1 - Map-based perception & decision-making & control testing and 3.2 - Cooperative perception and decision making and control
IFAG	Requirements mapping for radar sensor related requirements within sub-UC 1.1 – Perception testing. Outline section 3.1. UC 1: Urban AD validation.
Ika	Participated in discussions how to map subsystems from T4.1 to the use cases; Analyzed which traffic participant models may be relevant for use cases. Focused on identifying requirements for use cases 3.1 and 3.2 and mapping them to the simulation subsystems defined in D4.1.
SISW	Derive detailed requirements from SOTIF (ISO 21448) standard for the simulation framework through examination. Include topics of unknown-unsafe scenario exploration setup and methodology, evaluation and

	reporting of SOTIF, and safety argumentation. - Drafting KPIs to assess scenarios with special focus on SOTIF scenarios. Examples on how the requirements could be applied to a usecase, where needed, are presented for UC1.1. Focusing on subsystems related to scenario aspects & sensor and environment modelling. Perform mapping of all SOTIF requirements to the simulation subsystems. Identify requirements for SOTIF which fall outside the simulation framework, and make recommendations for mapping to other modules of the safety assurance framework. Contributions in deliverable: Section 4.1 on derivation of generic SOTIF requirements for all use cases with some examples for UC1.1, Section 5 on mapping of SOTIF requirements to simulation subsystems, and the conclusions chapter.
VED	Contribution to the mapping of requirements with the subsystems for the UC 1.3. Included in deliverable D4.2
ViF	Contribution for requirements mapping for sub-UC 1.1 - Urban AD Validation.

On task T4.2, the use case requirements defined in T7.1 are mapped to each of the subsystems identified in T4.1 for their demonstration in tasks T7.2 an T7.3. In addition, the work described in the deliverable D4.2 also includes refining or enriching the requirements defined in task T7.1.

An example of this "mapping" would be the coupling between a requirement about the camera's view angle with the "Subject Vehicle – Sensors" subsystem. This coupling paves the way for possible assessment of WP7 Use Cases by the *virtual* Simulation Framework (defined, developed, and validated in tasks T4.1 – T4.5). The results presented in this document, enable the selection of possible tools per subsystem in task T4.3.

The description of task T4.2 in the grant agreement mentions that "the resulting subsystem requirements, ... will be synchronized with WP5/6 activities to ensure correct interfaces". Although deliverable D4.2 treats some requirements that do not relate to the Simulation Framework itself (but to external matters), the interfaces between selected scenarios and their allocation on toolchain components, is a topic that will be treated in task T4.4.

1.3 Intended audience

The intended audience of the deliverable is primary the rest of work package 4 but may also be relevant for the rest of the project consortium. All the partners involved in the task T4.3 can use this document as a reference to know which requirements should be fulfilled by each subsystem, so that they can choose the tools that best complies with all of them. The most important information for them can be found in the sections 3, 4, and 5. The sections 3 and 4 contains summaries of the requirements, as well as the corresponding reference to the requirement table containing all their details. The Section 5 maps each requirement to each of the simulation subsystems. An overview of the subsystems can be found in Section 2, but they are explained more in-depth in the deliverable D4.1.

Also, the sub-section 5.9 contains mapping that may impact other SUNRISE tasks, such as T3.3 (sub-sub-section 5.9.1), T3.5 (sub-sub-section 5.9.2), T6.1 and T6.2 (sub-sub-section 5.9.3), and WP2 and 3 (sub-sub-section 5.9.4).

1.4 Structure of the deliverable

This deliverable is structured as follows: Chapter 2 gives an overview of the identified relevant subsystems, Chapter 3 presents a description of the subsystem requirements according to the use cases of WP7, Chapter 4 describes the generic requirements that aren't linked to any use case in particular, Chapter 5 maps the requirements to the subsystems, and finally Chapter 6 summarises the conclusions. An annex is included, meant to contain all the details of the requirements, to improve the readability of the chapters 3 and 4.

2 THE SUBSYSTEMS OF THE FRAMEWORK

2.1 The simulation framework in the SUNRISE context

The SUNRISE harmonized Verification and Validation (V&V) simulation framework is a fundamental part of the SUNRISE Safety Assurance Framework with the scenario-based SUNRISE methodology to be defined in WP3. At the time of submitting this deliverable, both the SUNRISE Safety Assurance Framework and the scenario-based SUNRISE methodology are still in the definition phase. In this context, Task 4.1 identified the subsystems of the V&V simulation architecture for virtual validation of CCAM systems, including the definition of requirements, providing the basis for selection of simulation tools (which will happen in Task 4.3). During task T4.1, contributing partners proposed subsystems of relevance, compared different inputs, and reached a common understanding.

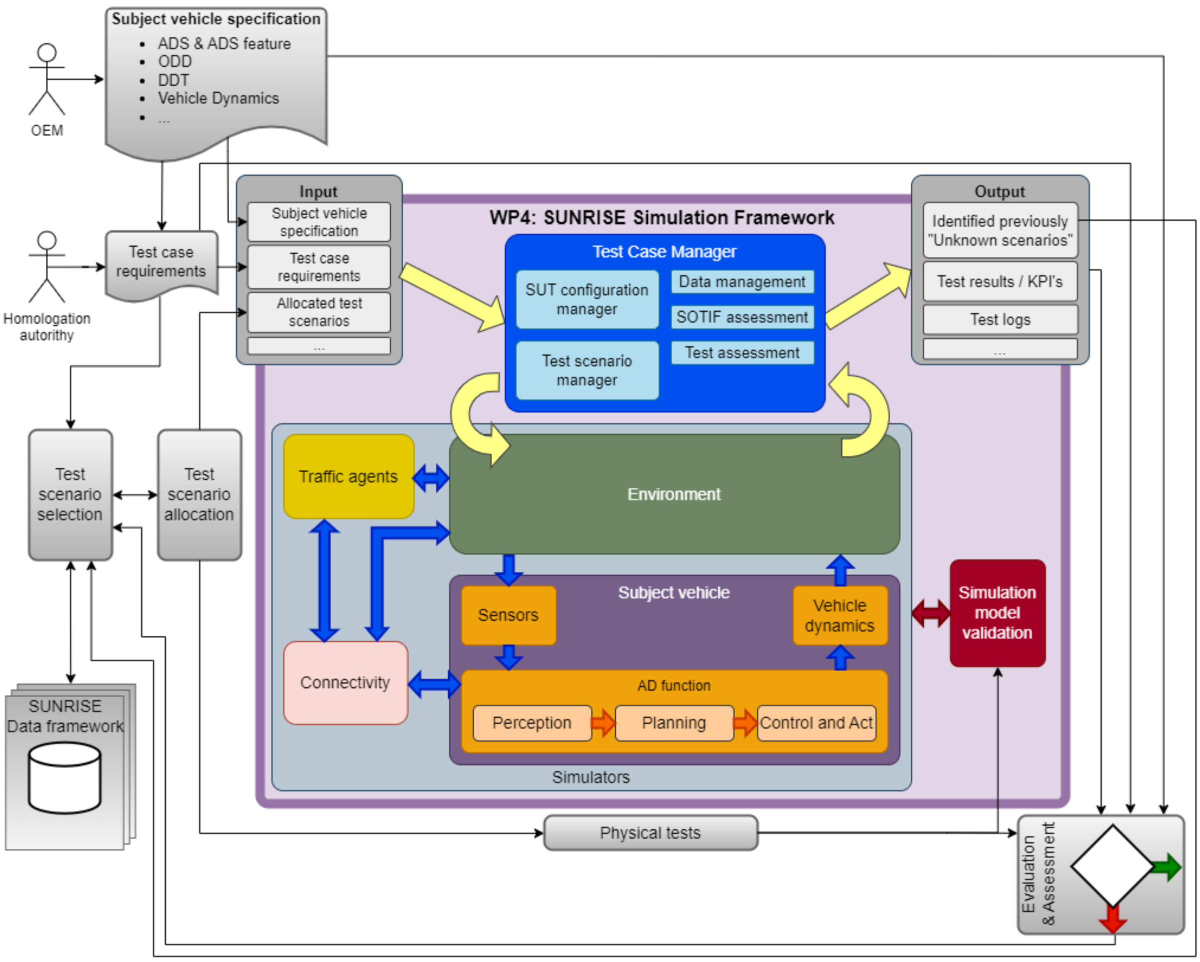

Figure 1. The SUNRISE simulation framework with its subsystems.

Figure 1 aims to illustrate the architecture of the SUNRISE simulation framework as well as the subsystems that compose it. The deliverable D4.1 contains more details about both the architecture of the framework and its subsystems.

2.2 Subsystems overview

In this subsection, the identified relevant subsystems in the Task 4.1, as shown in Figure 1, are briefly described. It should be noted that not all need to be implemented in a certain test and subsystems may be left out if not needed for the test. Finally, it is also important to note that a more detailed description of the subsystems below can be found in the Deliverable 4.1:

1. **Test case manager**: The test case manager has the following key roles:

    a) Interface the simulation framework with the rest of the safety assurance framework.

    b) Orchestrate execution of test scenarios in the simulation framework.

    c) Perform SOTIF assessment.

    d) Compute KPIs and metrics for the test scenarios from the simulation data.

    e) Perform checks on whether intended scenarios have occurred, and the corresponding pass/fail criteria mentioned above in point c & d.

2. **Environment**: The environment subsystem's main function is to describe the surrounding environment in which the autonomous vehicle operates. It serves as a base information in describing and interpreting everything from the outside that encompasses the autonomous vehicle. Depending on the desired vehicle functionalities and target virtual testing complexity, proper fidelity level of environment detail shall be defined. For simple autonomous functions that are based only on detected objects and predicted trajectories, simple environment entities can be defined with only base shape and position, however for more complex autonomous functionalities, detailed Environment shall cover all necessary details. In other words, it shall be sufficiently defined so that it covers the whole OD (Operational Domain) and ODD (Operational Design Domain) for the designed vehicle [5]. ODD represents the environment in which a function remains safe, while OD represents any condition whatsoever which the vehicle could encounter, thus in this case "OD" and the "Environment" have great similarity.

3. **Subject vehicle**: The subject vehicle includes the "Sensors" subsystem, the "AD function" subsystem, and the "Vehicle Dynamics" subsystem:

    3.1. **Sensors**: The sensor subsystem is a key element in enabling automated driving systems to provide both reliable vehicle localisation and robust environmental perception of the vehicle's surroundings within its ODD [7]. Environmental perception sensors include mainly cameras, radar and LiDAR, and their corresponding sensor models needed for virtual verification and validation tasks within the development process. Sensor models will enable the reduction of conventional test drives and physical component testing with simulations in virtual test environments to meet the increasing demands of ADS in terms of development cost, time, and safety. Given the variety and complexity of possible environmental conditions, realistic simulation of perception sensors is a particularly challenging issue.

3.2. **AD function**: Automated driving (AD) functions utilize a range of sensors, actuators, and other input data about vehicle’s surroundings to enhance safety and comfort for drivers, passengers, and other road users. By effectively processing the input data, AD functions control the vehicle's response to achieve desired outcomes. Advanced sensor technologies, including cameras, LiDAR, radar, and ultrasonic sensors, provide crucial information about the vehicle's surroundings. Vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication systems further enrich the input data. Sophisticated algorithms and artificial intelligence techniques analyse the sensor data in real-time, enabling the AD system to accurately perceive the environment, predict the behaviour of other road users, and make informed decisions.

3.3. **Vehicle Dynamics**: Vehicle dynamics describe the motion of a vehicle based on specific inputs (e.g., external, and internal forces). The simulation of vehicle dynamics has a wide array of applications, ranging from the development of vehicle technologies (e.g., active suspensions, driver assistance systems) towards the usage for the validation of automated driving systems (ADS). The respective simulation environments and mathematical foundations are considered to be well-established [9].

4. **Traffic agents**: The traffic agents are a subsystem, that simulates the behaviour of various types of traffic agents, i.e., all dynamic elements except the subject vehicle (SuT). Traffic agents include all living beings, transport systems for living beings and goods, and moving objects on roads [8].

5. **Connectivity**: The communication enables vehicles to establish communication links with other vehicles, pedestrians, cyclists, and infrastructure elements in their surroundings [22–25]. This technology is essential for Cooperative Connected and Automated Mobility (CCAM) and brings various advantages, such as improved safety, efficiency, and mobility on the roads [10].

6. **Simulation model validation**: For verification and validation, it is necessary to approve their quality and correlation to reality. This is especially important for the certification of ADAS/AD functions in multiple vehicle variants, supplemented by simulation. For example, validated suspension models will affect the virtual sensor output, such as radar, LiDAR, or camera, in a realistic manner, including e.g., pitching, and rolling motion of the chassis. Accurate tire models will result in realistic tire-surface interaction, especially on rough, non-even surfaces. Usually, the simulation quality and correlation with real-world measurements is assessed on three levels: a) vehicle dynamics behaviour, b) sensor and perception behaviour, and c) ADAS/AD system behaviour, i.e., the actuation of the controller.

3 USE CASE REQUIREMENTS

This section aims to briefly define the use cases and go through the requirements related to each of them, as well as a few additional generic requirements that don't apply to any of the use cases exclusively. These requirements are a refined version of the ones defined in D7.1, which is why they are listed in more detail in this deliverable. In addition to this, some of them were split into several requirements. That was done to map each requirement to a single subsystem. The requirements will be presented with their number and name, which will be accompanied by a description and, whenever further details are needed, a rational.

3.1 UC 1: Urban AD perception validation

The scope of **UC 1 - Urban AD perception validation** is to validate the perception of the environment for SAE L3+ vehicles in urban and/or suburban areas by implementing a hybrid validation test, combining virtual simulation and physical testing, and considering aspects of connected driving and collective perception. UC 1 - Urban AD Validation includes three main sub-UCs as follows:

- **Sub-UC 1.1 - perception testing:** covers sensor models used in simulation and perception subsystem validation methods and metrics.
- **Sub-UC 1.2 - connected perception testing:** builds on Sub-UC 1.1 and covers the integration of information from other vehicles/VRUs coming from external sources via V2X and the use of C-ITS services.
- **Sub-UC 1.3 - cooperative perception testing:** builds on Sub-UC 1.2 and covers the integration of information from other vehicles/VRUs coming from external sources via V2X and the use of C-ITS services.

Sub-UC 1.1 aims to cover the testing and safety validation of the different elements of the perception layer when the ADS Operational Design Domain (ODD) includes complex urban intersections and the inclusion of adverse weather conditions. The objective is to extend the current possibilities for testing and validation of CCAM functions in urban environments, focusing on intersections where most accidents occur due to distracted pedestrians or traffic light violations. In this context, a representative perception AD subsystem based on three different sensors (LiDAR, camera, and radar) will be addressed. With respect to the ADS under test, in this case an urban chauffeur ADS, UC 1 focuses mainly on all longitudinal manoeuvres except reversing in the context of mixed traffic and interactions with other users and with the infrastructure, with KPIs mostly related to safety. Types of data from other vehicles and infrastructure are described to be used for validation testing.

The specified ODD and its associated behavioural capabilities in terms of OEDR and MRM represent two major sources of requirements for the subsystems required to build the urban ADS validation use case.

In this work, the high-level validation requirements identified in Deliverable D7.1 in terms of ADS functional safety assessment, scenario description/generation and test framework are further detailed and mapped to the individual subsystems.

In addition, based on the described SUNRISE simulation framework and the included subsystems, deliverable D4.1 also discusses the subsystem requirements from an SAF perspective by analysing tool requirements, interface requirements and model fidelity requirements. They will also serve as an important input for the use case requirements and their mapping, together with deliverable D7.1, see Section 4 for more details.

The section below outlines the detailed requirements related to the three sub-use cases of UC 1 – Urban AD validation.

3.1.1 Sub-UC 1.1: Perception testing

The following requirements relate to the validation of LiDAR, camera, and radar-based perception functions, which is the main objective of Sub-UC 1.1. It covers topics such as radar sensors, LiDAR sensors, camera sensors, environmental simulation, vehicle dynamics, ADS under test and evaluation and validation topics in terms of scenarios and associated KPIs and metrics.

The requirements defined regarding the sub-UC 1.1 can be found in table 3 and they regard the following aspects:

- The metrics that shall be used to validate scenarios and radar detections (R1.1_01 and R1.1_02).
- Which features the radar sensor model shall have (parameters, environmental effects, real time, etc.) (R1.1_03_X).
- Which features the camera sensor model shall have (resolution, FoV, mounting position, data format, etc.). These are meant to be able to simulate a sensor able to replicate a real Continental MFC527 camera (R1.1_04_X).
- Which features the LiDAR sensor model shall have (protection rating, minimum detection distances, field of view, etc.). These are meant to be able to simulate a sensor able to replicate a real Velodyne LiDAR Puc VLP-32C (R1.1_05_X).
- How the scenery shall be defined (categories of surfaces, area types, directions, planes, etc.) (R1.1_06_X).
- How the atmospheric conditions shall be defined (wind, rainfall, particles and illumination) (R1.1_07_X).
- Which shall be the possible categories of the dynamic elements of the ODD (R1.1_08_X).
- Under which manoeuvres the ADS shall be tested (R1.1_09).

- Safe behaviour of the SuT (speed limits and detection of traffic agents) (R1.1_10_X).
- Detections and object list format for the traffic agents and road boundaries (R1.1_11_x).
- What kind of weather, roads and interaction between different traffic agents should appear in the generated scenarios (R1.1_12).
- Which ISOs and EU norms shall be applied for the functional safety assessment of the ADS (R1.1_13_X).
- Combination between virtual and physical testing is requested (R1.1_14).
- The simulation framework shall be able to take files following the OpenScenario format and generate a corresponding virtual environment (R1.1_16).
- Relationship between vehicle dynamics and sensor position (R1.1_17).
- Controllability of traffic agents (R1.1_18).
- Independence of the driving tasks from the perception module (R1.1_20).
- Minimal maximal speed of the vehicle under test (70kph) (R1.1_21).
- What should be represented in the virtual environment (R1.1_22).
- Required photorealism levels and checks (R1.1_23 and R1.1_24).
- Checks to verify that what is simulated is what was requested (R1.1_25).
- Minimal options of the configuration interface (R1.1_26).
- Minimal amount of data (in time) that the framework shall be able to store (R1.1_27).

3.1.2 Sub-UC 1.2: Connected perception testing

The following requirements relate to the validation of GLOSA (Green Light Optimal Speed Advisory) and C-ACC (Cooperative Adaptive Cruise Control) within a predefined ODD context and which relies on V2V acquisitions, which is the main objective of Sub-UC 1.2. It covers topics such as various ODD and behaviour competence related attributes, environmental simulation, ADS under test and evaluation and validation topics in terms of scenarios and associated KPIs and metrics.

The requirements defined regarding the sub-UC 1.2 can be found in table 4 and they regard the following aspects:

- Compliance with EURO NCAP and GSR (R1.2_01).
- Simulation Scenery description (types of drivable areas, lane specification, traffic signs, etc.) (R1.2_02_X).
- Atmospheric conditions description (wind, illumination, rainfall and connectivity (R1.2_03_X).
- Types of traffic agents (R1.2_04_X).
- Required manoeuvres (R1.2_05).
- Safe behaviours that the subject vehicle shall be able to do in urban intersections (respect traffic lights and react to violations by other road users) (R1.2_06_X).
- What should be detected by the perception data function and under which circumstances (R1.2_07).
- Which scenarios shall be used to validate connected perception systems (type of roads and actors and specific collection of scenarios) (R1.2_08_X).
- Which ISOs and EU norms shall be applied for the functional safety assessment of the ADS (R1.2_09_X).
- Need to validate the results obtained during the virtual validation in the real world (R1.2_10).

3.1.3 Sub-UC 1.3: Cooperative perception testing

The following requirements relate to the validation of an overall safety argumentation in virtual cooperative perception testing for urban collective perception within a predefined ODD context, which is the main objective of Sub-UC 1.3. It covers topics such as various ODD and behaviour competence related attributes, the validation of the test framework and evaluation and validation topics in terms of scenarios and associated KPIs and metrics.

The requirements defined regarding the sub-UC 1.3 can be found in table 5 and they regard the following aspects:

- Need to validate by using both virtual and real data *(*R1.3_01*).*
- Need for SiL and CoSim methods *(*R1.3_02*).*
- Which CPM data shall be included in the validation process *(*R1.3_04 and R1.3_05*).*
- Use of annotated or object-level data *(*R1.3_06*).*
- Description of how the roads shall be defined (*minimum* number of lanes, lines marking, uniformity of the surface, etc.) *(*R1.3_07*).*
- Which atmospheric conditions shall be used to test the ADS (wind, rain and illumination) *(*1.3_08*).*

- Which road users shall be present in the simulations and maximum subject vehicle speed *(*R1.3_09*).*
- The scenario manager shall be able to convert OpenScenario files in corresponding virtual environments *(*R1.3_10*).*

3.2 UC 2: Traffic jam AD validation

Based on “ERTRAC Connected, Cooperative and Automated Mobility Roadmap (2022)” [12] the scope of the UC ID 2 “Traffic Jam AD validation” is to validate the automated lane keeping system (ALKS) in a virtual/real manner for highly automated vehicles (SAE L4) on motorways and motorway similar roads via the implementation of a hybrid validation testing, by combining virtual simulations and physical tests.

This UC is focusing on AD behaviour validation and aims to optimise the workflow from test case generation to model creation and integration, as well as to test execution and assessment through new metrics designed for various scenarios.

The requirements defined regarding the UC 2 can be found in table 6 and they regard the following aspects:

- How the ADS shall react to foreseeable collisions and traffic rules (R2.1_01-04).
- How the ADS shall control the vehicle lateral and longitudinally, based on speed and other traffic agents (R2.1_05-14).
- Which shall be the inputs of the vehicle dynamics model (R2.1_15-17).
- How the ODD shall be defined (ontology, file format, and manoeuvres) (R2.1_18-19).
- How the roads shall be defined (surfaces and their variations, file format, road models, etc.) (R2.1_21-23).
- How the sensors shall be defined (sensor specifications, layout on the vehicle's body and object lists) (R2.1_24-26).
- How to make the functional safety assessment of the ADS. Which things the system is supposed to be able to do (keep lane, get speed limits, detect obstacles, manoeuvres, and control, etc.) (R2.1_27-34).
- Which should be available in the testing vehicle for testing (driving functions, sensors, metrics, middleware, KPI metrics for virtual-physical correlation, etc.) (R2.1_38-50).
- Requirements for the KPI dashboard (R2.1_51-52).
- How the scenery shall be defined (categories of surfaces, area types, directions, planes, etc.). (2.1_53_X).

- How the atmospheric conditions shall be defined (wind, rainfall, particles, and illumination) (R2.1_54_X).

- Which shall be the possible categories of the dynamic elements of the ODD (R2.1_55_X).

3.3 UC 3: Highway AD validation

The Highway Chauffeur **UC 3 - Highway AD validation**, aims to demonstrate the SUNRISE SAF on an equivalent system with additional V2C (map updates) or V2X (e.g. via use of V2V for C-ACC function) communication capability.

The scope of UC ID 3 is to validate semi/highly automated vehicles (SAE L2/L3+) on motorways and motorway similar roads via the implementation of a hybrid validation testing, by combining virtual simulations and physical tests. In SUNRISE project, UC ID 3 includes two main sub-UCs as follows:

- **Sub-UC 3.1 - Map-based perception & decision-making & control testing:** focuses on demonstrating how the vehicle's safety and awareness can be improved based on information coming from maps, sensors or connected services about road characteristics or road dynamic events.

- **Sub-UC 3.2 - Cooperative perception & decision making & control testing:** focuses on demonstrating how safety and surrounding awareness could be improved on motorways by including cooperative V2X functionality (with other vehicles in the neighbourhood) in the Highway Pilot (HWP) system (e.g., by leveraging and upgrading the driver assistance functionality developed previously in C-ACC from sub-UC 1.2).

3.3.1 Sub-UC 3.1: Map-based perception & decision-making & control testing

The requirements listed below relate to a safety assessment of a map-based highway pilot AD system within a predefined ODD context which is the focus of sub-UC 3.1. These requirements for the safety assessment with regards to map provided data include different topics like existing standards or regulations, the ODD of the system and the verification and validation process.

The requirements defined regarding the sub-UC 3.1 can be found in table 7 and they regard the following aspects:

- EURO NCAP and GSR requirements for validation metrics (R3.1_01).

- How the scenery shall be defined (categories of surfaces, area types, directions, planes, etc.). (R3.1_02_X).

- How the atmospheric conditions shall be defined (wind, rainfall, particles and illumination) (R3.1_03_X).

- Which road users shall be present in the simulations as well as the densities and speeds allowed for them. (R3.1_04_X).

- Required safe behaviours of the ADS - R3.1_05).

- Required scenarios to be validated (speed modifications due to newly perceived speed limits or incoming curves) (R3.1_06_X).

- Required detections and behaviours of the perception driving functions (R3.1_07).

- Required challenging situations to be validated (adverse weather, EURO NCAP, etc) (R3.1_08).

- Need to validate the results obtained during the virtual validation in the real world (R3.1_10).

3.3.2 Sub-UC 3.2: Cooperative perception & decision making &control testing

The requirements listed below relate to a safety assessment of a connected and cooperative highway pilot AD system within a predefined ODD context which is the focus of sub-UC 3.2. These requirements for the safety assessment with regards to other traffic agents and V2X connectivity include different topics like existing standards or regulations, the ODD of the system and the verification and validation process.

The requirements defined regarding the sub-UC 3.2 can be found in table 8 and they regard the following aspects:

- EURO NCAP and GSR requirements for validation metrics (R3.2_01).

- How the scenery shall be defined (categories of surfaces, area types, directions, planes, etc.). (R3.2_02_X).

- How the atmospheric conditions shall be defined (wind, rainfall, particles and illumination) (R3.2_03_X).

- Which connectivity and road users shall be present in the simulations as well as the densities and speeds allowed for them. (R3.2_04_X).

- Required safe behaviours of the ADS (R3.2_05).

- Required scenarios to be validated (different situations for the cooperative ACC) (R3.2_06_X).

- Required detections and behaviours of the perception driving functions (R3.2_07).

- Required challenging situations to be validated (adverse weather, EURO NCAP, etc) (R3.2_08).

- Need to validate the results obtained during the virtual validation in the real world (R3.2_10).

3.4 UC 4: Freight vehicle automated parking validation

The scope of "UC ID 4 – Freight vehicle automated parking validation" is to validate the environment perception and connected cyber-security perception for highly automated freight transport vehicles in confined areas via the implementation of a hybrid validation testing, by combining virtual simulations and physical tests. In SUNRISE project, UC ID 4 includes two main sub-UCs as follows:

- Sub-UC 4.1: Truck-low speed perception & decision-making testing
- Sub-UC 4.2: Truck-low speed connected perception cyber-security testing

In both cases, starting from a pre-defined area, the truck will reverse into a loading dock. A sensor mounted on the loading dock will monitor the area behind the truck and communicate its observations to the truck.

3.4.1 Sub-UC 4.1: Truck-low speed perception & decision-making testing

The requirements listed below relate to testing setup for a truck on slow reversing towards a docking area within a predefined ODD. The focus here is on testing the ability of a vehicle to reverse and park itself into a defined docking area.

The requirements defined regarding the sub-UC 4.1 can be found in table 9 and they regard the following aspects:

- Requirements regarding the sensors (which are needed and how the environment shall be inputted to them) (R4.1_01_X).
- Required path planning capabilities (R4.1_02).
- Required manoeuvrability and control (R4.1_03).
- Required real-time capabilities to adapt the actions to changes in the surroundings (R4.1_04).
- How the scenery shall be defined (categories of surfaces, area types, directions, planes, etc.). (R4.1_05_X).
- How the atmospheric conditions shall be defined (wind, rainfall, particles, illumination, and communication) (R4.1_06_X).
- Which agent types shall be excluded of the simulation (R4.1_07).
- Required accuracy, reliability, safety, and adaptability of the ADS (including required ISO compliance) (R4.1_08, 09, 10 and 11).

- Need to validate the results obtained during the virtual validation in the real world (including metrics and KPIs to be used) (R4.1_13).
- Required validity of vehicle dynamics, connectivity, and simulation model (R4.1_14, 15 and 16).

3.4.2 Sub-UC 4.2: Truck-low speed connected perception cyber-security testing

The requirements listed below relate to testing setup for a truck on slow reversing towards a docking area within a predefined ODD. The testing and validation activities here are focused on cybersecurity with the connection between the vehicle and docking area into focus.

The requirements defined regarding the sub-UC 4.2 can be found in table 10 and they regard the following aspects:

- Requirements regarding the system under test (sensors, path planning, manoeuvring and real time adjustment) (from R4.2_01 until R4.2_04*)*.
- How the scenery shall be defined (categories of surfaces, area types, directions, planes, etc.). (R4.2_05_X).
- How the atmospheric conditions shall be defined (wind, rainfall, particles, illumination, and communication) (R4.2_06_X).
- Which agent types shall be excluded of the simulation (R4.2_07).
- Requirements for the functional safety assessment (regulations to be followed and requirements regarding the perception system and cyber-attacks) (from R4.2_08 until R4.2_12).
- Requirements for the test framework (tools, environmental and cyber-security robustness, runtime measurements, etc.) (from R4.2_14 until R4.2_19).

4 GENERIC REQUIREMENTS

4.1 Generic requirements: ISO 21448 (SOTIF) standard

The ISO 21448 standard [11] is currently one of the most prominent standards for AV safety. It concerns the safety of the intended functionality (SOTIF). In the SUNRISE deliverable D7.1, several use cases, such as 1.1, 1.3, 4.2, mentioned the importance of ensuring SOTIF for the system under test. For example, in UC1.1, the following requirement is provided: *"UC1.1_REQ_SA_002: Apply ISO21448 and analyse safety in use, (considering external factors: environment and weather, and user interaction)".* However, from such a requirement, it is not clear what requirements emerge for the subsystems of a simulation framework. Thus, during this task, detailed requirements are derived related to the SOTIF standard and are presented in this section. To help the reader understand these requirements, a brief introduction to the SOTIF standard is presented first. Please refer to the standard [11] for more details.

SOTIF is defined as the absence of unreasonable risk due to a hazard caused by functional insufficiencies. The standard lists two types of functional insufficiencies: insufficiency of specification and performance insufficiency. *Insufficiency of specification* relates to specification gaps, e.g., system cannot handle uncommon road signs which were not part of its training dataset. On the other hand, if the system cannot detect traffic signs when there is some dirt on the signs, this relates to a *performance insufficiency*. Here, the perception of the system is not sufficiently robust to such perturbations and therefore is a performance limitation of the system. The SOTIF standard also includes within its scope functional insufficiencies related to preventing, detecting, and mitigating reasonably foreseeable misuse of the system. This may be direct misuse, for example, the user switches on AD function outside the ODD, or indirect misuse – where behaviour of the user which impacts controllability or severity of a hazardous event, such as when the user is not paying attention in a L2 or L3 automation vehicle.

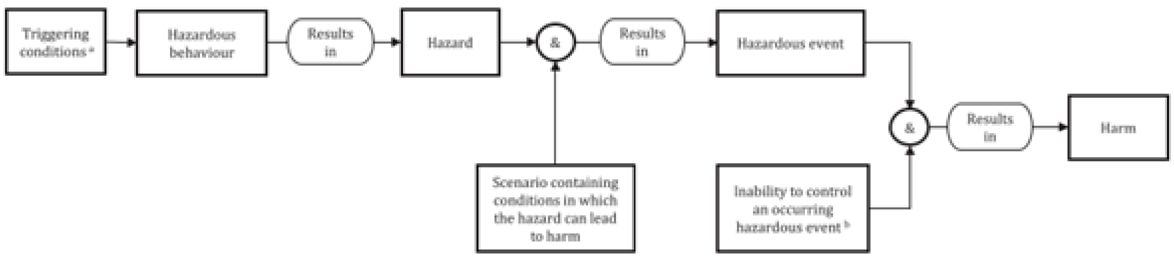

Figure 2: Flowchart in the SOTIF standard depicting how triggering conditions can activate functional insufficiencies and lead to harm. [11].

Functionality insufficiencies can lead to harm in the presence of a triggering condition, e.g., dirt on the road sign, if it results in hazardous behaviour from the system, e.g., ignores the road sign (e.g., a speed limit sign) and therefore disobeys traffic rules. This hazardous behaviour could subsequently lead to harm, as shown in Figure 22, if disobeying the traffic rule (e.g., reducing driving speed) results in a critical situation.

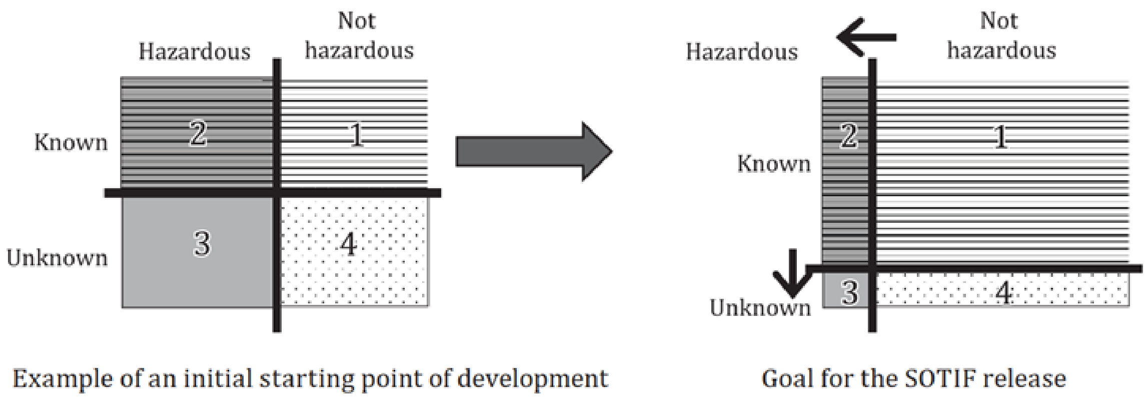

Figure 3: Representation of how application of the SOTIF standard can improve the safety of the ADS. [11]

Figure 33 shows the high-level aim of the SOTIF standard. Four areas categorize all possible scenarios which the AD may encounter by considering whether they are *known* or *unknown* and whether the system behaves safely or not in the scenario. The goal, by applying the SOTIF standard, is to reduce the unsafe areas (both known and unknown) and estimate the residual risk posed by the system for each of the unsafe areas.

For unknown scenarios, a systematic discovery process is needed to identify such scenarios. An unknown scenario is defined by the standard in three ways:

- Potential triggering condition are identified but behaviour of system unknown. For example, it is well-known that camera-based perception may suffer in fog or adverse weather conditions, but how this affects system behaviour may be unknown.
- Unknown triggering conditions, e.g., Sint Maarten parade in the Netherlands where people wear lights on top of their clothes[1] may confuse an object detection algorithm.
- Known parameters of scenarios can combine into unknown potential triggering conditions, for example, a Tesla vehicle had an accident when the glare of sun at a certain angle led the vehicle to crash into a white bus[2].

As this deliverable is primarily concerned with requirements for the simulation framework of the safety assurance framework, some topics addressed within the standard are not considered here such as in-vehicle monitoring and modification and design of the ADS to improve safety of intended function.

Derived requirements

The below section presents requirements which are derived from the SOTIF standard. The requirements are grouped in two main categories: the first relating to the process of

[1] https://www.sintmaartenparade.nl/
[2] https://www.carscoops.com/2021/12/tesla-model-s-wrecked-after-slamming-into-bus-in-california-did-sun-glare-play-a-role/

identifying unknown-unsafe scenarios and the second on the evaluation and reporting of SOTIF. To illustrate how these requirements would apply for a specific use-case, some examples are shown for UC1.1.

Category 1: Setup of unknown-unsafe scenario exploration

The requirements below relate to the process of identifying unknown-unsafe scenarios for the system under test. It covers topics including search space definition, exploration methods, safety argumentation, and necessary iteration of the process.

The requirements defined related to the identification of unknown-unsafe scenarios can be found in table 11 and they regard the following aspects:

- Need to explore unknown unsafe scenarios and how to refine the search, make it feasible (R10.1.7, 8, 10 and 11).
- Required justification for ODD coverage, search setup, exploration techniques and metrics (R10.1.9, 12, 13 and 14).
- Required iteration of the search when the ODD or SuT change (R10.1.15 and R10.1.15.1).

Category 2: evaluation and reporting of SOTIF

This category of requirements relates to the testing of the system against different scenario categories such as known-unsafe scenarios, scenarios with potential triggering conditions, and identified unknown-unsafe scenarios. The requirements also stipulate the reporting of test results and the activities to be performed for assessment of safety.

The requirements defined related to the testing of the system against different scenario categories can be found in table 12 and they regard the following aspects:

- The risk of the scenarios, triggering conditions and ODD boundaries shall be quantified and reported (R10.1.19, 20 and 21).
- The validation shall be run in all known unsafe scenarios (R10.1.20.1).
- The simulation shall be realistic and accurate regarding the environment, the sensors, the ADS behaviours, and the traffic inside the ODD, at its boundaries and outside of it (R10.1.21.1, 2, 3, 4 and 5).
- The validation shall be run in all the discovered unknown unsafe scenarios (which shall be added to the scenario database) (R10.1.18, R10.1.18.1, R10.1.16.1 and R10.1.16.2).
- The results of the testing against the discovered unknown unsafe scenarios shall be reported (R10.1.17.1 and R10.1.17.2).

- The residual risk regarding the unknown unsafe scenarios shall be assessed and reported (R10.1.6).

4.2 Generic requirements: ISO 34502 standard

The ISO 34502 standard is entirely conformant with SOTIF (ISO 21448) (and wider functional safety influences from the ISO 26262 series), adding specifically to content in the incorporation of a scenario-based safety evaluation process, to finetune application for ADS and the risks that should be considered in its evaluation. Due to the relevance of these extensions and additions to the SOTIF processes to the use cases established in the SUNRISE deliverable D7.1, some generic requirements have been extracted that can be applied across multiple use cases, rather than being derived explicitly form an individual case. As with section 4.1 a brief introduction to the standard and its extensions of the SOTIF process is given below to help the reader understand the context of the generic requirements and their introduction to the SUNRISE D4.2 deliverable. For a more complete understanding of the standard please refer to the full text [3].

ISO 34502 for road vehicles, titled "Road vehicles — Test scenarios for automated driving systems — Scenario-based safety evaluation framework," stands as a crucial benchmark in the rapidly evolving landscape of autonomous driving technologies. Developed by the International Organization for Standardization (ISO), this standard provides a comprehensive framework for evaluating the safety of automated driving systems (ADS) through scenario-based testing. With the increasing integration of autonomous features in vehicles, ISO 34502 addresses the critical need for standardized safety assessments, offering a structured approach to scenario testing that enhances the reliability and robustness of ADS.

At its core, ISO 34502 guides the automotive industry in defining and implementing scenario-based testing methodologies to evaluate the safety performance of automated driving systems. The standard emphasizes the importance of diverse and representative scenarios that span a wide range of driving conditions, ensuring thorough assessments of ADS capabilities in real-world situations. By establishing a common framework, ISO 34502 enables manufacturers, regulators, and researchers to assess and compare the safety performance of different automated driving systems consistently. This standard plays a pivotal role in instilling confidence among consumers, regulators, and stakeholders by providing a transparent and standardized methodology for evaluating the safety of autonomous vehicles.

In practical terms, ISO 34502 contributes to the ongoing development and deployment of autonomous driving technologies by fostering interoperability and transparency in safety assessments. As the automotive industry continues to innovate, this standard offers a valuable tool for ensuring the reliability and effectiveness of automated driving systems, ultimately promoting the widespread adoption of safe and dependable autonomous vehicles on the road.

Derived requirements

The below section presents a small selection of requirements which were derived from ISO 34503 that that were identified as not being captured in regular SOTIF derived requirements.

Table 2: Requirements derived from ISO 34503

Requirement number	Name	Description	Rational
R10.1.2	Validation of test methods/ simulation quality: VTP to test-track	Criteria to validate the results of VTPs with track testing when more than 1 testing method is being used.	ISO standards should be applied within the Sunrise methodology wherever possible. Especially concerning testing
R10.1.3	Validation of test methods/ simulation quality: VTP/Test-track to real-world	If real-world testing (not controlled track testing) is performed the results should also be compared with the results of VTP and track-tests	ISO standards should be applied within the Sunrise methodology wherever possible. Especially concerning testing
R10.1.4	Completeness of testing: testing platforms	Allocation of tests to different test platforms.	ISO standards should be applied within the Sunrise methodology wherever possible. Especially concerning testing
R10.1.5	Relevance of test cases to scenario space (UC) and coverage compared to ODD	Ensuring use cases have a suitable test case specification compared to the ODD of the UC	ISO standards should be applied within the Sunrise methodology wherever possible. Especially concerning testing

5 MAPPING OF THE REQUIREMENTS TO SUBSYSTEMS

After defining the relevant subsystems for the simulation and listing all the requirements, they can now be matched to each other. Next, a series of subsections will list which requirements are linked to each of the subsystems.

Note that while mapping the generic requirements to the subsystems, it is assumed that the use-case requirements already cover the representation of the use-case specific ODD by the simulation models. Also, whenever a requirement listed in this section has sub-requirements, it means that all the sub-requirements are included in that mapping. For example, if “R1.1_03” is mapped to a certain subsystem but there are requirements named “R1.1_03_01”, “R1.1_03_02”, etc. (sub-requirements), all the sub-requirements under “R1.1_03” are mapped to that subsystem.

5.1 Test Case Manager

The requirements mapped to the test case manager subsystem are the following:

- **UC 1 requirements**: R1.1_01, R1.1_02, R1.1_16, R1.1_26, R1.1_27 and R1.1_28, R1.3_01, and R1.3_10.
- **UC 2 requirements**: R2.1_18, R2.1_19, R2.1_20, R2.1_36, R2.1_37, R2.1_44, R2.1_46, R2.1_51, and R2.1_52.
- **UC 3 requirements**: R3.1_01, R3.1_06, R3.1_10, R4.1_12, and R3.2_10.
- **UC 4 requirements**: R4.1_13.
- **Generic requirements**: R10.1.3, R10.1.4, R10.1.5, R10.1.7, R10.1.8, R10.1.9, R10.1.10, R10.1.11, R10.1.12, R10.1.13, R10.1.14, R10.1.15.1, R10.1.16.1, R10.1.17.1, and R10.1.18.1.

5.2 Environment

The requirements mapped to the environment subsystem are the following:

- **UC 1 requirements**: R1.1_06, R1.1_07, R1.1_12, R1.1_22, R1.1_23, R1.1_24, R1.3_02, R1.3_07, R1.3_08, and R1.3_09.
- **UC 2 requirements**: R2.1_24, R2.1_53, and R2.1_54.
- **UC 3 requirements**: R3.1_02, R3.1_03, R3.2_02, R3.2_03.
- **UC 4 requirements**: R4.1_01_3, R4.1_05, R4.1_06, and R4.1_07.

- **Generic requirements**: R10.1.21.1.

5.3 Subject vehicle's sensors

The requirements mapped to the subject vehicle's sensors subsystem are the following:

- **UC 1 requirements**: R1.1_03, R1.1_03_01, R1.1_03_02, R1.1_03_03, R1.1_03_04, R1.1_03_05, R1.1_03_06, R1.1_03_07, R1.1_03_08, R1.1_03_09, R1.1_04_01, R1.1_04_02, R1.1_04_03, R1.1_04_04, R1.1_04_05, R1.1_04_06, R1.1_04_07, R1.1_05, R1.1_11, R1.1_11_01, R1.1_11_02, R1.1_26 and R1.3_06.
- **UC 2 requirements**: R2.1_08, R2.1_25, R2.1_26, R2.1_28, R2.1_38, and R2.1_39.
- **UC 3 requirements**: R3.1_05_01, R3.1_05_02, R3.1_07, and R3.2_07.
- **UC 4 requirements**: R4.1_01_1.
- **Generic requirements**: R10.1.21.2.

5.4 Subject vehicle's AD functions

The requirements mapped to the subject vehicle's AD functions subsystem are the following:

- **UC 1 requirements**: R1.1_09, R1.1_10, R1.1_13, and R1.1_20.
- **UC 2 requirements**: R2.1_01, R2.1_02, R2.1_03, R2.1_04, R2.1_05, R2.1_06, R2.1_07, R2.1_09, R2.1_10, R2.1_11, R2.1_12, R2.1_13, R2.1_14, R2.1_27, R2.1_29, R2.1_30, R2.1_31, , R2.1_32, R2.1_33, R2.1_34, R2.1_35, R2.1_40, andR2.1_41.
- **UC 3 requirements**: R3.1_05_02, R3.1_06, R3.1_06_01, R3.1_06_02, R3.2_05_02, R3.2_06, R3.2_06_01, R3.2_06_02, and R3.2_06_03.
- **UC 4 requirements**: R4.1_01_2, R4.1_02, R4.1_03, R4.1_04, R4.1_08, R4.1_09, R4.1_10, and R4.1_11.
- **Generic requirements**: R10.1.21.3.

5.5 Subject vehicle's dynamics

The requirements mapped to the subject vehicle's dynamics subsystem are the following:

- **UC 1 requirements**: R1.1_21.
- **UC 2 requirements**: R2.1_15 and R2.1_16.
- **UC 3 requirements**: R3.1_05 and R3.2_05.

- **UC 4 requirements**: R4.1_14.
- **Generic requirements**: R10.1.21.4.

5.6 Traffic agents

The requirements mapped to the traffic agents subsystem are the following:

- **UC 1 requirements**: R1.1_08_01, R1.1_08_02, R1.1_18, and R1.1_19.
- **UC 2 requirements**: R2.1_55.
- **UC 3 requirements**: R3.1_04_01, R3.2_04_01, and R3.2_07.
- **Generic requirements**: R10.1.21.5.

5.7 Connectivity

The requirements mapped to the connectivity subsystem are the following:

- **UC 1 requirements**: R1.3_03, R1.3_04, and R1.3_05.
- **UC 3 requirements**: R3.2_04_02 and R3.2_07.
- **UC 4 requirements**: R4.1_15.

5.8 Simulation model validation

The requirements mapped to the simulation model validation subsystem are the following:

- **UC 1 requirements**: R1.1_14.
- **UC 2 requirements**: R2.1_17, R2.1_21, R2.1_22, R2.1_23, R2.1_42, R2.1_43, R2.1_45, R2.1_47, R2.1_48, R2.1_49, R2.1_50.
- **UC 3 requirements**: R3.1_10 and R3.2_10.
- **UC 4 requirements**: R4.1_16.
- **Generic requirements**: R.10.1.2, R10.1.16.2, R10.1.19.1, R10.1.20.1, and R10.1.21.6.

5.9 Requirements external to the simulation framework

Generic requirements: ISO 21448 standard (SOTIF)

The SOTIF standard outlines processes to ensure that the specified functionality does not have any functional insufficiencies and is safe. However, ensuring SOTIF is not limited to the simulation framework but shall be incorporated in the entire safety assurance framework.

Therefore, several requirements derived from the SOTIF standard in this task are not limited to the simulation framework and need to be fulfilled by parts of the safety assurance framework external to the simulation framework. Therefore, a list of requirements is presented to be fulfilled by other components in the SAF. These requirements are refined from original requirements presented in Section 4 where part of the requirement was allocated to the safety assurance framework. The components in the draft SAF which may be responsible for these requirements are briefly described in the following paragraphs.

Apart from the unknown-unsafe scenarios which are explored within the simulation framework, SOTIF requires the system to be tested against known unsafe scenarios, known potential triggering conditions, and for scenarios at the boundary or outside the ODD. These scenarios are to be retrieved from scenario databases. As currently considered in the SAF, scenario selection from the scenario databases and allocation to different test benches (including simulation platform) occurs outside the simulation framework. Thus, the SOTIF requirements are also imposed on the scenario selection modules in the SAF (impacting task T3.3).

Once the selected scenarios have been simulated, the simulation framework provides the necessary outputs, including respective KPIs and found unknown-unsafe scenarios. Using these generated outputs, as per the SOTIF requirements, the overall risk for the SuT needs to be evaluated, assessed against the pre-defined validation targets, and then reported as part of the safety assessment. This assessment needs to be done at a holistic level, including results from other test benches, and therefore is also external to the simulation framework in the SAF (impacting task T3.5). The found unknown-unsafe scenarios also need to be provided to the SCDB for future reference.

Finally, as part of the overall workflow, the SOTIF assessment shall be performed at every iteration of the SuT, as well as for any changes in performance specifications or ODD description. The triggering of this workflow is initiated by the SAF itself or users of the SAF.

5.9.1 Scenario selection

The requirements mapped to the scenario selection are: R10.1.19.2, R10.1.20.2, and R10.1.21.7. This is relevant for the task T3.3.

5.9.2 Assessment

The requirements mapped to the assessment are: R10.1.6, R10.1.17.2, R10.1.19.3, R10.1.20.3 and R10.1.21.8. This is relevant for the task T3.5.

5.9.3 Scenario database federation layer

The requirement mapped to the scenario database federation layer is R10.1.18.2. This may be relevant for tasks T6.1 and T6.2.

5.9.4 Safety workflows

The requirement mapped to the safety workflows is R10.1.15.2. This may be relevant for the tasks in the work packages WP2 and WP3.

6 CONCLUSIONS

The successful implementation of Cooperative, Connected, and Automated Mobility (CCAM) systems hinges on robust safety assurance measures. Within the SUNRISE project, the development of a Safety Assurance Framework (SAF) stands as a pivotal endeavour aimed at ensuring the safety of CCAM systems. Recognizing the limitations of relying solely on physical testing for safety assurance, the creation of a well-defined virtual framework becomes imperative to accurately validate numerous test scenarios. Consequently, the delineation of subsystems and their corresponding requirements emerges as a fundamental precursor to SAF development.

Through the deliverable D4.2, the SUNRISE consortium meticulously refined the requirements across all identified use cases of the Safety Assurance Framework outlined in deliverable D7.1. In addition to that, the requirements which pertain to all use cases, termed "generic requirements" in this document, such as those coming from regulations and standards were considered. The requirements pertaining both the use cases and the SOTIF standard were refined to be relevant and to allow mapping each of them to a single simulation subsystem. The detailed SOTIF requirements encompass topics such as the unknown-unsafe scenario exploration setup and methodology, evaluation and reporting of SOTIF, and safety argumentation. Examples have been provided to illustrate how the generic SOTIF requirements apply to a particular use case for better understanding of the requirement and its mapping.

The full set of requirements were systematically mapped to the simulation subsystems enumerated in deliverable D4.1, encompassing components such as the test case manager, environment, sensors, AD functions, vehicle dynamics, traffic agent, V2X connectivity, and simulation model validation. In addition, requirements, which are not relevant to the simulation framework were identified and shall be mapped externally to other components of the safety assurance framework. Recommendations were made for suitable external components (the scenario selection, the assessment, the scenario database, and the safety workflows).

As detailed in the "Intended audience" section, this work (specially the mapping contained in Section 5) is mostly relevant for the task T4.3, but part of it (the Section 4) may impact other SUNRISE tasks, such as T3.3, T3.5, T6.1, T6.2, and those in the work packages WP2 and 3.

In the pursuit of enhancing the comprehensibility of this document and elucidating the overarching methodology of the SUNRISE project, a concerted effort was made to refine the requirements such that each pertained distinctly to a single subsystem. Following this refinement process, a total of 181 requirements were meticulously defined, distributed across the various use cases as follows:

- **Urban AD validation (UC 1)**: 69 requirements, further categorized into sub-use cases:
    - Perception (sub-UC 1.1): 48 requirements encompassing LiDAR, camera, and radar functions testing.

    - Connected Perception (sub-UC 1.2): 10 requirements for V2V-based GLOSA and C-ACC testing.
    - Cooperative Perception (sub-UC 1.3): 11 requirements for urban collective perception testing.
- **Traffic jam AD validation (UC 2)**: 55 requirements focusing on safety assessment and decision-making testing.
- **Highway AD validation (UC 3)**: 20 requirements, segmented into sub-use cases:
    - Map-based perception, decision-making, and control (sub-UC 3.1): 10 requirements.
    - V2X-based cooperative perception, decision-making, and control (sub-UC 3.2): 10 requirements.
- **Freight vehicle automated parking validation (UC 4)**: 37 requirements, divided into sub-use cases:
    - Perception and decision-making testing for trucks at low speed (sub-UC 4.1): 18 requirements.
    - Connected perception cyber-security testing for trucks at low speed (sub-UC 4.2): 19 requirements.

As per the requirements regarding the ISO 21448 and ISO 34502 standards, a list of 34 refined requirements was obtained, which were grouped in three categories:

- 10 requirements aiming to identify unknown unsafe scenarios.
- 20 requirements related to evaluation and reporting of SOTIF.
- 4 requirements derived from ISO 34502.

To ensure meticulous documentation and enhance the clarity of conclusions drawn by the consortium, each requirement was meticulously mapped to its corresponding subsystem. Also, where deemed necessary, specific examples were incorporated to facilitate a deeper understanding of the mapping process.

7 REFERENCES

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8 ANNEX 1: REQUIREMENT TABLES

This annex contains the tables listing all the requirements for all use cases, their names, and their descriptions. Note that whenever a requirement specifies that something is “excluded”, it means that it shall not be simulated.

8.1 Requirement tables for UC 1

Table 3. Requirements of sub-UC 1.1

Requirement number	Name	Description	Rational
R1.1_01	Validation scenario assessment	Intersection scenarios shall use the EURO NCAP and GSR KPIs.	The EURO NCAP metrics and GSR ensure the functional safety of the ADS. In the case of intersection scenarios, the need to replace the TTC by another metric is motivated by its low sensitivity to safety critical situation evolving collisions with VRUs.
R1.1_02	Radar validation metrics	The angular separability and the object reflection sensitivity metrics shall be used to validate the detection of VRUs next to bulkier objects like trucks.	Assess the performance of the Radar in the perception of the surrounding environment.
R1.1_03	Radar sensor model	The radar sensor model shall represent a radar sensor device with 4 transmit and 4 receive channels.	The requirements ensure the development of a high-fidelity radar sensor model representing the important properties of today’s radar sensors.
R1.1_03_1	Radar sensor model - Radar signals generation/reception	The model shall be capable of emitting radar signals with appropriate frequency, modulation, and power levels. It should simulate the transmission of radar waves into the environment, either by computing the received signal based on a geometrical analysis of the scenario, or by interfacing to a ray tracing engine of the scenario simulation. The received signal	The requirement ensures a proper radar signal propagation in the virtual environment.

		shall be mapped to the base band signal frequency for further radar signal processing – upfront impairments can be applied as specified in R1.1_03_2).	
R1.1_03_2	Radar sensor model - Parametrization	The model shall provide a parametrization of typical impairments imposed onto the radar signal generation and reception to reflect individual radar sensor characteristics, which are based on the circuit design e.g., of the phase locked loop, power amplifier, trans impedance amplifier, filter and analogue to digital converter and hence are individual to the specific radar sensor. Operation conditions, which have an impact to the impairments, like temperature, shall be also part of the input parameters.	The requirement enables a proper parametrization of typical impairments.
R1.1_03_3	Radar sensor model - Signal processing	The radar sensor model shall provide an exchangeable and parametrizable radar signal processing chain, so that a signal processing can be incorporated like it is used in the target application, including resolution of data types and computation. The interfaces to the signal processing chain shall follow the ASAM Open Simulation Interface (ASAM OSI) specification. Due to the exchangeability, the processing can be also simplified e.g., to provide object lists based on the known ground truth of the simulated scenario and the received signal as given by R1.1_03_1), which allows to reduce the computational effort, if the fidelity of the result still satisfies the overall validation criteria.	The requirements ensure a proper radar signal processing chain.
R1.1_03_4	Radar sensor model - Clutter and interference modelling	The model shall provide an interface to parametrize effects of clutter and interference that can impact radar performance. It should consider factors such as ground clutter, atmospheric clutter, electromagnetic interference, and noise.	The requirement enables a proper and configurable clutter and interference modelling.
R1.1_03_5	Radar sensor	The model shall consider	The requirement

	model - Environmental effects	environmental factors that can affect radar performance, such as weather conditions (rain, fog), terrain variations, and multipath effects. It shall simulate these effects to accurately represent real-world scenarios.	enables a proper consideration of environmental influences.
R1.1_03_6	Radar sensor model - Data output and visualization	The model shall provide data output in the ASAM Open Simulation Interface (OSI) format that can be easily interpreted and visualized. It should generate information such as object positions, velocities, sizes, and classification if applicable.	The requirement ensures a proper implementation of the ASAM OSI.
R1.1_03_7	Radar sensor model - Real-time performance	The radar sensor model shall be designed to achieve real-time performance in the simulation environment. It shall be able to process radar signals and generate output data within the desired time constraints.	The requirement ensures real-time performance of the radar sensor model.
R1.1_03_8	Radar sensor model - Calibration and configurability	The model shall allow for calibration and configuration of various parameters to match the characteristics of the specific radar sensor being modelled. This includes options to adjust sensitivity, noise levels, detection thresholds, and other relevant settings.	The requirement ensures proper configuration and calibration capabilities.
R1.1_03_9	Radar sensor model - Compatibility and integration	The radar sensor model shall be interoperable with simulation environments following the open simulation specification.	The requirement enables a proper integration of the radar sensor model into various simulation environments.
R1.1_04_01	Camera model - resolution	The camera sensor model shall provide a resolution of 1.7 MP (1820 x 940).	Ensure to be able to simulate a sensor able to replicate a real camera (Continental's MFC527 was taken as reference).
R1.1_04_02	Camera model - Horizontal FoV	The camera sensor model shall provide a horizontal field of view 110°.	
R1.1_04_03	Camera model – Vertical FoV	The camera sensor model shall provide a vertical field of view 47°.	
R1.1_04_04	Camera model - Frequency	Video data rate shall run at 2x16 fps.	
R1.1_04_05	Camera model - Algorithm	The camera sensor model shall include ISP and camera control.	

R1.1_04_06	Camera model - pose	The camera sensor model shall be installed in a bracket behind the windscreen.	
R1.1_04_07	Camera model - Data format and exchange	The camera model shall deliver an output image to a middleware that will insure the transition to other subsystems. An image shall be in NV12 format.	
R1.1_05_01	LiDAR model – Protection rating	Protection rating: the LiDAR shall be mounted on the outside of the vehicle and shall be able to withstand ambient dirt and various weather conditions.	Ensure the high fidelity of the simulation LiDAR model in representing the real LiDAR sensor provided by partners in this use case.
R1.1_05_02	LiDAR model - Frequency of data delivery	The measurements obtained by the LiDAR shall be sent to the vehicle's processing system with sufficient frequency so that the information available to the vehicle is as recent as possible. As a standard, a frequency of 10Hz is assumed to be sufficient.	
R1.1_05_03	LiDAR model – Minimum safe distance	The minimum safe distance at which objects shall be detected should be detected shall be defined depending on the operating speed of the car and its dynamics, so that braking can be initiated in time to avoid collision with the obstacle. For velocities lower than 40kph, a minimum safe distance of 40m is calculated.	
R1.1_05_04	LiDAR model – Density of information	The LiDAR shall have at least the number of layers necessary for there to be detections at least at the minimum safe distance.	
R1.1_05_05	LiDAR model – Field of view	The selected LiDAR shall provide 360° visibility around the vehicle on which it is mounted and have a vertical field of view sufficient to cover at least the full height of the vehicle throughout the detection range. [0-2m height, 0-40m distance].	
R1.1_05_06	LiDAR model – Mounting point	The mounting point of the LiDAR on the vehicle is determined by the FOV of the sensor and the geometry of the car. It shall be mounted in such a way as to maximize the detection area around the vehicle, avoiding that the vehicle itself generates shadows in the obtained point cloud. Normally the most suitable position for this is the mounting in	

		the centre of the roof, at a height that ensures adequate vertical coverage of the navigation space (not too high, so that the central area of the LiDAR, which has more density of points, is at the height of the possible vehicles that may be on the road), while trying to avoid the loss of layers because these emit on the sheet metal of the vehicle (if it is placed too low, the lower layers of the LiDAR are lost, generating shadows on the skirts of the car and preventing the visibility of small objects very close to the car).	
R1.1_05_07	LiDAR model – Specific model for physical testing	The specific LiDAR model that is used for physical testing shall fulfil all the abovementioned LiDAR-related requirements (e.g., the Velodyne LiDAR Puc VLP-32C).	
R1.1_06_01	ODD's scenery description – Drivable area types	The drivable area types shall fall in one of the following categories: minor roads or outdoor parking.	Ensure that all types of sceneries that can be encountered in the DF's ODD are covered by the test scenarios.
R1.1_06_02	ODD's scenery description – Excluded drivable area types	Motorways, radial roads, and distributor roads shall not be a type of drivable areas.	
R1.1_06_03	ODD's scenery description – Lane types	The lane types shall be "traffic lane".	
R1.1_06_04	ODD's scenery description – Excluded lane types	Bus, lane, cycle lane, tram lane, emergency lane shall not be types of lanes.	
R1.1_06_05	ODD's scenery description – Direction of travel	The driving shall be done on the right-hand side of the roads.	
R1.1_06_06	ODD's scenery description – Excluded direction of travel	Driving on the left side of the road shall not happen.	
R1.1_06_07	ODD's scenery	The drivable area surface conditions shall fall in one of the	

	description – Drivable area surface conditions	following categories: dry or wet road.
R1.1_06_08	ODD's scenery description – Excluded drivable area surface features	Cracks and swells shall not be features of the drivable surfaces.
R1.1_06_09	ODD's scenery description – Road surface types	The road surface type shall fall in one of the following categories: segmented or uniform.
R1.1_06_10	ODD's scenery description – Horizontal planes	The horizontal planes shall fall in one of the following categories: straight roads or curved roads.
R1.1_06_11	ODD's scenery description – Vertical planes	The vertical planes shall fall in one of the following categories: up-slope, down-slope, or level plane.
R1.1_06_12	Simulation "ODD/Scenery" description – Transverse planes	The transverse planes shall fall in one of the following categories: undivided or pavements.
R1.1_06_13	ODD's scenery description – Excluded transverse planes	The barriers on the edges shall not be transverse planes.
R1.1_06_14	ODD's scenery description – Drivable area surfaces	The drivable area surface type shall either be asphalt or concrete.
R1.1_06_15	ODD's scenery description – Excluded drivable area surfaces	Cobblestone, gravel, and granite setts shall not be drivable areas.
R1.1_06_16	ODD's scenery description - Drivable area signs	The drivable area signs shall fall in one of the following categories: regulatory, warning, and information

R1.1_06_17	ODD's scenery description – Traffic information signs	The traffic information signs shall be full-time traffic lights full-time.	
R1.1_06_18	ODD's scenery description - Intersections	The intersections shall fall in one of the following categories: T-junctions, Y-junctions, crossroads, and roundabouts.	
R1.1_06_19	ODD's scenery description – Special structures	The special structures shall fall in one of the following categories: tunnels, bridges, toll plazas and pedestrian crossings.	
R1.1_07_01	ODD's atmospheric conditions description - Wind	The wind shall fall in one of the following categories: no wind, calm, light air, light breeze, or gentle breeze.	Ensure that the DF is tested against all the possible atmospheric conditions, including the nominal and the adverse conditions, during the test scenarios.
R1.1_07_02	ODD's atmospheric conditions description – Excluded rainfall	Violent rain and cloudburst shall not be options to describe the rainfall.	
R1.1_07_03	ODD's atmospheric conditions description - Particles	The particles shall be non-precipitating water droplets.	
R1.1_07_04	ODD's atmospheric conditions description - Illumination	The illumination shall fall in one of the following categories: day, night, cloudiness, fog, or artificial illumination.	
R1.1_08_01	ODD's Dynamic elements – Agent types	The agent types shall fall in one of the following categories: bikes, pedestrians, motos, trucks, or vehicles.	Ensure that relevant categories of the traffic agents are covered by the test scenarios.
R1.1_08_02	ODD's Dynamic elements – Excluded special agents	Ambulances and police vehicles shall not be.	
R1.1_09	ADS behaviour manoeuvres	The ADS shall be tested on the following manoeuvres: Maintain speed car following, lane centring, follow driving laws, navigate roundabouts, navigate intersections, route planning, collision avoidance, emergency braking.	Ensure that all relevant possible manoeuvres of the other subject vehicle are covered by the test scenarios.

R1.1_10_01	SuT required safe behaviour for the validation – Obstacles while starting	When starting the AV, the perception system shall check if there are any obstacles before moving forward. If an obstacle is present, the vehicle shall wait until it is gone.	Provide a description of the acceptable safe behaviour from the ADS, it also allows to derive the proper criticality metrics and KPIs for the assessment of the scenarios.
R1.1_10_02	SuT required safe behaviour for the validation – Speed limits	AV shall follow speed limits in the area and reduce speed when approaching an intersection.	
R1.1_10_03	SuT required safe behaviour for the validation - Stops	When arriving to a stop, the AV shall recognise it and stop.	
R1.1_10_04	SuT required safe behaviour for the validation – Awareness of other traffic agents	Before moving forward, the perception system shall check the presence of any other obstacles in any direction. Distance and speed to obstacles are needed to check if there is time/space to move safely.	
R1.1_10_05	SuT required safe behaviour for the validation – Giveaway speed	When arriving to a giveaway, the AV shall recognise it and reduce its speed.	
R1.1_11_01	Perception DF required detections	The perception DF shall be able to: • Detect the relevant static obstacles in the ego-lane. • Provide the position, distance, and velocity of the detections with a high confidence level. • Detect the relevant cyclists and pedestrians, including semi-occluded and crossing ones. • Oncoming vehicles. • Speed limit changes. • Relevant stopped vehicles. • Maintain a safe behaviour in presence of adverse	Provide a description of the acceptable safe behaviour from the ADS, it also allows to derive the proper criticality metrics and KPIs for the assessment of the scenarios.

		• weather conditions despite a reduced performance. • Run in real time.	
R1.1_11_02	Perception DF required detections – Camera-detected traffic agents	Camera model shall deliver an object list with 2D positions of the objects in an image plane with the corresponding bounding box and object class.	
R1.1_11_03	Perception DF required detections – Camera-detected road boundaries	Camera model shall deliver an object list containing road boundaries (lane detection function) with their coordinates, type of line and number of lanes.	
R1.1_12_01	Generated scenarios requirements - Weather	The collection of validation scenarios shall include adverse weather conditions affecting the perception system.	Provide a baseline for the selection of the test scenario (from the GSR and the EURO NCAP) and allows for the sorting of relevant test scenario to test the corner cases of the DF.
R1.1_12_02	Generated scenarios requirements - Roads	The collection of validation scenarios shall include urban intersections, narrow roads, and 2 lanes-roads (maximum).	
R1.1_12_03	Generated scenarios requirements – User interactions	The collection of validation scenarios shall include interactions between VRUs and other vehicles, including situations where occlusions cause one (or more) sensor to not capture a certain user while another sensor does see it. EURO NCAP intersection scenarios shall be used as the basis to validate the requirements imposed onto the perception system.	
R1.1_13_01	ADS Functional safety assessment – ISO26262	Apply ISO26262 shall be applied and the possible hazards and risks shall be analysed and assessed.	Apply traditional approach to validate the functional safety of the ADS prior to the full ODD exploration and coverage.
R1.1_13_02	ADS Functional safety assessment – ISO21448	The ISO21448 shall be applied and the safety in use (SOTIF) shall be analysed.	
R1.1_13_03	ADS Functional safety assessment - (EU) 2019/2144	The EU General Safety Regulation (EU) 2019/2144 shall be applied and the compliance to the applicable safety regulations shall be analysed.	
R1.1_14	Validation of the test framework	A comparison between the ADS behaviour in the virtual environment and in physical tests	Ensures the fidelity of the virtual validation framework to the real

		shall be performed to confirm the robustness and representativeness of the virtual validation framework.	world and the real performance of the ADS/DF by having the real-world data as main baseline for this assessment.
R1.1_16	Test scenario manager	The simulation framework shall be able to read as input a scenario description file in OpenScenraio format and generate a corresponding scenario environment.	
R1.1_17	Vehicle dynamics – Sensor position	The vehicle model shall be able to adapt to a specified sensor position.	
R1.1_18	Controllability of the traffic agents	The traffic agents shall be able to perform a specified manoeuvre on request of the scenario generator.	
R1.1_20	AD function behaviour	The subject vehicle shall perform driving tasks in a convenient manner independently from the perception under test.	
R1.1_21	Vehicle dynamics	The system under test shall be able to perform up to 70 kph.	
R1.1_22	Environment - Landscape category	The simulation environment shall visually represent an urban environment.	
R1.1_23	Environment - Photo-realism	Image rendering quality produced by the environment shall be sufficiently photorealistic to admit the camera perception functions perform as in real environment.	
R1.1_24	Simulation model validation – Photo-realism checks	An image rendering quality check shall be performed to evaluate the realism of the simulation environment.	
R1.1_25	Simulation model validation - Control of traffic agents	The framework shall contain a module dedicated to verifying that the executed simulations correspond to the requests from the scenario manager.	
R1.1_26	SuT configuration manager	There shall be a configuration interface allowing the user to configure at least the sensor position and its basic parameters.	
R1.1_27	Data manager - Data storage	The framework shall be able to store at least 1 hour of video data from the camera.	
R1.1_28	Test assessment - Metrics	There shall be a module dedicated to analysing the scenario results and generating a metric that	

		allows to evaluate the test coverage.	

Table 4. Requirements of sub-UC 1.2

Requirement number	Name	Description	Rational
R1.2_01	Validation metrics and KPIs compliance	The validation metrics and KPIs shall comply with the EURO NCAP and GSR requirements	
R1.2_02_01	Simulation Scenery description – Drivable area types	All drivable areas shall fall in one of the following categories: distributor roads, or minor roads.	
R1.2_02_02	Simulation Scenery description – Excluded drivable areas	Motorways, and radial roads shall not be drivable areas.	
R1.2_02_03	Simulation Scenery description – Horizontal planes	All horizontal planes shall fall in one of the following categories: straight roads, or curved roads.	
R1.2_02_04	Simulation Scenery description – Vertical planes	All vertical planes shall fall in one of the following categories: up-slope, down-slope, or level plane.	
R1.2_02_05	Simulation Scenery description – Transverse planes	All transverse planes shall fall in one of the following categories: divided roads, pavements, or barriers on the edges.	
R1.2_02_06	Simulation Scenery description – Lane specification	All roads shall have at least one lane of at least 3.5 m width.	
R1.2_02_07	Simulation Scenery description – Lane type	All lanes shall be of type “traffic lane”.	
R1.2_02_08	Simulation Scenery description – Direction of travel	The driving shall be done on the right-hand side of the roads.	
R1.2_02_09	Simulation Scenery	Bus lane, cycle lane, tram lane, and emergency lane shall not be drivable	

	description – Excluded drivable lanes	lane types.	
R1.2_02_10	Simulation Scenery description – Drivable area signs	All drivable area signs type shall fall in one of the following categories: regulatory, warning, or information.	
R1.2_02_11	Simulation Scenery description – Drivable area edge types	All drivable area edge types shall fall in one of the following categories: line markers, shoulder, none, solid barriers, or temporary line markers.	
R1.2_02_12	Simulation Scenery description – Drivable area surfaces	All drivable area surfaces shall be either asphalt or concrete.	
R1.2_02_13	Simulation Scenery description – Excluded drivable area surfaces	Cobblestone, gravel, and granite setts shall not be a type of drivable area surfaces.	
R1.2_02_14	Simulation Scenery description – Drivable area signs	All drivable area signs shall be either full-time traffic lights, or variable traffic signs.	
R1.2_02_15	Simulation Scenery description – Junction types	All junctions shall fall in one of the following categories: intersections, signalized, or non-signalized.	
R1.2_02_16	Simulation Scenery description – Intersection types	All intersections shall fall in one of the following categories: T-junctions, staggered, crossroads]. Excluded junctions are [roundabouts, or Y-junction.	
R1.2_02_17	Simulation Scenery description – Special structure types	The only special structure shall be pedestrian crossings	
R1.2_02_18	Simulation Scenery description – Excluded special structures	automatic access control, tunnels, bridges, toll plaza, buildings, street lights, street furniture, vegetation shall not be categories of special structures	
R1.2_03_01	Atmospheric conditions	The wind most be from 0 up to 5 m/s (from calm to a gentle breeze).	

	description – Wind		
R1.2_03_02	Atmospheric conditions description – Illumination	The illumination shall be one of the following types: day, cloudiness, artificial illumination, or night.	
R1.2_03_03	Atmospheric conditions description – Excluded conditions	Rainfall, snowfall, and fog shall not be atmospheric conditions	
R1.2_03_04	Atmospheric conditions description – Connectivity	The connectivity in the simulation shall be V2X communication (DSRC, ITS-G5).	
R1.2_04_01	Included dynamic elements	All agents shall fall in one of the following categories: vehicles, trucks, or vulnerable road users.	
R1.2_04_02	Excluded dynamic elements	Ambulances and police vehicles shall not be agents.	
R1.2_05	ADS behaviour manoeuvres	All basic longitudinal manoeuvres shall be supported (speed keeping, braking, and accelerating). The reversing manoeuvre is not required.	The function shall be capable of driving in proximity of urban intersections with RSUs and handle situations of traffic lights adaptation, car following, pedestrian crossing thanks to the combination of sensors and V2X information.
R1.2_06_01	SuT required behaviour for the validation – ACC+GLOSA	Whenever the subject vehicle is approaching an urban intersection with ACC and GLOSA and there are no obstacles in front of it, the subject vehicle shall adapt its speed based on the SpaT and MAP messages that include traffic light phases, timing and map information.	
R1.2_06_02	SuT required behaviour for the validation – Orthogonal crossing VRU	Given a situation like the one described in R1.2_06_01, if the subject vehicle receives a DENM informing of a VRU violating an orthogonal red traffic light, the subject vehicle shall be able to take it into account if it affects its planned trajectory.	
R1.2_06_03	SuT required behaviour for the validation – Crossing VRU	Given a situation like the one described in R1.2_06_01, when the SpaT message content resets due to a VRU crossing the street, the subject vehicle shall be able to stop, since the	

		planned phase changed, and the traffic light remains red.	
R1.2_06_04	SuT required behaviour for the validation – Red traffic light violation	Given a situation like the one described in R1.2_06_01, the subject vehicle shall be able to stop to avoid an impact with another vehicle who violated a red light. The subject vehicle shall receive CAM from the vehicle who is violating the red light.	
R1.2_07	Perception DF requirements	The perception data function shall be able to: • Detect ODD boundary transitions. • Detect relevant static and dynamic obstacles. • Provide the position, distance and velocity of the detected obstacles via sensors and V2X. • Detect traffic light phases, timing and map information included in SpaT and MAP messages. • Detect VRUs included in DENM messages. • Maintain a safe behaviour under adverse weather conditions.	
R1.2_08_01	Scenario description - Environment	Adverse weather conditions affecting the connected perception system shall be considered	
R1.2_08_02	Scenario description - Roads	Urban intersections are the type of roads that shall be generated.	
R1.2_08_03	Scenario description – User interactions	VRUs shall be considered, including those that are not captured from specific sensors.	
R1.2_08_04	Scenario description - Scenarios	The EURO NCAP scenarios containing intersections shall be the basis to validate the requirements imposed onto the connected perception system.	
R1.2_09_01	ADS Functional safety assessment – ISO26262	The ISO26262 shall be applied and the possible hazards and risks shall be analysed and assessed.	
R1.2_09_02	ADS Functional safety assessment – ISO21448	The ISO21448 shall be applied and the safety in use (SOTIF) shall be analysed.	

R1.2_09_03	ADS Functional safety assessment – (EU) 2019/2144	The EU General Safety Regulation (EU) 2019/2144 shall be applied and the compliance to the applicable safety regulations shall be analysed.	
R1.2_10	Validation of the test framework with both virtual and real data	A combination of physical and virtual testing shall be used to validate the systems and ensure correlation between virtual and real results. The validation shall start in the virtual environment using a prototype of the software, traffic flow simulations, diverse conditions and sensor and vehicle models. That will provide an understanding of the performance of the algorithms in terms of latencies and KPIs and allow to tune the necessary parameters. After the virtual testing, the developed algorithms shall be tested in the physical world, in a proving ground with traffic infrastructure. Finally, a comparison shall be done between the results obtained in the virtual tests and the results obtained in the physical tests to confirm the robustness and representativeness of the simulated approach.	

Table 5. Requirements of sub-UC 1.3

Requirement number	Name	Description	Rational
R1.3_01	Validation of the test framework – Combination of virtual and real data	A combination of physical and virtual testing shall be used to validate the systems and ensure correlation between virtual and real results. Ground truth data extracted from the simulations and available data sets shall be used together with real measurements to ensure the accuracy, robustness, and representativeness of the virtual validation.	
R1.3_02	Validation of the test framework – SIL and	Virtual testing shall include SIL and CoSim methods.	

	CoSim		
R1.3_03	Validation of the test framework – Hybrid VIL	Hybrid VIL testing including physical testing with a connected vehicle in parallel to a virtual scenario executed on the cloud, if supported, requires a PG with V2C connectivity.	
R1.3_04	Validation of the test framework – CPM data from other road users	Simulated CPM data coming from other road users in the vicinity of the subject vehicle shall be included in the validation process.	
R1.3_05	Validation of the test framework – CPM data from sRSUs	Simulated CPM data coming from sRSUs shall be included in the validation process.	
R1.3_06	Validation of the test framework – Annotated data usage	Annotated recorded data or simulated object-level data (including uncertainties) derived from the perception layer of the subject vehicle and other vehicles in the vicinity shall be included in the validation process.	
R1.3_07	ODD's scenery description	The scenery shall include B-roads straight road segments, urban unsignalized intersections and urban roundabouts. The road/lanes geometry shall be composed of straight roads without physical separation between traffic directions (i.e., "undivided" roads) joining at an intersection and possibly having pedestrian crossing structures. There shall be at least one lane per driving direction, with good quality lane markings (both solid and dashed). The roadway edge shall be line-marked, and the road surface shall be uniform (asphalt).	Ensure that all types of sceneries that can be encountered in the ADS's ODD are covered by the test scenarios.
R1.3_08	ODD's atmospheric conditions description	The ADS shall be tested against the presence of calm wind and light or moderate rain, under daytime illumination conditions and irrespective of cloudiness or position of the sun.	Ensure that the ADS is tested against all the possible atmospheric conditions, including the nominal and adverse conditions, during the test scenarios.

R1.3_09	ODD's dynamic elements and their behaviours	The simulation shall support ODDs of at least low flow rates and presence of VRUs, especially pedestrians, as detectable objects. Other road users can be passenger cars, busses, trucks, and pedestrians. The maximum speed of the subject vehicle shall be 50km/h. Excluded zones and conditions are roadwork zones, heavy rain, and flooded or snowy roads.	Ensure that relevant possible manoeuvres of the other traffic agents are covered by the test scenarios.
R1.3_10	Test scenario manager – Compatibility with OpenScenario	The simulation framework shall be able to read as input a scenario description file in the OpenScenario format and generate a corresponding scenario environment.	
R1.3_11_01	ADS functional safety assessment - ISO21448	The ISO21448 shall be applied and the safety in use (SOTIF) shall be analysed.	Apply well-established approaches to validate the functional safety of the ADS prior to the full ODD exploration and coverage.
R1.3_11_02	ADS functional safety assessment - (EU) 2019/2144	The EU General Safety Regulation (EU) 2019/2144 shall be applied and the compliance to the applicable safety regulations shall be analysed.	

8.2 Requirement tables for UC 2

Table 6. Requirements of UC 2

Requirement number	Name	Description
R2.1_01	Basic Feature Requirements	If the ADS is activated, the feature shall perform the DDT.
R2.1_02		If the ADS is activated, the feature shall not cause any collisions that are reasonably foreseeable and preventable.
R2.1_03		If the ADS is activated and if a collision can be safely avoided without causing another one, the feature shall avoid the collision.
R2.1_04		If the ADS is activated, the feature shall comply with traffic rules relating to the DDT in the country of operation, including responding to emergency/enforcement vehicles.

R2.1_05	DDT/OEDR	If the ADS is activated, the feature shall keep the vehicle inside its lane of travel and ensure that the vehicle does not unintentionally cross any lane marking (outer edge of the front tyre to outer edge of the lane marking).
R2.1_06		The ADS shall aim to keep the vehicle in a stable lateral and longitudinal motion inside the lane of travel to avoid confusing other road users.
R2.1_07		If the ADS is activated, the feature shall control the speed of the vehicle.
R2.1_08		If the ADS is activated, the feature shall be able to detect the distance to the next vehicle in front.
R2.1_09		If the ADS is activated, the feature shall adapt the vehicle speed to adjust a safe following distance to avoid a collision.
R2.1_10		If the ADS is activated and for operating speeds above 60 km/h, the feature shall comply with minimum following distances in the country of operation.
R2.1_11		If the ADS is activated, the feature shall detect the risk of collision with another road user ahead or beside the vehicle, due to a decelerating lead vehicle, a cutting in vehicle or a suddenly appearing obstacle.
R2.1_12		If the ADS is activated, the feature shall automatically perform appropriate manoeuvres to minimize risks to safety of the vehicle occupants and other road users.
R2.1_13		If there's an imminent collision risk, the ADS shall carry out an emergency manoeuvre.
R2.1_14		If the ADS is activated, the feature shall recognize all situations in which it needs to transition the control back to the driver.
R2.1_15	Vehicle Dynamics Data	Basic Vehicle Parameters shall be provided. (e.g., dimensions, weight distribution)
R2.1_16		Measurement data shall be provided for creating a digital twin of the test vehicle (e.g., steering system, powertrain, wheels, brakes, suspension, chassis controls, etc.)
R2.1_17		A 3D Vehicle Body Model shall be created for visualization (e.g., in Unreal Engine / CARLA)
R2.1_18	Scenario Data	ODD Definition shall be used for creating the scenario ontology.
R2.1_19		OpenSCENARIO files shall be used for scenario definition and simulation execution which are created from the ontology.
R2.1_20		Manoeuvre Catalogue shall be provided for proving ground tests.
R2.1_21	Road Data	OpenDRIVE file of the proving ground shall be created to correlate measurements with simulation, road pavement surface data.

R2.1_22		OpenDRIVE files for synthetic road models for simulation shall be created with parametric variations in lane width, curvature, road markings etc.
R2.1_23		Pavement surface data for synthetic road models for simulation shall be created with parametric variations in longitudinal and lateral roughness.
R2.1_24	Sensor Data	Environment sensor specifications shall be determined
R2.1_25		Sensor layout on vehicle body shall be determined
R2.1_26		Sensor models shall generate object list data.
R2.1_27	ADS functional safety assessment	In case of feature activation, ADS shall keep the vehicle in the lane markings.
R2.1_28		Obstacles position, distance and speed shall be perceived in real time with acceptable delays.
R2.1_29		The ADS shall be capable of detecting speed limit signs or receiving speed limit information from map data.
R2.1_30		The ADS shall be able to perform all the longitudinal manoeuvres (speed keeping, braking, accelerating, etc.) except reversing.
R2.1_31		The ADS shall be capable to control the longitudinal movement of the vehicle except reversing to adapt the velocity.
R2.1_32		The ADS shall adapt its speed to slower vehicles ahead driving on same lane by keeping the safety distance in case of lower speeds than subject vehicle.
R2.1_33		The ADS shall adapt its speed according to road slope and curvature received.
R2.1_34		ADS MRM – Fail-safe solutions in case of failure in the system shall be provided.
R2.1_35	Scenario description/generation	This UC targets the original UN-R 157 with a maximum speed of 60 km/h.
R2.1_36		Apart from the regulation, the scenario include lane keeping while various curve driving.
R2.1_37		The test cases shall cover the complete ODD and DDT (based on the regulation) through ontology approaches and smart scenario generation methods (e.g., combinatorial testing).
R2.1_38	Test framework (methods/tools/data)	Test vehicle shall be fully equipped with the complete system to execute consecutive proving ground tests.
R2.1_39		Vehicle shall be equipped with a perception system, e.g., camera, able to detect and track vehicles and trucks and lane markings in a range of around 100 ms.
R2.1_40		Vehicle shall be equipped with a map system (e.g., eHorizon or HERE maps) able to provide road information within a specific horizon regarding curvature, slope, etc.
R2.1_41		Vehicle shall be equipped with ACC system, compliant with the corresponding reference standard.

R2.1_42		Physical vs. virtual testing: the amount of proving ground tests depends on the model correlation quality.
R2.1_43		The simulations shall be real-time capable and deterministic.
R2.1_44		Safety KPIs shall include: TTC, acceleration and deceleration (lateral and longitudinal), vehicle speed.
R2.1_45		Simulation framework should be capable to simulate real world simulations, including controller performance and environmental conditions.
R2.1_46		There should be a built-in scenario management tool to allow manual selection and parametrization of test cases.
R2.1_47		A cloud computing interface shall be available to be able to run parallel simulations.
R2.1_48		Middleware for integrating various models and software tools (CAN, FMU, ROS, Python, etc.).
R2.1_49		Simulation model output shall correlate with physical measurements, expressed by correlation and error KPIs such as R2, RMSE or correlation coefficients.
R2.1_50		The simulation shall have a proven deterministic behaviour and repeatable results.
R2.1_51	KPI dashboard requirements	KPI dashboard for easy and quick evaluation and reporting of results.
R2.1_52		The KPI dashboard should be configurable and adaptable, e.g., the type of KPIs and their thresholds.
R2.1_53_01	ODD's scenery description – Drivable areas	Drivable areas shall be of type "motorways".
R2.1_53_02	ODD's scenery description – Excluded drivable areas	Radial roads, distributor roads, minor roads, slip roads, parking, and shared spaces shall not be drivable areas.
R2.1_53_03	ODD's scenery description – Horizontal planes	All horizontal planes shall fall in one of the following categories: straight roads, or curved roads.
R2.1_53_04	ODD's scenery description – Vertical planes	All vertical planes shall fall in one of the following categories: up-slope, down-slope, or level plane.
R2.1_53_05	ODD's scenery description - Transverse planes	All transverse planes be "divided roads".
R2.1_53_06	ODD's scenery description – Excluded transverse planes	Barriers on the edges shall not be transverse planes.

R2.1_53_07	ODD's scenery description – Lane width	The lane width shall be determined.
R2.1_53_08	ODD's scenery description -	The lane type shall be "traffic lane".
R2.1_53_09	ODD's scenery description – Excluded lane types	Bus lane, cycle lane, tram lane, emergency lane, and special purpose lane shall not be lane types.
R2.1_53_10	ODD's scenery description – Direction of travel	The driving shall be done on the right-hand side of the roads.
R2.1_53_11	ODD's scenery description – Drivable area surfaces	All drivable area surfaces shall be either asphalt or concrete.
R2.1_53_12	ODD's scenery description – Drivable area signs	All drivable area signs shall fall in one of the following categories: regulatory, warning, information, or full time.
R2.1_53_13	ODD's scenery description – Drivable area edges	All drivable area edges shall be either solid lines or curbs.
R2.1_53_14	ODD's scenery description – Excluded drivable area edges	Broken and temporary lines, paved/grass/gravel shoulders, grating, rails, cones, and solid barriers shall not be drivable area edges.
R2.1_53_15	ODD's scenery description – Excluded junctions	Roundabouts, and intersections shall not be junctions.
R2.1_53_16	ODD's scenery description – Special structures	Bridges shall be special structures
R2.1_53_17	ODD's scenery description – Excluded temporary road structures	Construction detours, road works, road signages, and refuse collections shall not be temporary road structures.
R2.1_54_01	ODD's atmospheric conditions description - Wind	The wind speed shall be determined.
R2.1_54_02	ODD's atmospheric	Heavy or violent rain or cloudburst shall not be rainfall.

	conditions description – Excluded rainfall	
R2.1_54_03	ODD’s atmospheric conditions description - Particles	The particles shall be mist or fog.
R2.1_54_04	ODD’s atmospheric conditions description - Illumination	The illumination shall be either day or artificial illumination.
R2.1_54_05	ODD’s atmospheric conditions description – Excluded illumination	Night or low shall not be illumination options.
R2.1_55_01	ODD’s dynamic elements – Agent types	All agents should be either two-wheelers or vehicles.
R2.1_55_02	ODD’s dynamic elements – Excluded agent types	Bicycles, pedestrian, animals, and special vehicles (e.g., ambulances) shall not be agent types.
R2.1_55_03	ODD’s dynamic elements – Agent speed limit	The agent speed limit shall be 15 Km/h.

8.3 Requirement tables for UC 3

Table 7. Requirements of sub-UC 3.1

Requirement number	Name	Description
R3.1_01	Validation metrics and KPIs	The validation metrics shall comply with the EURO NCAP and GSR requirements
R3.1_02_01	ODD’s scenery description – Drivable areas	All drivable areas shall be motorways.
R3.1_02_02	ODD’s scenery description – Lane types	All lanes shall be traffic lanes.
R3.1_02_03	ODD’s scenery description – Direction of travel	The driving shall be done on the right-hand side of the roads.
R3.1_02_04	ODD’s scenery	There shall be at least two lanes.

	description – Minimum number of lanes	
R3.1_02_05	ODD's scenery description – Lane width	The lanes shall be less than 3.5 m wide.
R3.1_02_06	ODD's scenery description – Drivable area conditions	All drivable area surface conditions shall be either dry or wet.
R3.1_02_07	ODD's scenery description – Drivable area features	All drivable area surface features shall fall in one of the following categories: cracks or swells.
R3.1_02_08	ODD's scenery description – Road surfaces	All road surface types shall fall in one of the following categories: segmented or uniform.
R3.1_02_09	ODD's scenery description – Horizontal planes	All horizontal planes shall fall in one of the following categories: straight roads or curved roads.
R3.1_02_10	ODD's scenery description – Vertical planes	All vertical planes shall fall in one of the following categories: up-slope, down-slope, or level plane.
R3.1_02_11	ODD's scenery description – Transverse planes	All transverse planes shall be divided roads.
R3.1_02_12	ODD's scenery description – Lane types	All types of lanes together shall be traffic lanes.
R3.1_02_13	ODD's scenery description – Drivable area surfaces	All drivable area surfaces shall be either asphalt or concrete.
R3.1_02_14	ODD's scenery description – Drivable area signs	All drivable area signs shall fall in one of the following categories: regulatory, warning, or information.
R3.1_02_15	ODD's scenery description – Excluded traffic information signs	Traffic lights shall not be traffic information signs.
R3.1_02_16	ODD's scenery description – Special structures	All special structures shall be bridges.
R3.1_03_01	ODD's atmospheric conditions description - Wind	All wind shall fall in one of the following categories: no wind, calm, light air, light breeze, or gentle breeze.
R3.1_03_02	ODD's atmospheric conditions description – Excluded rainfall	Violent rain and cloudburst shall not be types of rainfall.

R3.1_03_03	ODD's atmospheric conditions description - Particles	All particulates shall be non-precipitating water droplets.
R3.1_03_04	ODD's atmospheric conditions description - Illumination	All illumination shall fall in one of the following categories: day or cloudiness.
R3.1_04_01	ODD's dynamic elements – Excluded agent types	Vulnerable road users, animals, and non-motor vehicles shall not be agent types.
R3.1_04_02	ODD's dynamic elements – Excluded special vehicles	There shall not be any special vehicles.
R3.1_04_03	ODD's dynamic elements – Minimum speed	The flow rate shall be at least 60 Km/h.
R3.1_04_04	ODD's dynamic elements – Maximum agent density	The density of agents shall be less than 185 agents per mile per lane.
R3.1_05	ADS safe behaviour	The system shall be capable of: • Controlling the longitudinal and lateral movement of the vehicle to adapt the velocity to speed limits and to keep the vehicle at the centre of its lane considering safety aspects based on information of curvature and in general road geometry coming from the maps. • Detecting lane markings surrounding it, which means to detect its lane. In case of missing or not detected lane markings or too wide lanes the system shall not operate. • Detecting and tracking other vehicles ahead on same lane, also possible cut-out manoeuvres. The system shall adapt its speed to slower vehicles ahead driving on same lane by keeping the safety distance in case of lower speeds than subject vehicle. Otherwise, the speed limit shall be respected. • Detecting and tracking vehicles on neighbouring lanes (also coming from behind) doing a cut-in manoeuvre. • Detecting speed limit signs or receiving speed limit information from map data. • Detecting the driver's state and always be overwritable by the driver. In case of any situation outside the operational design domain, any system error, or any hazard like unavoidable collision the system shall stop the vehicle or give control back to the driver if

		possible and in active mode, or otherwise not be able to be activated by the driver if inactive. Even if the system is deactivated it shall permanently check the environment to be able to detect any situation outside its ODD and to block its activation. In case the driver is not attentive the system shall bring the vehicle to a safe stop with activated hazard lights.
R3.1_06_01	Required scenarios to be validated – Adapt speed to new limit	The subject vehicle's speed shall be automatically adapted to the new speed limits (which can come from static or dynamic speed limit signs, or via V2I or HD maps). Several speeds, distances to speed limit and speed limit changes (reductions and increases) shall be tested. If the speed limit is lower than the speed set in the ACC (while it is active), the only action required to the driver is to accept the speed adaptation, otherwise the speed limit will be ignored.
R3.1_06_02	Required scenarios to be validated – Adapt speed to road curvature	The subject vehicle's speed shall be automatically adapted to the road curvature ahead. Different curvature values shall be teste. The minimum allowed speed shall be reached at the beginning of the curve and maintained for the whole curve length.
R3.1_07	Perception DF requirements	The perception DF shall: • Detect ODD boundary transition. • Detect speed limits. • Detect curvature from map perception. • Maintain a safe behaviour in presence of adverse weather conditions
R3.1_08	Generated scenarios requirements	The system shall be validated under adverse weather conditions affecting system under test. No user interaction is required. EURO NCAP highway scenarios shall be the basis for validation requirements imposed onto the highway AD system.
R3.1_10	Validation of the test framework with both virtual and real data	A combination of physical and virtual testing shall be used to validate the systems and ensure correlation between virtual and real results. The validation shall start in the virtual environment using a prototype of the software, traffic flow simulations, diverse conditions and sensor and vehicle models. That will provide an understanding of the performance of the algorithms in terms of latencies and KPIs and allow to tune the necessary parameters. After the virtual testing, the developed algorithms shall be tested in the physical world, in a proving ground with traffic infrastructure. Finally, a comparison shall be done between the results obtained in the virtual tests and the results obtained in the physical tests to confirm the robustness and representativeness of the simulated approach.

Table 8. Requirements of sub-UC 3.2

Requirement number	Name	Description
R3.2_01	Validation metrics and KPIs	The validation metrics and KPIs shall comply with the EURO NCAP and GSR requirements
R3.2_02_01	ODD’s scenery description – Drivable areas	All drivable areas shall be motorways.
R3.2_02_02	ODD’s scenery description – Lane types	All lanes shall be traffic lanes.
R3.2_02_03	ODD’s scenery description – Direction of travel	The driving shall be done on the right-hand side of the roads.
R3.2_02_04	ODD’s scenery description – Minimum number of lanes	There shall be at least two lanes.
R3.2_02_05	ODD’s scenery description – Lane width	The lanes shall be less than 3.5 m wide.
R3.2_02_06	ODD’s scenery description – Drivable area conditions	All drivable area surface conditions shall be either dry or wet.
R3.2_02_07	ODD’s scenery description – Drivable area features	All drivable area surface features shall fall in one of the following categories: cracks or swells.
R3.2_02_08	ODD’s scenery description – Road surfaces	All road surface types shall fall in one of the following categories: segmented or uniform.
R3.2_02_09	ODD’s scenery description – Horizontal planes	All horizontal planes shall fall in one of the following categories: straight roads or curved roads.
R3.2_02_10	ODD’s scenery description – Vertical planes	All vertical planes shall fall in one of the following categories: up-slope, down-slope, or level plane.
R3.2_02_11	ODD’s scenery description – Transverse planes	All transverse planes shall be divided roads.
R3.2_02_12	ODD’s scenery description – Lane types	All types of lanes together shall be traffic lanes.
R3.2_02_13	ODD’s scenery description – Drivable area surfaces	All drivable area surfaces shall be either asphalt or concrete.
R3.2_02_14	ODD’s scenery description – Drivable area signs	All drivable area signs shall fall in one of the following categories: regulatory, warning, or information.

R3.2_02_15	ODD's scenery description – Excluded traffic information signs	Traffic lights shall not be traffic information signs.
R3.2_02_16	ODD's scenery description – Special structures	All special structures shall be bridges.
R3.2_03_01	ODD's atmospheric conditions description - Wind	All wind shall fall in one of the following categories: no wind, calm, light air, light breeze, or gentle breeze.
R3.2_03_02	ODD's atmospheric conditions description – Excluded rainfall	Violent rain and cloudburst shall not be types of rainfall
R3.2_03_03	ODD's atmospheric conditions description - Particles	All particles shall be non-precipitating water droplets.
R3.2_03_04	ODD's atmospheric conditions description - Illumination	All illumination shall fall in one of the following categories: day or cloudiness.
R3.2_04_01	ODD's dynamic elements – Excluded agent types	Vulnerable road users, animals, and non-motor vehicles shall not be agent types.
R3.2_04_02	ODD's dynamic elements - Connectivity	The communication shall be V2X, including DSRC and ITS-G5.
R3.2_04_03	ODD's dynamic elements – Excluded special vehicles	There shall not be any special vehicles.
R3.2_04_04	ODD's dynamic elements – Minimum speed	The flow rate shall be at least 60 Km/h.
R3.2_04_05	ODD's dynamic elements – Maximum agent density	The density of agents shall be less than 185 agents per mile per lane.
R3.2_05	ADS safe behaviour	The system shall be capable of: • Controlling the longitudinal and lateral movement of the vehicle to adapt the velocity to speed limits and to keep the vehicle at the centre of its lane considering safety aspects based on information of curvature and in general road geometry coming from the maps. • Detecting lane markings surrounding it, which means to detect its lane. In case of missing or

		not detected lane markings or too wide lanes the system shall not operate. • Detecting and tracking other vehicles ahead on same lane, also possible cut-out manoeuvres. The system shall adapt its speed to slower vehicles ahead driving on same lane by keeping the safety distance in case of lower speeds than subject vehicle. Otherwise, the speed limit shall be respected. • Detecting and tracking vehicles on neighbouring lanes (also coming from behind) doing a cut-in manoeuvre. • Detecting speed limit signs or receiving speed limit information from map data. • Detecting the driver's state and always be overwritable by the driver. In case of any situation outside the operational design domain, any system error, or any hazard like unavoidable collision the system shall stop the vehicle or give control back to the driver if possible and in active mode, or otherwise not be able to be activated by the driver if inactive. Even if the system is deactivated it shall permanently check the environment to be able to detect any situation outside its ODD and to block its activation. In case the driver is not attentive the system shall bring the vehicle to a safe stop with activated hazard lights. • Communicating with other road users using V2X messages (e.g., CAM or DENM) for cooperative perception and share its perception or map information.
R3.2_06_01	Required scenarios to be validated – Cooperative ACC	The following four (4) scenarios will be used to rate the cooperative perception of the HWP system: The following scenario shall be included in the validation: The subject vehicle is driving in highway, it detects a cooperative vehicle ahead on the same lane through V2X CAM messages and decide to turn the cooperative ACC setting the speed accordingly with the vehicle in front even if it is obstructed by other no cooperative vehicle in the middle with a higher speed. The detection of the target vehicles through V2X CAM messages on the same ego lane shall be tested.
R3.2_06_02	Required scenarios to be validated – Deceleration of leading vehicle	The following scenario shall be included in the validation: The subject vehicle is driving in highway; it detects a cooperative vehicle ahead on the same lane through V2X CAM messages and it decides to turn on the cooperative ACC and set the speed accordingly with the vehicle in front even if it is obstructed by other faster and no cooperative vehicle in the middle. The ACC is controlling the distance through radar sensing. The preceding vehicle cut-outs, the subject vehicle decelerates knowing that the cooperative vehicle is decreasing speed. The V2X communication this

		scenario is similar to the deceleration and cut-out scenario from the regulation UN-R No. 157 for ALKS.
R3.2_06_03	Required scenarios to be validated – Cut-in ego-lane	The following scenario shall be included in the validation: The subject vehicle is driving in highway with cooperative ACC turned on, it detects a cooperative vehicle on the next lane that wants to perform a cut-in. The subject vehicle accepts to decelerate opening a gap with the vehicle in front. The V2X communication this scenario is similar to the cut-in scenario from the regulation UN-R No. 157 for ALKS.
R3.2_06_04	Required scenarios to be validated – Vehicle control loss	The following scenario shall be included in the validation: The subject vehicle is driving in highway with cooperative ACC turned on, it detects a cooperative vehicle on the same lane. The subject vehicle receives a CAM (or DENM) that informs that the vehicle has the ESC/ABS triggered and is losing control. The subject vehicle decides to perform a harsh brake manoeuvre.
R3.2_07	Perception DF requirements	The perception DF shall: • Detect ODD boundary transition. • Detected relevant static and dynamic obstacles and provide position, distance, and velocity with high confidence level via sensors and V2X. • Maintain a safe behaviour in presence of adverse weather conditions.
R3.2_08	Generated scenarios requirements	The system shall be validated under adverse weather conditions affecting system under test. No user interaction is required. EURO NCAP highway scenarios shall be the basis for validation requirements imposed onto the highway AD system.
R3.2_10	Validation of the test framework with both virtual and real data	A combination of physical and virtual testing shall be used to validate the systems and ensure correlation between virtual and real results. The validation shall start in the virtual environment using a prototype of the software, traffic flow simulations, diverse conditions and sensor and vehicle models. That will provide an understanding of the performance of the algorithms in terms of latencies and KPIs and allow to tune the necessary parameters. After the virtual testing, the developed algorithms shall be tested in the physical world, in a proving ground with traffic infrastructure. Finally, a comparison shall be done between the results obtained in the virtual tests and the results obtained in the physical tests to confirm the robustness and representativeness of the simulated approach.

8.4 Requirement tables for UC 4

Table 9. Requirements of sub-UC 4.1

Requirement Number	Name	Description
R4.1_01_01	Subject Vehicle - Sensors	The subject vehicle shall be able to accurately sense its surroundings, including the docking bay, any obstacles or vehicles in the area, and the distance between the vehicle and the bay. This shall be achieved using sensors such as cameras, LiDAR, and radar.
R4.1_01_02	Subject Vehicle - Perception AD functions	The sensor information shall be fused in the perception sub-block.
R4.1_01_03	Environment	The ODD where the automated truck is operating shall be properly simulated giving appropriate input to the used sensors.
R4.1_02	Subject Vehicle - Planning	The subject vehicle shall be able to plan a path to the docking bay that avoids any obstacles and ensures that it can safely manoeuvre into the bay by using algorithms to determine the optimal path based on the vehicle's size, the area's layout, and other relevant factors.
R4.1_03	Subject Vehicle - Control and Act	The subject vehicle shall be able to manoeuvre precisely into the docking bay by using automated steering and braking technologies to ensure the truck is correctly aligned with the bay and can be safely docked.
R4.1_04	System under test – Real-time adjustments	The subject vehicle shall be able to make real-time adjustments based on any changes in the environment, such as the movement of other vehicles or changes in the layout of the area.
R4.1_05_01	ODD’s scenery description – Drivable areas	The drivable areas shall be either freight distribution centre or shared space.
R4.1_05_02	ODD’s scenery description – Lane type	The lane type shall be “special purpose lane”.
R4.1_05_03	ODD’s scenery description – Direction of travel	The driving shall be done on the left-hand side of the roads.
R4.1_05_04	ODD’s scenery description – Drivable area surface conditions	The surface conditions of the drivable areas shall be either dry or wet.
R4.1_05_05	ODD’s scenery description – Features of drivable area surfaces	The features of the drivable area surfaces shall fall in one of the following categories: cracks or swells.
R4.1_05_06	ODD’s scenery description – Road surfaces	The road surfaces shall be either segmented or uniform.
R4.1_05_07	ODD’s scenery description – Horizontal planes	All horizontal planes shall fall in one of the following categories: straight roads or curved roads.

R4.1_05_08	ODD's scenery description – Vertical planes	All vertical planes shall fall in one of the following categories: up-slope, down-slope, or level plane.
R4.1_05_09	ODD's scenery description – Transverse planes	All transverse planes shall be undivided roads.
R4.1_05_10	ODD's scenery description – Lane type	All lanes shall be traffic lanes.
R4.1_05_11	ODD's scenery description – Drivable area surfaces	All drivable area surfaces shall be either asphalt or concrete.
R4.1_05_12	ODD's scenery description - Drivable area signs	All drivable area signs shall fall in one of the following categories: Regulatory, warning, or information.
R4.1_06_01	ODD's atmospheric conditions description - Wind	The wind shall either be "no wind" or calm.
R4.1_06_02	ODD's atmospheric conditions description – Excluded rainfall	Violent rain and cloudburst shall not be types of rainfall.
R4.1_06_03	ODD's atmospheric conditions description - Particles	All particles shall be non-precipitating water droplets.
R4.1_06_04	ODD's atmospheric conditions description - Illumination	All illumination shall fall in one of the following categories: day or cloudiness.
R4.1_06_05	ODD's atmospheric conditions description - Communication	V2I communication shall be included
R4.1_07	ODD's dynamic elements – Excluded agent types	Vulnerable road users, animals, non-motor vehicles, ambulances, and police vehicles shall not be agent types.
R4.1_08	AD system accuracy	The ADS shall accurately position the vehicle within a certain tolerance of the docking bay. This tolerance should be defined based on the size of the vehicle and the space available in the logistics hub.
R4.1_09	AD system reliability	The ADS shall be reliable and consistent in its behaviour. This means it should be able to dock the vehicle correctly every time, without fail.

R4.1_10	AD system safety	The ADS shall be designed to ensure the vehicle's safety, the cargo it is carrying, and any people in the vicinity. This may involve incorporating safety features such as collision detection and avoidance systems, emergency stop buttons, and fail-safe mechanisms. The tests will be defined based on expert knowledge. The risks shall be identified by a HARA. The ADS shall comply with ISO 21448, ISO 26262, and ISO 21434.
R4.1_11	AD system adaptability	The ADS shall be adaptable to different types of docking bays and vehicles and varying environmental conditions such as lighting and weather. The ADS developed shall run faithfully in simulation, in a scale model and in full size vehicle.
R4.1_12	Scenario description/generation	Regardless of the limited number of movable objects in the scenario (due the restricted interactions and manoeuvres), the ADS shall maintain service in different environmental conditions.
R4.1_13	Validation of the test framework with both virtual and real data	The ADS shall be thoroughly tested in various conditions to ensure it meets all the requirements, and to gain insights into scenario-based testing. This shall involve simulated testing in a controlled environment as well as testing in real-world logistics hubs with a real truck and with a miniature size truck. The following KPIs and metrics that shall be considered to perform this validation: • Collision Avoidance performance • Accuracy of docking • Reliability of Docking • Response Time • Environmental Robustness
R4.1_14	Vehicle dynamics	The vehicle dynamics of a reverse driving truck with semitrailer shall be simulated with appropriate fidelity and validity.
R4.1_15	Connectivity	The vehicle dynamics of a reverse driving truck with semitrailer shall be simulated with appropriate fidelity and validity.
R4.1_16	Validation of the simulation model	The validity of the simulation model shall be show, either online or offline.

Table 10. Requirements of sub-UC 4.2

Requirement Number	Name	Description
R4.2_01	System under test – Accurate sensing	The subject vehicle shall be able to accurately sense its surroundings, including the docking bay, any obstacles or vehicles in the area, and the distance between the subject vehicle and the bay

		by using sensors such as cameras, LiDAR, and radar.
R4.2_02	System under test – Path planning	The subject vehicle shall be able to plan a path to the docking bay that avoids any obstacles and ensures that it can safely manoeuvre into the bay by using algorithms to determine the optimal path based on the vehicle's size, the area's layout, and other relevant factors.
R4.2_03	System under test – Precise manoeuvring	The subject vehicle shall be able to manoeuvre precisely into the docking bay by using automated steering and braking technologies to ensure the truck is correctly aligned with the bay and can be safely docked.
R4.2_04	System under test – Real-time adjustments	During the reversing process, the subject vehicle shall be able to make real-time adjustments based on any changes in the environment, such as the movement of other vehicles or changes in the layout of the area. This requires the subject vehicle to monitor its surroundings and adjust its behaviour as necessary constantly.
R4.2_05_01	ODD's scenery description – Drivable areas	The drivable areas shall be either freight distribution centre or shared space.
R4.2_05_02	ODD's scenery description – Lane type	The lane type shall be "special purpose lane".
R4.2_05_03	ODD's scenery description – Direction of travel	The driving shall be done on the left-hand side of the roads.
R4.2_05_04	ODD's scenery description – Drivable area surface conditions	The surface conditions of the drivable areas shall be either dry or wet.
R4.2_05_05	ODD's scenery description – Features of drivable area surfaces	The features of the drivable area surfaces shall fall in one of the following categories: cracks or swells.
R4.2_05_06	ODD's scenery description – Road surfaces	The road surfaces shall be either segmented or uniform.
R4.2_05_07	ODD's scenery description – Horizontal planes	All horizontal planes shall fall in one of the following categories: straight roads or curved roads.
R4.2_05_08	ODD's scenery description – Vertical planes	All vertical planes shall fall in one of the following categories: up-slope, down-slope, or level plane.
R4.2_05_09	ODD's scenery description – Transverse planes	All transverse planes shall be undivided roads.
R4.2_05_10	ODD's scenery description – Lane type	All lanes shall be traffic lanes.

R4.2_05_11	ODD's scenery description – Drivable area surfaces	All drivable area surfaces shall be either asphalt or concrete.
R4.2_05_12	ODD's scenery description - Drivable area signs	All drivable area signs shall fall in one of the following categories: Regulatory, warning, or information.
R4.2_06_01	ODD's atmospheric conditions description - Wind	The wind shall either be "no wind" or calm.
R4.2_06_02	ODD's atmospheric conditions description – Excluded rainfall	Violent rain and cloudburst shall not be types of rainfall.
R4.2_06_03	ODD's atmospheric conditions description - Particles	All particles shall be non-precipitating water droplets.
R4.2_06_04	ODD's atmospheric conditions description - Illumination	All illumination shall fall in one of the following categories: day or cloudiness.
R4.2_06_05	ODD's atmospheric conditions description - Communication	V2I communication shall be included
R4.2_07	ODD's dynamic elements – Excluded agents	Vulnerable road users, animals, non-motor vehicles, ambulances, and police vehicles shall not be agent types.
R4.2_08	ADS functional safety assessment - ISO21448 (SOTIF)	ISO21448 (SOTIF) shall be followed to assess the safety of the automated parking functionality for a perception system that integrates external V2X information while being under attack.
R4.2_09	ADS functional safety assessment - ISO/TR 4804	ISO/TR 4804 shall be followed to analyse the safety and security co-engineering aspects.
R4.2_10	ADS functional safety assessment – Self-localization	The connected perception system shall accurately self-localize the subject vehicle within an acceptable tolerance within the area of the docking bay.
R4.2_11	ADS functional safety assessment – Object detection	The connected perception system shall reliably detect object positions around the automated track.
R4.2_12	ADS functional safety assessment – Cyber-attacks	The connected perception system should be robust to different effects of cyber-attacks in V2X messages.

R4.2_13	Scenario description/generation	Regardless of the limited number of movable objects in the scenario (due the restricted interactions and manoeuvres), the ADS shall maintain service in different environmental conditions.
R4.2_14	Test framework – XiL requirements	The framework shall include both SiL and MiL testing.
R4.2_15	Test framework – Tools for environment and collective perception	CARLA shall be used for the representation of the physical environment and the ruck/RSU sensor detections, while a ROS bridge to an external collective perception module shall be integrated.
R4.2_16	Test framework – Tools for connectivity	ARTERY can be potentially used to simulate V2X connectivity.
R4.2_17	Test framework – Artificial CPM messages	CPM messages shall be artificially generated based on CPM properties to falsify positions, speeds, or other object characteristics**.**
R4.2_18	Test framework – Cyber-threats	The connected perception module shall be able to perform in a range of environmental conditions, as well as artificially created cyber threats affecting the quality of the V2I object information.
R4.2_19	Test framework – Runtime measurements	The runtime of the connected perception module shall be measured (tested in a CARLA-ROS simulation framework).

8.5 Requirements tables derived from ISO 21448

Table 11. Requirements related to the identification of unknown-unsafe scenarios

Requirement number	Name	Description	Rational
R10.1.7	Unknown-unsafe scenario exploration: search space definition from ODD	The complete search space of the ODD shall be explored for unknown-unsafe scenarios including *possible actor behaviours, static environment, and dynamic conditions such as weather and illumination, and foreseeable misuse of the SuT.*	SOTIF: "One aspect is a representative coverage of the possible scenario space by the whole set of V&V activities."
EXAMPLE UC1.1: the ODD includes various illumination conditions. These shall be extracted for the search space.		The illumination conditions within the ODD [day, night, cloudiness, fog, artificial illumination] shall be extracted for the search space.	
R10.1.8	Unknown-unsafe scenario exploration: search space definition from recorded data	Recorded data in the ODD, when available, shall be used to refine the search space for exploration of unknown-unsafe scenarios.	SOTIF: "One aspect is a representative coverage of the possible scenario space by the whole set of V&V activities."

R10.1.11	Unknown-unsafe scenario exploration: search problem setup	The search problem shall be setup such that the search space can be explored with a finite (reasonable) number of runs. (e.g., limiting the number of actors in each scenario)	This is necessary for sufficient exploration of search space to be finite and practical to perform.
R10.1.10	Unknown-unsafe scenario exploration: exploration methods	Exploration techniques (such as adaptive sampling, optimization) shall be employed such that the search space can be explored with a finite (reasonable) number of runs.	Suggestions from SOTIF for identifying unknown-unsafe scenarios: "inductive analysis, deductive analysis, exploratory analysis, exploratory simulation (with advanced combinatorial techniques), and exploratory driving (with adequate safety measures)."
R10.1.9	Unknown-unsafe scenario exploration: search space definition coverage	Sufficient justification (safety argumentation) shall be provided on the coverage of the ODD by the defined search space	SOTIF: "One aspect is a representative coverage of the possible scenario space by the whole set of V&V activities."
R10.1.12	Unknown-unsafe scenario exploration: safety argument on search problem setup	Sufficient justification (safety argumentation) shall be provided on the setup of the search problem.	Sufficient coverage of the search space during exploration is important for safety argument.
R10.1.13	Unknown-unsafe scenario exploration: safety argument on exploration techniques	Sufficient justification (safety argumentation) shall be provided on the exploration techniques with respect to the coverage of the search space with the generated scenarios.	Sufficient coverage of the search space during exploration is important for safety argument.
R10.1.14	Unknown-unsafe scenario exploration: safety argument on metrics	Sufficient justification (safety argumentation) shall be provided for the metrics used to identify unknown-unsafe scenarios	The metrics used to define an unknown-unsafe scenario are part of safety argument as they influence the output scenarios from the

	used for unknown-unsafe scenarios		search.
R10.1.15	Unknown-unsafe scenario exploration: iteration	Unknown-unsafe scenario exploration shall be iterated for changes in ODD or system-under-test.	SOTIF is affected by changes in ODD or system-under-test and shall be iterated efficiently.
R10.1.15.1	Unknown-unsafe scenario exploration: effective iteration	The iteration of unknown-unsafe scenario exploration shall be effective with respect to the changes in ODD or system-under-test. The exploration shall not need to evaluate the entire search space from scratch.	
Example UC1.1: ODD previous excluded emergency vehicles, but now includes them.		Unknown-unsafe scenario exploration shall be iterated to include emergency vehicles in the search space.	

Table 12. Requirements related to the evaluation and reporting of SOTIF

Requirement number	Name	Description	Rational
R10.1.20	Testing of system behaviour in known unsafe scenarios	System behaviour shall be tested and evaluated for risk in known unsafe scenarios (including foreseeable misuse). The risk shall be quantified against the (input) validation targets and reported as part of overall assessment of SuT.	One of the key goals in SOTIF is to "Perform risk acceptance evaluation for known unsafe scenarios"
R10.1.20.1	Simulation model validation: known-unsafe	Perform simulation model validation on known-unsafe scenarios identified for SOTIF.	
R10.1.19	Testing of system behaviour for known potential triggering conditions	System behaviour shall be tested and evaluated for risk for known potential triggering conditions and reported as part of overall assessment of SuT.	One type of "unknown area" in SOTIF is "potential triggering condition are identified but behaviour of system unknown". Thus, to reduce the probability of unknown-unsafe, the system
R10.1.19.1	Simulation model validation for known potential triggering conditions	Perform simulation model validation on scenarios identified for SOTIF which contain known potential triggering conditions.	

EXAMPLE UC1.1: adverse weather conditions are included in the ODD. These are known potential triggering conditions for an AV perception system. Test the system under heavy fog.		System behaviour shall be tested and evaluated for risk in heavy fog conditions. Simulation models shall also be validated for heavy fog conditions.	behaviour shall be tested in such cases.
R10.1.21	Testing of system behaviour at boundaries of ODD and outside ODD	System behaviour shall be tested and evaluated for risk at the boundaries of the ODD and outside of ODD – for conditions which are inside the target operational domain (TOD), e.g., weather conditions outside of ODD, unfamiliar objects. The test results and risk assessment are reported as part of overall assessment of SuT.	SOTIF mentions: ""The verification and validation strategy is focusing not only on performance evaluation and risk identification within the ODD, but also on the boundaries and outside of the ODD. One aspect of the strategy includes verifying that the system is not engageable from anywhere outside the ODD.""
R10.1.21.1	Environment simulation outside of ODD	Simulate environment accurately at the ODD boundary and outside of the ODD within the TOD.	
R10.1.21.2	Sensor simulation outside of ODD	Sensor models shall have realistic behaviour at ODD boundaries and outside of ODD within the TOD.	
R10.1.21.3	AD behaviour specification outside of ODD	The system behaviour of the AD shall be specified outside of the ODD, e.g., the system may deactivate with advance warning to the human driver within the TOD.	
R10.1.21.4	Vehicle dynamics model outside of ODD	Vehicle dynamics models shall have realistic behaviour at ODD boundaries and outside of ODD within the TOD.	
R10.1.21.5	Traffic agent behaviour outside of ODD	Simulate traffic agent behaviour at the ODD boundary and outside of the ODD within the TOD, e.g., illegal behaviour such as exceeding speed limits.	
R10.1.21.6	Simulation model validation outside of ODD	Perform simulation model validation at the ODD boundary and outside of the ODD within the TOD.	
EXAMPLE UC1.1: rain is included in the ODD but violent rain is excluded. Here, the system behaviour at boundary of ODD can be explored with respect to rain conditions. Test the system under rain parameters at ODD boundary.		System behaviour shall be tested and evaluated for risk in rainy conditions corresponding to the maximum value in the ODD, slightly higher values of rain (which it might consider within ODD due to noise).	
R10.1.16	Unknown-unsafe scenario: SuT assessment	The SuT shall be assessed against the identified unknown-unsafe scenarios.	Evaluation of SOTIF in previously unknown-unsafe

R10.1.16.1	Unknown-unsafe scenario: SuT testing	Testing of the SuT is done for the identified unknown-unsafe scenarios. KPIs for unknown-unsafe scenarios will be generated after testing SuT for those scenarios.	scenarios is part of safety argument.
R10.1.16.2	Unknown-unsafe scenario: simulation model validation	Perform simulation model validation for (a representative subset of) identified unknown-unsafe scenarios.	
Example UC1.1: an identified unknown-unsafe scenario reveals that the AV tried to overtake another vehicle at the intersection. The other vehicle occluded a pedestrian crossing the road. The AV did not detect the pedestrian until very late.		The SuT shall be assessed for the identified unknown-unsafe scenario where overtaking another vehicle in the intersection led to collision with an occluded pedestrian.	
R10.1.17	Unknown-unsafe scenario: SuT assessment results reporting	The test assessment for the SuT against the identified unknown-unsafe scenarios shall be reported as part of the overall assessment of the SuT.	Evaluation of SOTIF in previously unknown-unsafe scenarios is part of safety argument.
R10.1.17.1	Unknown-unsafe scenario: assessment results	Report results for testing of SuT for identified unknown-unsafe scenarios.	
R10.1.17.2	Unknown-unsafe scenario: overall safety assessment	R10.1.17.2: Test results for unknown-unsafe scenarios to be included in overall assessment.	
R10.1.6	Unknown-unsafe scenario: evaluation of residual risk	Evaluation of residual risk with respect to unknown-unsafe scenarios shall be performed against (input) validation targets and reported as part of the overall assessment of the SuT.	One of the key goals in SOTIF is to "Reduce probability of unknown-unsafe to an acceptable level through V&V strategy"
R10.1.18	Unknown-unsafe scenario: enriching the scenario database	The identified unknown-unsafe scenarios shall be used to enrich the scenario database.	This supports SOTIF aim of reducing the unknown scenario space.
R10.1.18.1	Unknown-unsafe scenario:	Representative set of unknown-unsafe scenarios is created to be shared with the scenario database. Selection	

	representative set creation	process shall select most important unknown-unsafe scenarios. Duplicates shall be avoided.	