Deliverable D3.1 /

Use cases definition and description

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Executive summary

The main goal of this deliverable is to describe how the Hi-Drive use case (UC) catalogue was generated based on a set of Hi-Drive automated driving systems (ADS) under test. Each UC is constructed from test scenarios of the ADS to be tested, through which the project will demonstrate how the Hi-Drive (connected) automated driving (AD/CAD) functions perform in a variety of operational domain (OD) conditions. This in turn will allow the project to analyse the user acceptance, robustness, reliability, and functional safety of these prototype systems. Most of Hi-Drive's AD/CAD functions constitute advanced versions of L3Pilot's[1] AD functions (ADFs) following their integration with one or more technology enablers developed during Hi-Drive. Therefore, mapping to Hi-Drive's novel technology enablers also forms part of the Hi-Drive ADF description. One of the main objectives of the project is to show how the integration of different enablers improves performance within the operational design domain (ODD) or extends the ODD of the AD/CAD functions.

This work starts with the description and categorization of Hi-Drive AD/CAD functions and targeted ODDs, then moves to generating UCs and associated test scenarios. In the proposed methodology, and in line with the research questions defined by the project, two types of ODD conditions have been considered for testing the integration of a Hi-Drive enabler technology in the ADF instance under test: a) the ODD for testing "AD performance", in which we test if higher AD performance and prolonged AD usage can be achieved under nominal ODD conditions, and b) an extended ODD for testing "AD availability", where additional challenging operating conditions are tested to assess the AD robustness under conditions beyond the nominal ODD of the AD system under test.

The templates and methods produced during this work are as follows:

- **a.** Two templates, one for the ADF instance specification and one for the description of UCs and test scenarios, have been designed to facilitate collection of information from the numerous Hi-Drive ADF owners. Both textual and tabular formats, along with illustrations and photographs, have been implemented to produce easy-to-read ADF and UC cards. In the second template, guidelines for the description of test scenarios per Hi-Drive UC are proposed in alignment with ISO 34502.
- **b.** A customized ODD specification format is proposed for the purposes of the project following a state-of-the-art review, which includes international standards and other EU-funded or national projects.

[1] EU-funded project L3Pilot, predecessor of Hi-Drive project; information available at https://l3pilot.eu/.

- **c.** A grouping of ODD extension types is proposed that highlights all the different challenging OD conditions targeted by the Hi-Drive operations.
- **d.** Indexing and grouping of the numerous Hi-Drive UCs is proposed that will lead to creation of a handy Hi-Drive Use Case and Test Scenario catalogue.

As a result of this work, 29 ADFs by 20 Hi-Drive prototype owners are described: a) 12 challenging OD conditions are identified for consideration in testing, b) a UC/Test scenario catalogue of 40 UCs grouped in 18 UC clusters is produced including 113 associated test scenarios.

The work produced in this deliverable will help guide the preparation of real-life (and virtual testing) experimentation and subsequent evaluation of the Hi-Drive ADFs by the subprojects SP4 *Methodology*, SP5 *Operations*, and SP7 *Effects* that run in parallel to, and will follow up on, the work done here.

1 Introduction and Objectives

1.1 Hi-Drive – Addressing challenges toward the deployment of higher automation

Connected and automated driving (CAD) has become a megatrend in the digitalization of society and the economy. CAD has the potential to drastically change transportation and to create far-reaching impacts. SAE L3 automated functions were piloted in Europe by the L3Pilot project in 2017–2021. Hi-Drive builds on the L3Pilot results and advances the European state-of-the-art from SAE L3 'Conditional Automation' further up towards 'High Automation' by demonstrating in large-scale trials the robustness and reliability of CAD functions in demanding and error-prone conditions with special focus on:

- Conditionally automated vehicles (CAVs) travelling in challenging conditions covering variable weather and traffic scenarios
- Connected and secure automation providing vehicles/their operators with information beyond the line of sight and on-board sensor capabilities
- Complex interaction with other road users in normal traffic
- Factors influencing user preferences and reactions including comfort and trust — and, eventually, enabling viable business models for AD.

The project's ambition is to extend considerably the ODD from the present situation, which frequently demands that a human driver resume control of the vehicle. As experienced in the EU flagship piloting project L3Pilot, on the way from A to B, a prototype automated vehicle (AV) will encounter a number of ODD factors, leading to fragmented availability of the AD function. Hi-Drive addresses these key challenges, which are currently hindering the progress of vehicle automation. The concept builds on reaching a widespread and continuous ODD, where automation can operate for longer periods, and the interoperability is assured across borders and brands. Hi-Drive strives to extend the ODD and reduce the frequency of take-over requests by selecting and implementing technology enablers leading to highly capable CAD functions, operating in diverse driving scenarios including, but not limited to, urban traffic and motorways. The removal of fragmentation in the ODD is expected to give rise to a gradual transition from conditional operation towards higher levels of automated driving.

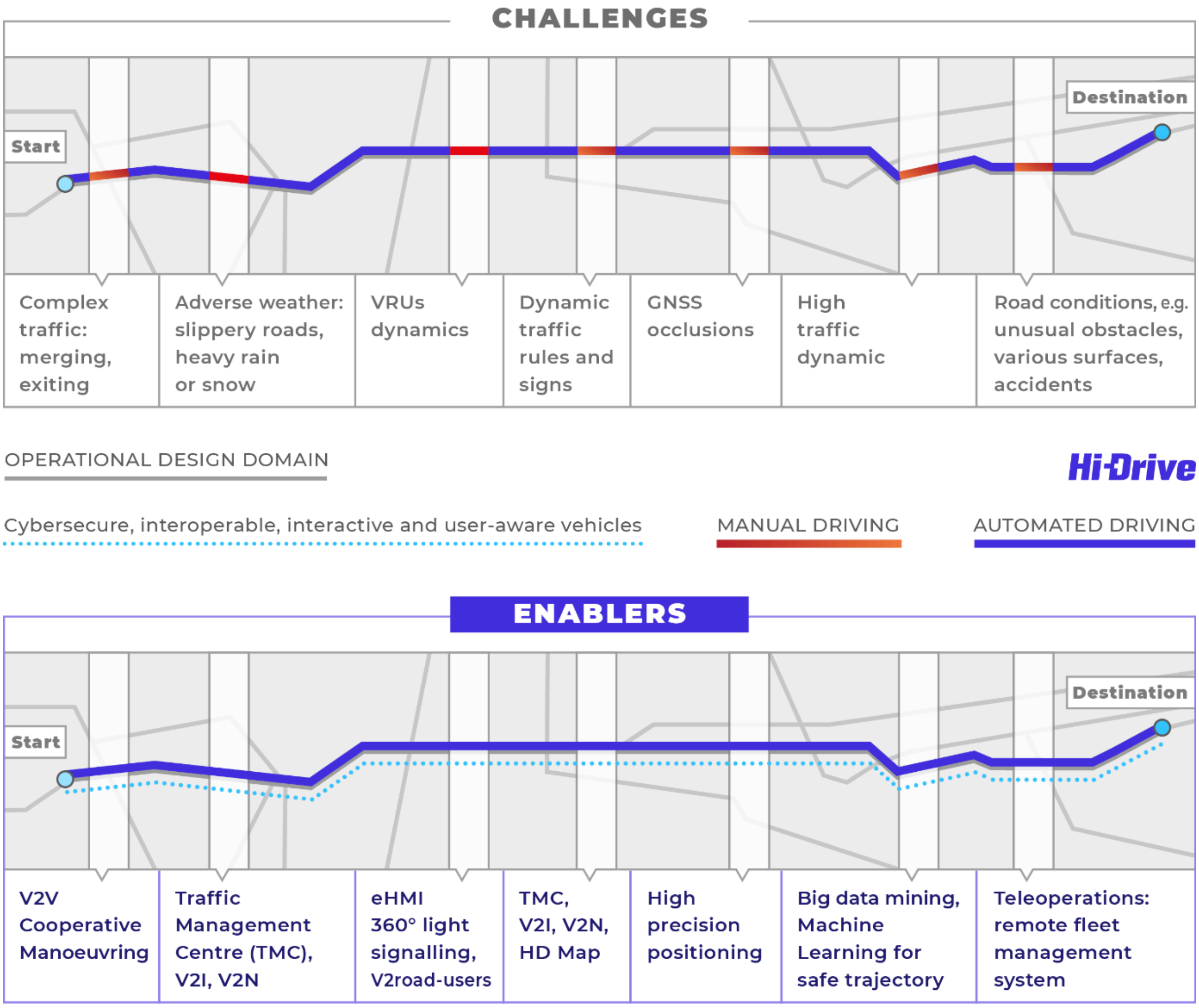


Figure 1.1: Hi-Drive addressing ODD defragmentation against challenges

The work started with the collection and description of the different automated driving functions, enabling technologies, and ODDs. When testable functions and use cases are defined, research questions and hypotheses are formulated leading to specification of data needed for evaluation and then actual recording of vehicle-driver behaviour. The evaluation will focus on three areas: 1) Users; 2) AD performance and possible extension of the ODD; and 3) Assessment of impacts (on safety, efficiency, environment, mobility, transport system, and society). Furthermore, these assessments serve as input to determine whether the socioeconomic benefits outweigh the costs. The project also engages in a broad dialogue with the stakeholders and general public to promote the Hi-Drive results. Dissemination and communication are boosted by a demonstration campaign to showcase the project's achievements.

Overall, Hi-Drive strives to create a deployment ecosystem by providing a platform for strategic collaboration. Accordingly, the work includes an EU-wide user education and driver training campaign and a series of Codes of Practice (CoP) for the Development of ADFs and road-testing procedures, while also leading the outreach activities on standardization, business innovation, extended networking with interested stakeholders, and coordinating parallel activities in Europe and overseas.

1.2 Objectives

From an ADF design point of view, the main objective of this work was to identify the use cases/scenarios which combine and allow to demonstrate the vehicles' functions, the enablers' impact, and the users' reactions in a holistic way. From an ADF evaluation point of view, the test scenarios need to show how the advanced AD functions of Hi-Drive can improve their performance in their nominal ODD or even achieve an ODD extension compared to state-of-the-art, maximising AD availability for longer automated driving durations while ensuring user acceptance, robustness, reliability, and functional safety. To meet these objectives, it is necessary to collect and document a set of use cases for Hi-Drive multi-domain testing activity, considering a broad ODD that includes urban, motorway, motorway-to-urban transition, cross-border, and parking driving scenarios.

To describe the driving functions hosted in a range of prototype vehicles constituting the Hi-Drive fleet, a dedicated structured template has been created describing the enabling technologies, functionality, ODD, and driver role in each on-board ADF setup. Next, for each ADF, a set of use cases and corresponding test scenarios (prerequisites, triggering condition, sequence of actions) have been portrayed using a dedicated template. Additionally, to assist the project's evaluation and methodology work running in parallel, information about the system under its test limits (technical, operational, etc.), test scenario execution domain, and expected evaluation domain has been noted for each use case.

Two main objectives are addressed by this work:

1. **To describe the on-board (C)AD functions of the Hi-Drive fleet**

   The description will include the on-board functionality and embedded enablers along with the corresponding ODDs, as well as any external network-based connected entity supporting any collaborative driving features.

2. **Description, categorization, and grouping of collected Hi-Drive (C)AD use cases.**

   The description will include the ADFs' usage/testing scenarios either on open roads (public road network) and/or in a controlled environment and/or virtual environment.

The resulting Hi-Drive Use Case and Test Scenario catalogue will provide a comprehensive and broad scenario coverage of the Hi-Drive testing activity.

1.3 Interrelations with other SPs/WPs

For this work, which belongs inside Hi-Drive SP3 (Vehicles), interaction is needed with other SPs to ensure that the use cases planned to be tested are known to the evaluation (SP6 Users and SP7 Effects) and methodology teams (SP4 *Methodology*) and vice versa, that the ADF owners are aware of Hi-Drive's data analysis targets (SP4 *Methodology*), and consequently that the vehicles are capable of generating the required data for the evaluation studies in SP7 and SP6, according to the data requirements defined by SP4.

Following the ordered sequence of SPs, the following inputs/outputs from/to other SPs are processed/produced by SP3 during the work of this deliverable:

- SP2 *Enablers*
  - From SP2: Enablers to be integrated into existing vehicle ADFs.
  - To SP2: Vehicle ADF capabilities and potential to host an enabler.
- SP4 *Methodology*
  - From SP4: Preliminary criteria for clustering use cases based on a preliminary list of research questions.
  - To SP4: Description of Hi-Drive ADFs and associated use cases grouped into distinctive classes to feed the work on RQs and analysis methods. Use-case test scenarios with sketches also contribute to the experimental procedures. The data requirements defined in WP4.4 will serve as input for the data logging equipment needs, and dialogue between SP3 and SP4 is needed to set the common data formats for data provision.
- SP5 *Operations*
  - From SP5: Test scenario execution domain for each ADF and general time plan for ADF testing campaigns, referred to as 'Operations' in Hi-Drive (on public roads, controlled environments, or simulations).
  - To SP5: Description of the set of Hi-Drive ADFs, as well as associated use-case and test scenario descriptions grouped into classes for increased readability and for facilitating scenario-based operations' grouping when needed during the data analysis/evaluation phase.

- SP6/SP7 *Users/Effects*
  - To SP6-7: Description of Hi-Drive ADFs and associated use cases grouped into distinctive use case classes, as well their test scenarios with sketches. Identification and preparation of vehicles that will contribute to the SP6 and SP7 studies.

In addition to the above, SP3 *Vehicles* is also cooperating with SP1 *Collaboration* for reviewing the CoP guidelines, and with SP8 *Outreach* to support the work on interaction with standards.

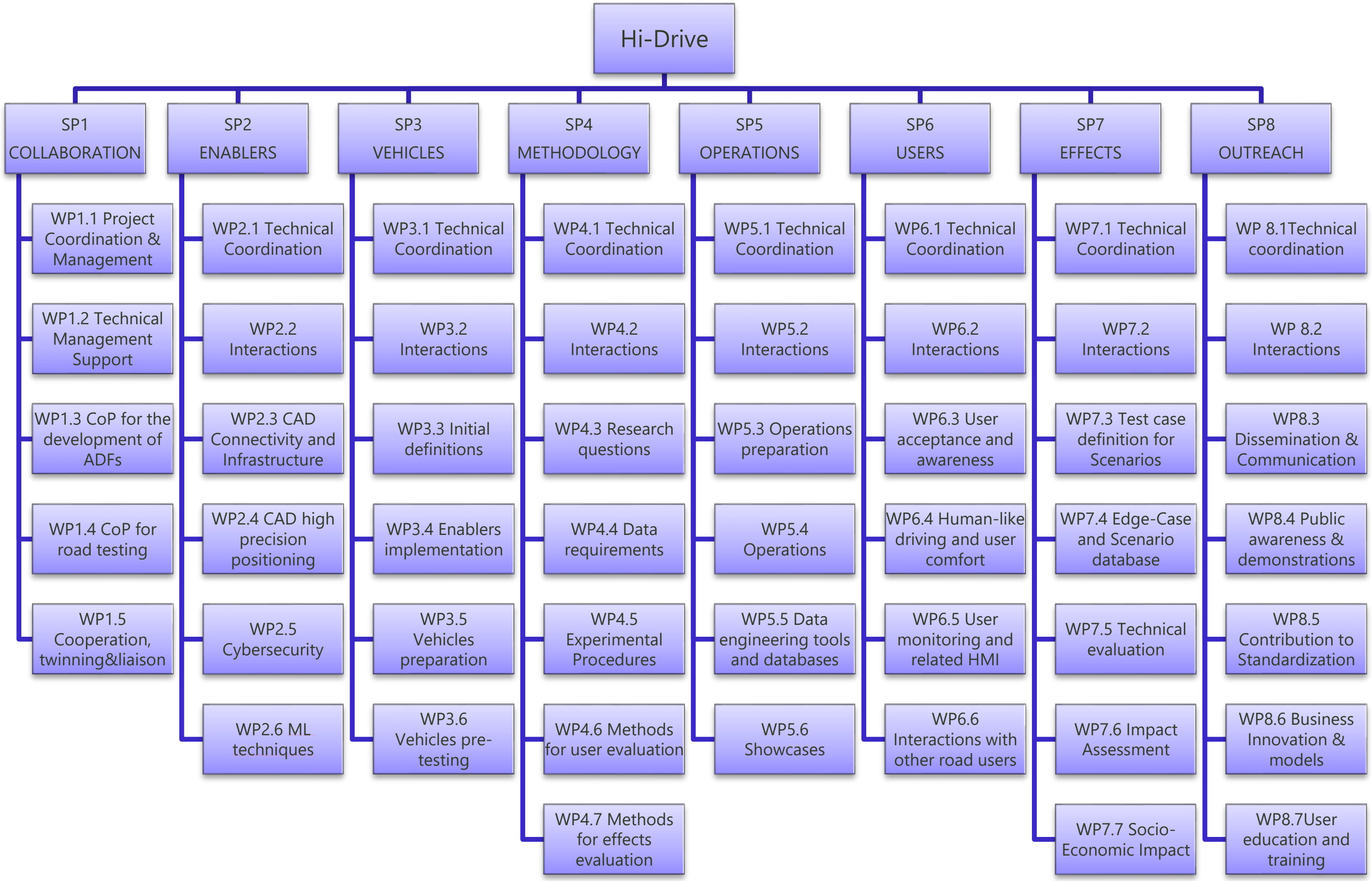


Figure 1.2: Work breakdown structure

1.4 Structure of the deliverable

The content of this deliverable is structured as follows: Section one introduces the objectives of this work and its interrelation with other Hi-Drive work packages. Section two hosts the state-of-the-art review and the proposed methodology for generation of the UC catalogue. This includes the two templates proposed for this purpose, the first for ODD specification and the second for the ADF description and its associated UCs (see Section 2.3.3). The next two Chapters, 3 and 4, present the main results of the work: Chapter 3 summarises the Hi-Drive ADFs and their relation to the technology enabler groups, and Chapter 4 presents in detail the associated set of Hi-Drive UCs and test scenarios. This latter chapter concludes with section 4.6, with an overview of the Hi-Drive UC catalogue in tabular format. Section 5 provides an overview of all the results described previously. Finally, Chapter 6 concludes the deliverable. There are two annexes providing detailed information excluded from the main body of the deliverable for reasons of space: the Hi-Drive ADF instances (one page) in Annex 1 and the Hi-Drive ODD template in Annex 2.

2 Methodology

2.1 Introduction

For the purpose of describing the Hi-Drive ADFs, use cases, and test scenarios, and in order to come up with templates for collecting all the necessary information from the numerous ADF instances implemented by the ADF owners, background work has been discussed and a focused state-of-the-art (SoA) review performed targeting the ODD and test scenario specification for evaluation of the CAD systems. The reviewed material and findings are reported in Sections 2.2.1 (Terminology), 2.2.2 (ODD specification format), 2.2.3 (Relation to L3Pilot ADF description), and 2.2.4 (Hi-Drive Technology Enablers group). Based on this review of the background work, the proposed methodology for ADF description and generation of the UC catalogue is derived in Section 2.3.

2.2 Background work

2.2.1 Terminology

The Hi-Drive glossary defines a set of useful terms relevant to the representation/description of ADFs and UCs. As described in Section 2.3, each UC will be further detailed through test scenarios. In order to define a minimum set of elements for describing the Hi-Drive test scenarios, two more draft standards were reviewed, the ISO DIS 34501 (ISO, 2022) and the ISO/TR 21934 (ISO, 2021). Table 2.1 below lists the terms used in this work from other sources and indicates the few terms coined by us, like the term 'Hi-Drive UC'.

Table 2.1: Glossary (grey highlighted rows indicate terms used for ADF/UC template construction)

Source	Terms [original source if applicable)	Explanation
Hi-Drive glossary + international standards	Automated Driving System (ADS) *[SAE J3016]*	The hardware and software that are collectively capable of performing the entire DDT on a sustained basis, regardless of whether it is limited to a specific operational design domain (ODD); this term is used specifically to describe a Level 3, 4, or 5 driving automation system.
	Automated Driving function (ADF) *[SAE J3016]*	A common feature addressed by a group of automated driving systems. *Example: Motorway ADF, Urban ADF* NOTE: Similar ADFs share the same level of driving automation and quite similar ODDs.

Source	Terms [original source if applicable)	Explanation
		NOTE: ADF types considered in Hi-Drive are Motorway Chauffeur, Urban Chauffeur, Rural Chauffeur, and Parking Chauffeur.
	Driver *[SAE J3016]*	A user who performs in real time part or all of the DDT and/or DDT fallback for a particular vehicle. This definition of "driver" does not include a robotic test device designed to exercise steering, braking, and acceleration during certain dynamic test manoeuvres.
	Driving scenario *[L3Pilot, see Metz et. al, 2019]*	Driving scenarios describe the development of a situation within a traffic context in which at least one actor performs a (pre-)defined action and/or the driving scenario is triggered by a (predefined) event. The action or event is specified without the definition of concrete parameters. The influenced actor may either be the ego vehicle (e.g., performing a lane change or a minimum risk manoeuvre) or another traffic participant (e.g. a cut-in manoeuvre by another vehicle). The event triggering the driving scenario can be a change in road infrastructure (e.g., an end of lane or a change in speed limit) or an external obstruction (e.g,. an obstacle on the road). *Example: ego vehicle performing a lane change.*
	Enabler	Technological tools (SW, HW, Methodology) that have the potential to enable new vehicle automated function/s and/or upgrade existing vehicle automated function/s. *Examples: SW to be installed into vehicles to acquire and fuse data received from other vehicles, HW board to be installed into vehicles to connect to the 5G core network, Methodology: Threat Analysis and Risk Assessment.*
	Event *(based on* *ISO/DIS 34501)*	Events are either single time-points for which one or several criteria (change of an actor state, actors' relations, or an environmental attribute) are fulfilled. *Example: pedestrian starts crossing the street, falling below TTC threshold, lane ending*
	Experiment	Experiment consists of a series of test runs/trips to investigate a common aspect (ADF, Enabler, User) and is conducted under comparable circumstances. It is made up of several test runs/trips. Experiment types may include open road, test track, driving simulator, simulation models, etc. *Note: see also 'Operation' below.*

Source	Terms [original source if applicable)	Explanation
	UC *(defined by this work)*	Abstract description of the interaction between a Hi-Drive AD function and its environment in order to reach a particular goal. *Note: In this work, six classes of Hi-Drive UCs have been considered based on the road environment, namely, Motorway (M), Motorway-to-Urban Transition (MtU), Urban (U), Rural (R), Cross-Border (CB), Parking (P)***.**
	Test scenario *(defined by this work based on ISO/TR 21934)*	Description of sequence of triggers, events, and actions among UC entities (ego vehicle, other traffic participants, etc.) in order to reach a UC goal. A test scenario usually consists of a starting and ending triggering point and a sequence of driving scenarios (see above) in between. *Example: test scenario on-ramp merging may consist of:* • Triggering point: approaching merging section while another vehicle is also approaching in the main motorway right-hand lane • On-ramp driving • Change lane for merging • In-lane driving on motorway rightmost lane • Ending point
	Operation *[Hi-Drive D5.1, Sauvaget et. al (2022)]*	The execution of experiment(s) in a defined place and time. NOTE: In HI-Drive an operation usually includes testing a specific advanced ADF instance against a set of different UCs, where each UC testing corresponds to an execution or experiencing of a set of test scenarios.
ISO/DIS 34501	Action	Single purposeful act or behaviour that is executed by any actor in a scenario.
	Actor	Traffic participant with the capability to act and react in the scenario.
	Scenario category	Set of scenarios that share one or more characteristics.
	System Under Test (SUT)	Automated driving system that is tested with test scenarios.
	Subject vehicle	Vehicle under observation (e.g., in the process of testing, evaluation, or demonstration, etc.).
	Manoeuvre	Series of actions to change or maintain the position of an actor.
	Trigger	Event that initiates or ends an action.

Source	Terms [original source if applicable)	Explanation
		Note: This should not be confused with term 'triggering event' that is considered by SOTIF (ISO 21448, 2019] to be a potential cause for hazardous disturbances that increase safety risk.
ISO/DIS 34503	ODD	Operational Design Domain: the domain in which the ADF has been designed to function safely
	(T)OD	(Target) Operational Domain: the domain in which the ADF is (will) be operated.
	COD	Current Operational Domain: the domain in which the ADF operates at a specific point in time.

2.2.2 ODD specification formats

For specifying the true capabilities and limitations of an AD system, the ADF designer needs to define the Operational Design Domain of its ADF instance, abbreviated as ODD. The ODD has been formally defined by SAE J3016 (SAE, 2021) as the "Operating conditions under which a given driving automation system or feature thereof is specifically designed to function, including, but not limited to, environmental, geographical, and time-of-day restrictions, and/or the requisite presence or absence of certain traffic or roadway characteristics." Essentially, an ODD refers to the operating environment (road type, weather conditions, traffic conditions) in which an AD system has been designed to be operated safely. For example, for Low-Speed Automated Driving (LSAD) systems such as pods and shuttles, the ODD may include urban areas with predefined routes that include pedestrians and cyclists. On the other hand, for a motorway chauffeur system, an ODD may include a four-lane divided motorway and dry conditions only. The types of scenarios a vehicle may encounter will be a function of its defined ODD, making ODD specification fundamental to any subsequent AD system evaluation.

Technical note 1: As also discussed within ISO/DIS 34503 (ISO/DISa, 2023), an ADF's ODD should not be confused with the test Operational Domain (OD) which can be smaller (a subset of the ODD) or bigger (a superset of the ODD) depending on the applicable experiment's test track or open road's surface and structure, weather characteristics, etc. The test OD is roughly described by the test scenarios and will be further detailed by SP5 *Operations*.

Technical note 2: A low-level driving scenario, i.e., "concrete scenario" in the terminology set by project Pegasus and then adopted by ISO 34502 and later by ISO 34504 (ISO 2022, ISOb 2023), defines the behaviour (e.g., trajectories) of various actors and entities in an ODD. Scenario variations may be tested by a) applying different ODDs or b) applying different scenario actors' actions. A toy example of how an ODD and a low-level scenario description can look like is given below:

Toy *example of a readable ODD:*
ODD-Motorway-spec-1: Expect (Road_Type =: Motorway) AND (Daytime =: Daylight) AND (Weather=: No fog, No snow) AND (traffic =: low OR medium OR high AND NOT_traffic jam)

Handcrafted *example of a low-level readable scenario:*
Sub-scenario-1: Ego Vehicle drives with speed not exceeding 120 km/h following vehicle in front, adjusting speed and staying in lane during daylight conditions and rainy weather conditions.

Figure 2.1: Toy example of an ADF ODD and a low-level scenario description

In order for stakeholders to be able to share, compare, and re-use ODD definitions, there is a need for standards to provide guidance to the stakeholders on both the attributes to be used for ODD definition and a format for defining the ODD using those attributes. The NHTSA (National Highway Traffic Safety Administration) (Staplin et. al, 2018) was first to propose a set of ODD attributes (structured as part of an ODD taxonomy) that could be used as a common reference by AD system designers and testers in the US. The BSI PAS 1883 (BSI PAS, 2020) specification provided the first European ODD taxonomy in 2020. More recently, ISO 34503 (ISO, under development) has been working upon the BSI PAS 1883 taxonomy to provide a high-level definition format for ODD and relevant domains.

During shaping of the Hi-Drive ODD specification template, a cross-SP ODD taskforce was formed that reviewed the following pieces of the SoA:

1. Framework for Automated Driving System Testable Cases and Scenarios by NHTSA (Staplin et. al, 2018): This report describes a framework for establishing sample preliminary tests for ADS. The focus is on light duty vehicles exhibiting higher levels of automation, where the system is required to perform the full dynamic driving task, including lateral and longitudinal control, as well as object and event detection and response.
2. SAE Automated Vehicle Safety Consortium, ODD specification guideline (SAE AVSC, 2020): This report aims to establish a best practice for ODD description, establishing commonly defined terms and recommending a framework in which they can be applied.
3. Catapult MUSICC project, 'Design considerations for ODD ontology' (Myers, 2020): This report aims to establish a first ODD ontology, its requirements, and internal relations

among the ontology elements. It was used as an input for creating a Multi-User Scenario Catalogue for CAVs.

4. ASAM OpenODD concept paper (ASAM, 2021): ASAM OpenODD studied the requirements for a first abstract ODD domain language specification proposing alternatives for its syntax and semantics which enables machines to interpret and perform the required ODD interpretation. An important requirement of the ASAM OpenODD specification is that all attributes specified shall be measurable and verifiable.
5. BSI PAS 1883 (BSI, 2021): Provides a taxonomy that can be used to specify ODDs for automated driving systems. It should here be noted that there are currently two international standards under development, namely the ISO/DIS 34503:2022: Clause 8-11 (DRAFT) "Taxonomy for Operational Design Domain for Automated Driving Systems" and SAE J3259 "Taxonomy & Definitions for Operational Design Domain (ODD) for Driving Automation Systems" (WIP), which are expected to further detail the ODD definition and are well aligned with the meta model presented in PAS 1883 (BSI, 2020).

Based on reviewing all the above, Section 2.3.3.1 proposes the adopted Hi-Drive ODD taxonomy and ODD specification format.

2.2.3 Relation to L3Pilot ADF description

L3Pilot deliverable D4.1 "*Description and Taxonomy of Automated Driving Functions*" (Griffon et. al., 2019) was reviewed to check for attributes proposed within it for summarizing an ADF. Many fields in the proposed Hi-Drive ADF description template (to be introduced in Section 2.3.3.2.1) are inspired by the L3pilot ADF description format (e.g., elements describing AD activation/deactivation, functionality, control transition, etc.). However, in our work the description is much more condensed to fit in a tabular format hosted in the project's file-sharing web tool. Additionally, the ADF's ODD description, although very similar to L3Pilot ADF "context of use", is separated in our work from ADF description, while the ODD template follows a standardized taxonomy proposed by recent standards (to be introduced in Section 2.3.3.1). Finally, in the Hi-Drive description, description of the enabler technology and how this advances the AD functionality is included.

2.2.4 Hi-Drive Technology Enablers

In Hi-Drive, one of the core objectives of the evaluation is to assess the effects of technology enablers on AD performance and availability when these enablers are integrated in current CAD vehicle functions. The ultimate goal is to leverage on the most-advanced technology enablers to make CAD vehicle functions able to operate in defragmented ODDs and in various driving scenarios by i) reducing the number of take-over requests to human drivers, ii) addressing driving situations beyond vehicle' sensor range and iii) increasing the ODD awareness during runtime. Hi-Drive Technology Enablers are grouped in four thematic areas and twelve groups as shown in Table 2.2.

Table 2.2: Technology Enablers Groups (TECH = Technology, METH = Methodology, TOOL = SW tool)

TECH ENABLER THEMATIC AREA	TECH ENABLER GROUPS
VEHICLE COMMUNICATION	E.2.3.1 V2V Vehicle-to-Vehicle Communication (TECH)
	E.2.3.2 V2I Vehicle-to-Infrastructure and Infrastructure-to-Vehicle Communication (TECH)
	E.2.3.3 Vehicle to Cloud (Edge and Core) (TECH)
	E.2.3.4 Vehicle Intention Communication (TECH)
VEHICLE HIGH PRECISION POSITIONING & LOCALIZATION	E.2.4.1 Geo-referenced Cloud Services (TECH)
	E.2.4.2 Sensor Fusion for Localization (TECH)
VEHICLE COMMUNICATION CYBERSECURITY	E.2.5.1 TARA Threat Analysis and Risk Assessment (METH)
	E.2.5.2 V2X Cyber-Risk Mitigation (TECH)
VEHICLE MACHINE LEARNING	E.2.6.1 CAD ML Toolkit (TOOL)
	E.2.6.2 CAD ML Perception, Object Detection and Classification (TECH)
	E.2.6.3 CAD ML Decision Making (TECH)
	E.2.6.4 CAD ML Driver Monitoring (TECH)

2.3 Hi-Drive ADF description and UC catalogue generation process

For generating the Hi-Drive UC catalogue, three types of information had to be provided as shown in Figure 2.2:

- **a.** Description of Hi-Drive ADF instances: here the SW/HW of the system under test and the targeted ODD is briefly described by each ADF owner.
- **b.** Description of UCs for testing a particular ADF instance: here an abstract description of the interaction between the Hi-Drive AD function and its environment in order to reach a particular goal is provided that serves the purpose of Hi-Drive ADF instance testing.
- **c.** Description of a set of test scenarios applicable for each UC: here more details about actors, actions, and events for each UC are provided through a test scenario format.

In order to collect this type of information, two templates have been implemented, one to be used for the ODD specification (see Section 2.3.3.1), and a composite one to be used for the description of the ADF instance and its associated UCs and test scenarios (see Section 2.3.3.2).

The process to generate the Hi-Drive UC catalogue starting from a set of ADF instances that were described via the template of Table 2.4 included three steps:

Step 1: Each ADF owner uses the UC/Test scenario template to describe the UCs and test scenarios to be considered in its future Hi-Drive operations. Based on the template of Table 2.5, complementary info on SuT limitations, test scenario execution domain, and test scenario evaluation area are also provided for each UC giving a preliminary picture of the ADF evaluation purpose and context.

Step 2: Collection of information from each ADF owner leads to an internal table where all ADFs are listed and get a unique ID. Another table shows the set of all Hi-Drive UCs and test scenarios.

Step 3: The D3.1 core editing team checks and merges all the information collected from step 2, based on the criteria listed in Section 2.3.1 that follows, creating a Hi-Drive ADF catalogue (see Chapter 3) and a Hi-Drive UC catalogue (see Chapter 4).

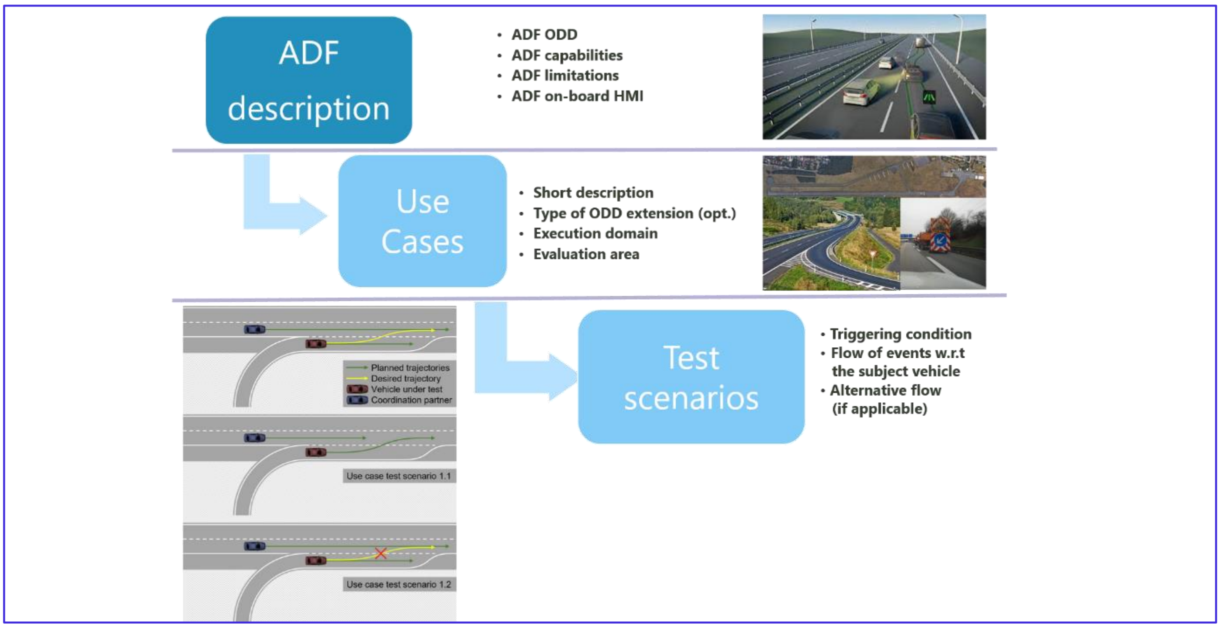


Figure 2.2: From ADF description to test scenarios

2.3.1 From Use Cases to Test Scenarios

As stated in the draft EU regulation (Ares 2667391, 2022), "the combination of objects, events and their potential interaction, as a function of the ODD, constitute the set of nominal scenarios pertinent to the ADS under analysis. The identification of nominal scenarios is not limited to traffic conditions but also covers environmental conditions, human factors, connectivity." Taking this general approach and based on the test scenario format proposed by ISO/DIS 34502 0, where the test scenario flow of events starts with a triggering condition, guidelines for forming test scenarios were derived.

Each test scenario is described starting from a triggering "event", abbreviated as 'trigger' by ISO 34501 (ISOa, 2022). The trigger can be an ODD condition change (e.g., weather deterioration) or a specific traffic interaction with another road user in the vicinity of the ego vehicle (e.g., a cut-in vehicle) or a driving manoeuvre initiated by the ego vehicle (e.g., a take-over of the leading vehicle). More specifically:

- Based on ISO/DIS 34501, for each formulation of the UC's test scenarios, a triggering condition and a set of alternative-event flows is reported.
- A "trigger" is here loosely defined as a driving environment condition change, such as ODD dynamic entities or actions by other traffic agents, which then activates an action by the AV; regarding open road tests, we are using the term 'trigger' in a not-so-strict manner: in reality, no actual trigger is activated; changing of conditions simply does or does not occur.
- When two very similar UCs are merged, the test scenarios are also merged to form a superset.
- Test scenarios are collected by all ADF owners using the UC/Test scenario template described in Section 2.2.3.2.2.

Note 1: Based on the adopted methodology, describing test scenarios for later execution on a test track is straightforward. However, in case the Hi-Drive experiment only includes real-world driving (where there is no possibility of conducting a specific pre-defined test scenario), the test scenarios shall be interpreted as those conditions that can be detected in the data and that render the scenario interesting for investigation/evaluation in the next phase of the project.

2.3.2 Grouping UCs to Enhance Catalogue Readability

After completion of Step 2 described above, where each ADF owner described one to six UCs for testing its ADF instance, a long list of Hi-Drive UCs was gathered which had to be filtered for duplicates (any two UCs that were very similar and could be listed as one UC) and checked for consistency (any UCs missing a clear target or description). On top of this first filtering, a rough empirical grouping of UCs into a smaller set of UC clusters was deemed necessary mainly for two reasons:

1. Presenting and outlining the Hi-Drive UC catalogue to an external audience by summarizing the main ego-vehicle manoeuvres/traffic interactions/ODD areas that the Hi-Drive UC catalogue covers.
2. Supporting the evaluation methodology team to derive meaningful analysis clusters for the work that will follow as part of the Hi-Drive technical and user evaluation.

Therefore, as schematized in

Figure 2.3, several grouping criteria have been applied to the pool of Hi-Drive UCs collected by the ADF owners in order to come up with the final Hi-Drive UC catalogue per ADF type. Grouping criteria are listed hereafter:

- To avoid many slightly different UCs, grouping of similar UCs (similar target and ODD context) under a merged UC is performed. The goal is to create a UC catalogue where each UC is semantically distinct from another.
- Splitting of an abstract UC (e.g., urban driving) into more detailed UCs (e.g., urban driving on a straight road segment versus turning in an intersection) is recommended, as we try to be specific on the driving situations we want to study. In particular:
  - We differentiate between AV-to-VRU and AV-to-vehicle interaction if we believe that logged data will support this kind of actor-based analysis (more suitable for the test tracks experiments).
  - We differentiate between cooperative/non cooperative ADFs, since studying the ODD defragmentation through connectivity is an important project objective.
  - We differentiate between signalized/non-signalized intersections, since they represent quite different traffic contexts.
  - We differentiate among driving manoeuvres if needed (lane keeping vs overtaking)

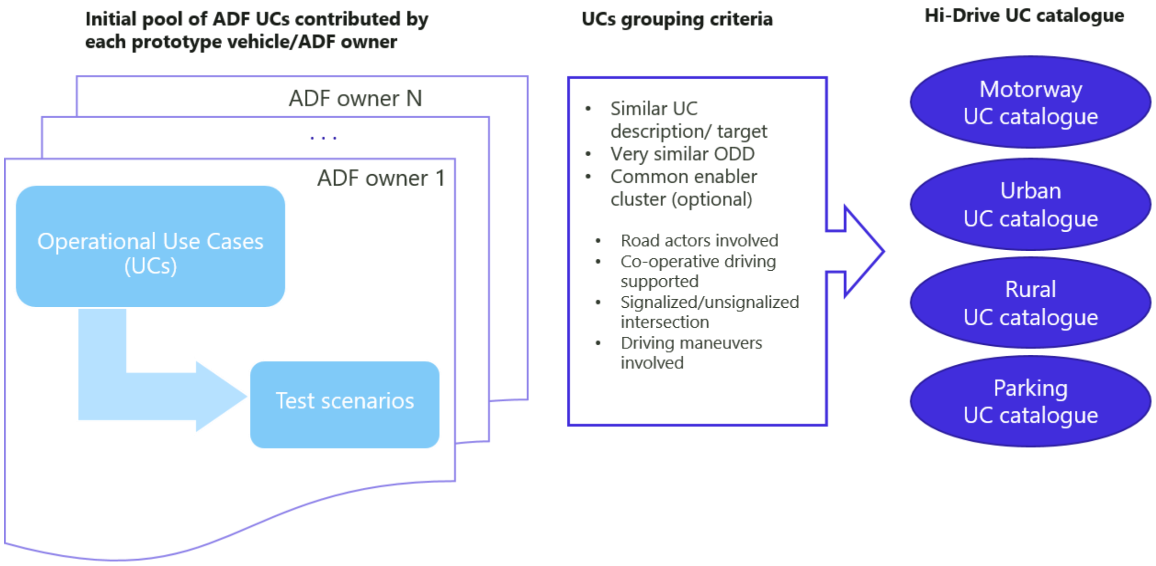


Figure 2.3: Hi-Drive UC catalogue generation via grouping of ADF UCs

2.3.3 Proposed Templates

There are two templates proposed by this work for collecting information on the ADF instances and associated test scenarios: the first is dedicated to the ODD specification of each ADF instance, presented in Section 2.3.3.1. The second is dedicated to a description of the ADF instance and its associated UC/Test scenarios, presented in Section 2.3.3.2.

2.3.3.1 ODD specification template design

<u>ODD taxonomy:</u> An Operational Design Domain (ODD) taxonomy is needed before defining our ADF ODD. This usually consists of a tree-like structure of attributes with binary or numerical values from a predefined range of values as in BSI PAS 1883 (BSI, 2020). The designer of the system (here the system's tester too) is invited to fill in the ODD template to report the detailed operational conditions where its AD system can be deployed. Based on light adaptations of the taxonomy defined in BSI PAS 1883 (BSI, 2020), and combining elements from the two ODD-related technical reports by AVSC (SAE AVSC, 2020) and MUSICC (Myers, 2020), the Hi-Drive ODD taxonomy, which is presented in Figure 2.4, was defined. Some of the modifications with respect to BSI PAS 1883 that were considered appropriate in the context the Hi-Drive operational context include:

1. For parent category 'Scenery':
    - The category was renamed 'Roads' (for audiences not familiar with scenario representation terms).

- The attribute ‘Ramps (on/off motorway)’ was added to the child category ‘Road type/motorways’ (because Hi-Drive is developing technology enablers especially for motorway entry/exit).
- The attribute ‘lane marker quality’, borrowed from SAE AVSC report (SAE AVSC, 2020), was added to the child category 'Lane specification' (because Hi-Drive is developing enablers able to identify deteriorated lane marking conditions).
- The attributes ‘rush-hour affected zones’ and ‘local on-road hazard affected zone" were added to the ‘Zones’ child category.

2. For parent category 'Environmental conditions':

- Child category ‘Connectivity’ was not used, since in Hi-Drive, connectivity attributes needed by the ADF are already described in the enabler technology specification. (Note that GNSS signal interruption is already covered by the ODD element ‘Interference zones’ under the ‘Zones’ child category).

3. For parent category ‘Dynamic elements’:

- The category title was changed to ‘Road Users’ for clarity, since other ODD attributes belonging to the categories ‘Environmental conditions’ or ‘Scenery’, like weather, are also dynamic.
- Child category "traffic" is further split into ‘Vehicles’ and ‘VRUs’.
    - New traffic agent types were added based on the SAE AVSC report (SAE AVSC, 2020).
- Child category ‘Subject vehicle’ was replaced by ‘Ego vehicle’, split into passenger car or truck, borrowed from the MUCICC report (Myers, 2020).

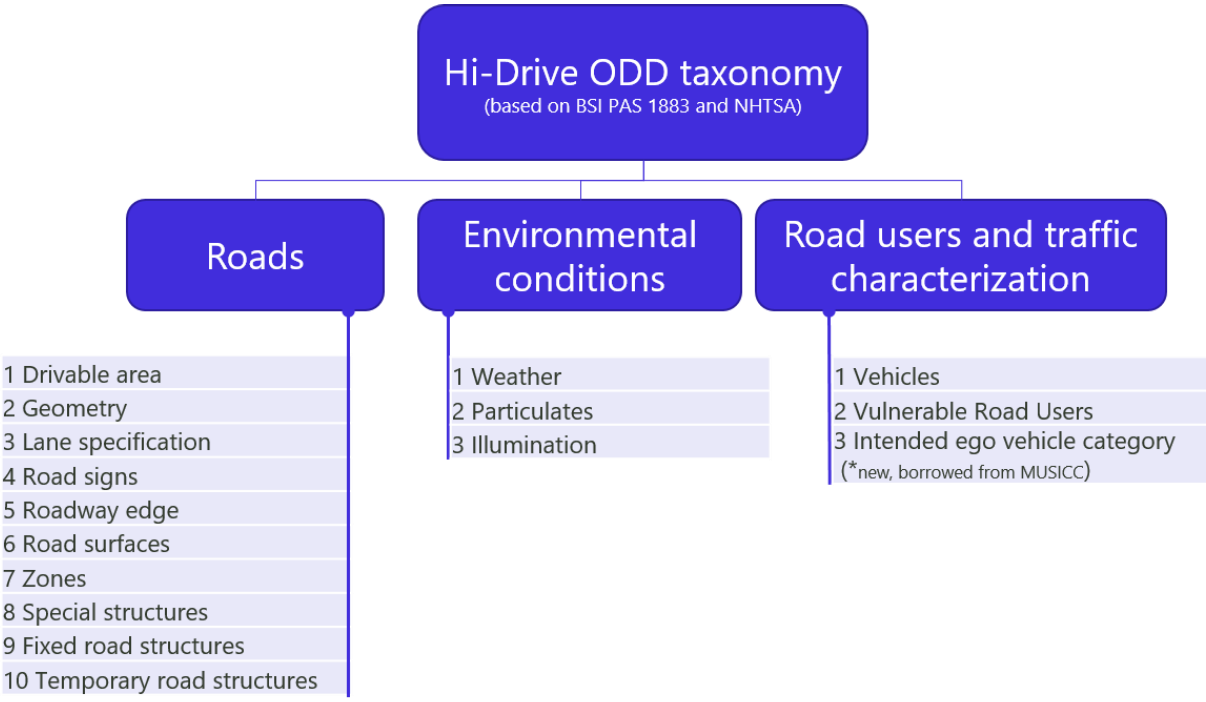


Figure 2.4: Illustration of the Hi-Drive ODD taxonomy

The complete ODD list of attributes is given in the three ODD tables of Annex 2 that constitute the Hi-Drive ODD specification.

<u>ODD specification integrating tags relevant for evaluation:</u> In Hi-Drive, a significant technical evaluation aspect is how the technology enablers (developed, integrated into the prototype vehicles of the project, and evaluated by the project) perform under nominal ODD conditions, and whether ODD extension via support for new ODD attributes (i.e., not handled by the ADF without the enabler), can be achieved during testing. For this reason, and in line with the project's research questions as described in the recently published Hi-Drive deliverable D4.1 (Metz, 2022)), for each Hi-Drive ADF a customized ODD spec file is created, where each ODD attribute is tagged as belonging to one of the following three types:

1. Nominal ODD: All operational conditions the ADF was designed to safely handle when the Hi-Drive project started (e.g., a motorway ADF deals with motorway sections with three lanes and fairly good weather, excluding tunnels and entries/exits).
2. Performance ODD: A subset of nominal ODD conditions describing the Hi-Drive challenging operational conditions in which ADS performance (e.g., lateral stability or ride comfort) after enabler integration will be tested (e.g., motorway sections with three lanes, some with poor-quality lane markings and fairly good weather, excluding tunnels and entries/exits).

3. Extended ODD: An additional set of ODD attributes not handled before Hi-Drive but now possible due to the project's enabler integration (e.g., adverse weather conditions added, on-ramp road segment added, special or temporary road structure or new type of traffic agent that is now handled, etc.).

2.3.3.2 ADF instance template and associated UC/Test scenario template

In Hi-Drive, a system-centric approach was followed where first we defined the system under test (i.e., advanced ADF features to be tested), after which for each ADF instance a small set of test UCs and scenarios were described. The template therefore consists of two main tables: one for the ADF instance description which hosts information about the ODD, ADF technical characteristics and the user role (see Table 2.4), and the other dedicated to the description of applicable UCs and associated test scenarios (see Table 2.5).

The template makes use of the following pre-defined types:

a) Four types of ADF are considered: Motorway (M), Urban (U), Rural (R), and Parking (P).

b) Twelve types of ODD extension were identified across the set of Hi-Drive ADFs as depicted in Figure 2.5:

ODD extension types

- ☐ New type of road environment (e.g., urban)
- ☐ On-ramp
- ☐ Off-ramp
- ☐ Temporary or special road structure/road hazard
- ☐ Challenging environmental conditions (heavy rain or snow)
- ☐ Challenging road condition (deteriorated lane markings, shadows on road surface)
- ☐ New type of traffic agent (vehicle or VRU)
- ☐ Visibility blockage due to traffic, buildings or road furniture
- ☐ Increased traffic volume
- ☐ GNSS interruption
- ☐ Smart traffic light
- ☐ Cross-border connectivity

Figure 2.5: UC template field 'ODD extension types'

c) Three types of UC execution domain have been considered as depicted in Figure 2.6 (for further details on the Hi-Drive operations, see Hi-Drive deliverable D5.1 (Sauvaget et. al, 2022).

d) Three types of UC execution domain have been considered as depicted in Figure 2.6 (for further details on the Hi-Drive operations, see Hi-Drive deliverable D5.1 (Sauvaget et. al, 2022):

Test scenario execution domain

- ☐ Open Road
- ☐ Controlled Track
- ☐ Virtual

Figure 2.6: UC template field 'Test scenario execution domain'

e) The following types ofUC evaluation domain have been considered, as depicted in Figure 2.7 (for further details on the Hi-Drive research question groups for the experimental analysis, see Hi-Drive deliverable D4.3 (Sintonen et. al, 2023):

Test scenario evaluation domain

- ☐ Safety
- ☐ Performance
- ☐ ODD extension
- ☐ System-user interaction
- ☐ Road user interaction
- ☐ Other

Figure 2.7: UC field: 'evaluation domain'

Finally, an auxiliary table (its structure is shown in Table 2.3) is used for mapping each ADF instance to the technology enabler cluster IDs and associated UCs to be used for our internal reference and for creating the summary tables of Chapters 3 and 4. Instructions and examples for filling in the two tables were provided to all ADF owners.

Table 2.3: Auxiliary table for mapping technology enabler clusters, UCs, and test scenarios to ADF instances

ADF ID	Technology enabler group(s)	UC ID(s)	Test scenario set

2.3.3.2.1 ADF instance template

The ADF instance template is provided in Table 2.4. Guidelines for filling in the template are integrated within the template.

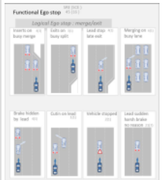
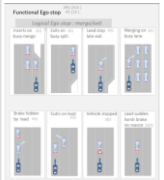
Table 2.4: ADF template

<table>
<tr><td>[ADF Type: M, U, R, P].ADF.[id]</td><td colspan="3">Focus area of Hi-Drive Testing: Motorway chauffeur with support of […] for […] sections / conditions</td></tr>
<tr><td>Technology enabler</td><td colspan="3">Please describe briefly how the enabler is integrated with the existing on-board ADS (perception layer, decision making layer, control layer, runtime safety verification layer)</td></tr>
<tr><td>ODD specification</td><td colspan="3">Please provide a short description of the ODD you target in Hi-Drive Operations. Additionally:
Special ODD conditions to be tested: ▪ Testing ODD transition (e.g., weather turns from sunlight to snow): y/n
▪ Testing ODD new attribute that was not handled before (e.g., motorway on-ramp entry): y/n
▪ Testing ODD violation (e.g., deteriorated lane markings): y/n</td></tr>
<tr><td>Advanced ADF capabilities / MRM</td><td>Please describe in free text what your ADF+Enabler is capable of handling (lane changes, merging to motorway traffic, driving in signalized intersection or roundabout, etc.).</td><td>Speed range</td><td>In km/h</td></tr>
<tr><td>Activation condition</td><td>Please describe the conditions when the ADF can be activated.
(Is lead vehicle existence a pre-requisite? Is driver alert status a pre-requisite?)</td><td>Conditions for automated de-activation</td><td>Please describe when the system is automatically de-activated (e.g., ODD exit detection criteria, system malfunction).</td></tr>
<tr><td>List of ADAS active</td><td colspan="3">Please describe any ADAS active before and during ADS activation.</td></tr>
<tr><td>Activation by user</td><td>Please describe how the vehicle indicates that automation is available.</td><td>De-activation by the user</td><td>Please describe how the ADF may be de-activated by the user.</td></tr>
<tr><td>ToR activation</td><td colspan="3">If the system decides to de-activate the ADS, does it issue a ToR request to the driver or does it perform an MRM? How many seconds is the ToR active?</td></tr>
<tr><td>Type/location/purpose of HMI used</td><td colspan="3">▪ Auditory: Please describe type/location/purpose of this type of HMI (if applicable).
▪ Haptic: Please describe type/location/purpose of this type of HMI (if applicable).
▪ Visual: please describe type/location/purpose of this type of HMI (if applicable).
    ▪ Please provide pictures, too.
▪ Other: Please describe type/location/purpose of this type of HMI (if applicable).</td></tr>
<tr><td>Driver role</td><td colspan="3">Please describe the driver role during the trip and during ADS activation.
What is the driver allowed to do during automation, i.e., engagement in other tasks, location of these tasks (e.g., centre console, own device, etc.).</td></tr>
<tr><td>Safety driver seat position and role</td><td colspan="3">Please describe safety driver seat position and role during trip and during ADS activation. Is annotation of interesting events an option via a handheld device or vehicle HMI?</td></tr>
<tr><td>Optional features activation (if applicable)</td><td colspan="3">Please describe any conditional features that can be (de-)activated by the driver in addition to the ADS features set by default.</td></tr>
</table>

2.3.3.2.2 UC/Test scenario template

The UC/Test scenario template is provided in Table 2.5, including auxiliary information on the test scenario execution environment.

Table 2.5: UC/Test scenario catalogue template (blue background: main info field;, grey background: auxiliary info fields)

Use cases (UCs) associated with an ADF and test scenarios (TS) associated with each UC						Operations preview		
UC ID [UC.class]. [id]	UC Title	UC short description	UC test scenarios (Description starts with "trigger: event that initiates or ends an action" per *ISO/DIS 34504*)	UC test scenario sketch (can be a scene or a scenario sketch)	Technology enabler group to be tested	SuT **limitations** for this particular UC (optional)	Test scenario execution domain (please tick if applicable)	Test scenario evaluation domain (please tick if applicable)
Example: *M1*	*Example:* *Cooperative lane merging via V2V*	*Example:* *On-ramp AV cooperates with a motorway vehicle, by evaluating broadcasted planned trajectory.*	*Example:* *Trigger: On-ramp vehicle sends merge request.* *1. Please insert TS here* *2. Please insert TS here* *3. Please insert TS here*		*Example:* *E.2.3.1* *V2V Vehicle-to-Vehicle Communication*	Free text [bullets] --- *Examples: manoeuvres not supported, known hazardous situations/unsafe control actions to be avoided if available from prior testing, fail-cases based on simulation testing)*	☐ Open Road ☐ Controlled Track ☐ Virtual	☐ Safety ☐ Performance ☐ ODD extension ☐ System-user interaction ☐ Road user interaction ☐ Other
			Example: *Alternative Trigger: …* *1. Please insert TS here* *2. Please insert TS here*					

Guidelines for formulating the description of UCs and associated test scenarios for the template of Table 2.5 are provided in Table 2.6.

Table 2.6: Guidelines for UC/Test scenario formulation

How to formulate your UC (Table C of the template)
UC title field**:** (ADF task) **on** (road Environment) **via** (technology enabler if applicable) Examples: *(class Motorway):* M.1 - Cooperative Lane Merging on Motorway entry via V2V; M.2 - Lane keeping in Motorway tunnels via Camera and Lidar fusion. *(class Urban):* U.1 - Cooperative Left-Hand Turn in unsignalized intersection with pedestrian and vehicle presence via V2I. **UC short description** field**:** Must further detail the main 'ADF task' by outlining the interactions with other road users. **UC test scenarios** field***:*** Must describe a trigger condition or event and then different sequence of actions between the subject vehicle (the ego vehicle) and other road users. (Formulation follows ISO/DIS 34504 (2023)). Example: UC X – Cooperative merging on motorway entrance UC X Test scenario description: Trigger: Motorway vehicle receives merge request. • TS.1 The motorway vehicle accepts the merging request and decelerates. • TS.2 The motorway vehicle accepts the merging request and changes one lane to the left. • TS.3 The motorway vehicle rejects the merging request and continues without decelerating.

3 Hi-Drive ADF instances

3.1 Introduction

This section hosts a summary description of the Hi-Drive ADF instances based on the information collected using the template described in Section 2.2.3. A more detailed but brief one-page description of ADF instances is given in Annex 1 of this deliverable.

Hi-Drive ADF instances are grouped per operational road environment forming four subsections, namely Motorway, Urban, Rural, and Parking ADFs (Sections 3.2 – 3.5). It is important to note that in this report, the ADF owner's identity is fully anonymized and therefore only ADF instance-unique IDs will be reported. For this purpose, each ADF instance is assigned a unique ID. An example is M.ADF1, where "M" denotes the ADF type [Motorway] and ADF1 is the unique ID of this ADF instance (see first row of Table 2.4).

Guidelines on how to read the ADF instance summary tables of Sections 3.2 – 3.5:

- It is recommended first to visit Annex 1 to understand what an ADF description is in the Hi-Drive context; recalling that the ADF instance description template was presented in Table 2.4.
- Most Hi-Drive Driving Functions are categorized as Driving Automation Level 3 (per SAE J3016) and represent an advanced ADF variant after the Hi-Drive enabler technology integration into the original ADF instance. However, we also include some prototype ADF instances developed for testing perception and decision-making subsystems which either host a Hi-Drive enabler technology that runs in so-called 'shadow mode' (i.e. the module runs in an open loop without being integrated with the AD system), or there is no AD system and the enabler is in shadow mode while the vehicle is manually driven. These are denoted with an asterisk '*' (e.g., M.ADF6*).
- Regarding the column 'SuT limitation' appearing in the tables of Sections 3.2 – 3.5, reacting to an emergency vehicle is a limitation for all ADF instances under test. The same holds for adverse weather conditions (heavy rain and snow) and night-time, unless otherwise stated in the column 'target OD condition'. Hence those three broadly applicable limitations will not be reported in the column 'SuT limitation'.
- Regarding the column 'Target OD condition' appearing in the tables of Sections 3.2 – 3.5, it does not include the main road environment: motorway, urban, or rural, since this is implicitly inferred by the ADF class.
- Regarding the last column 'User aspects': if Yes is indicated, this mean that in the evaluation purpose, human factors are explicitly considered. It should be noted that

additional use cases and test scenarios crafted specifically for driver simulator experiments or Wizard of Oz studies which do not necessary involve an AD vehicle prototype are also considered within the project as part of Sub-Project 6.

3.2 Motorway and peri-urban Motorway Hi-Drive Functions

In Hi-Drive, various existing Motorway-chauffer ADF instances have been upgraded by integrating a set of enabler technologies developed within the project, leading to nine advanced ADF instances and three shadow-mode AD subsystems, outlined in Table 3.1, which focus on the ADF system under test: its advanced features, its target OD, the enabler technology integrated, its speed range, and any SuT limitations (see second to sixth columns). The last column indicates whether the operation is also targeting user aspects.

Information about enabler technology clusters adopted by each ADF instance is provided in Table 3.2 below. A more detailed description for each Motorway ADF, providing full ODD description, activation/de-activation conditions and other ADF features, defined by the ADF instance description template presented in 2.3.3.2.1, is provided in Annex A1.1.

Table 3.1: Summary of Motorway and peri-urban Motorway ADF instances (for colouring of the technology enabler groups, please refer to Section 2.2.4 or the next table)

ADF instance ID	Advanced AD feature under test	Target OD condition (where AD performance / AD availability will be measured)	Technology enabler group active				Speed range (km/h)	SuT limitation (when applicable)	User aspects (Yes/No)
			1	2	3	4			
M.ADF1 **M.ADF2**	▪ Cooperative lane management in motorway entry/merging areas via V2V (ETSI MCM) (cooperation among two AV actors is considered) ▪ Automated lane change (supported only by M.ADF2)	On-ramp	x				60-130 km/h on motorway; 30-100 km/h on on-ramp	▪ Connectivity continuum ▪ No automated lane change ▪ Lane markers quality must be good. ▪ Curve not too steep ▪ No road construction crossing	N
M.ADF3	▪ Cooperative lane management in motorway entry/merging areas via V2V (ETSI MCM, CAM) (Cooperation among two or three actors, one being an AV and one or two of them being a truck, is considered)	▪ Urban motorway ▪ On-ramp ▪ Cooperation with vehicle and/or truck	x		x		0-60 km/h	▪ Connectivity continuum ▪ Lane markers quality must be good. ▪ Curve not too steep ▪ No road construction crossing	
M.ADF4	▪ Cooperative off-ramp driving via I2V (ETSI DENM) ▪ Cooperative overtaking via V2V (ETSI CAM, CPM) ▪ Localization under GNSS disturbances ▪ Hazard warning reaction on motorway via I2V connectivity and driver monitoring ▪ Monitoring of cooperative on-ramp merging for V2V or I2V cyber-attack and mitigation ▪ Automated lane change	▪ Motorway with traffic in daylight and at night ▪ On-ramp ▪ Off-ramp ▪ GNSS interruption ▪ Temporary or special road structure/road hazard ▪ Rain /fog ▪ Bridge over the road	x	x	x	x	0-120 km/h	▪ Connectivity continuum ▪ Lane marker quality must be good. ▪ No road construction crossing	N

ADF instance ID	Advanced AD feature under test	Target OD condition (where AD performance / AD availability will be measured)	Technology enabler group active				Speed range (km/h)	SuT limitation (when applicable)	User aspects (Yes/No)
M.ADF5	Cooperative lane management in motorway entry/merging areas via V2V (ETSI MCM, cooperation among two AV actors is considered) ▪ Cooperative speed/route adaptation responding to hazard (ETSI DENM, IVIM) ▪ Cooperative speed/route adaptation responding to dynamic road signage notification (ETSI DENM, IVIM)	▪ On-ramp ▪ Construction site ▪ Road hazard	x	x			60-130 km/h	▪ Connectivity continuum ▪ No automated lane change ▪ Lane marker quality must be good. ▪ No road construction crossing	N
M.ADF6*	▪ ODD near-exit identification (enabler in shadow mode, works offline) ▪ Driving scenario identification e.g., aggressive cut-in by another vehicle (enabler in shadow mode, trained in simulation) (Conceived to support a continuous runtime safety concept similar to situational awareness proposed by ISO 21448)	Motorway with traffic and sunlight or light rain ODD exits: ▪ Motorway exit ▪ Road construction site ▪ Deteriorated lane markings ▪ Adverse weather conditions		x		x	0-130 km/h	▪ Presence of lead vehicle required ▪ no automated lane Change ▪ No lane merging ▪ No road construction crossing	N
M.ADF7	▪ Localization under GNSS or visibility disturbances ▪ Motorway to urban road lane merging ▪ Automatic transition from Highway assist to Traffic-jam assist function ▪ Driver monitoring	▪ Motorway with traffic and sunlight or light rain ▪ Challenging road condition (deteriorated lane markings, shadows on road surface) ▪ GNSS shortage ▪ Road hazard ▪ Tunnel	x	x		x	0-130 km/h	▪ No lane merging ▪ No road construction crossing	Y
M.ADF8	▪ Motorway ACC with front free area estimation by radar (SAE L2 AD level)	▪ Motorway with traffic and sunlight or light rain				x	0-100 km/h	▪ No automated lane change ▪ No lane merging	N

ADF instance ID	Advanced AD feature under test	Target OD condition (where AD performance / AD availability will be measured)	Technology enabler group active				Speed range (km/h)	SuT limitation (when applicable)	User aspects (Yes/No)
		▪ Rain/fog ▪ Tunnel ▪ Bridge over the road ▪ Road construction site							
M.ADF9	▪ Localization during tunnel crossing ▪ Localization during construction area crossing ▪ ADF adjusts the speed limit according to the road signs ▪ ADF keep distance to other road users in the right lane (acceleration, deceleration) ▪ ADF monitors its position on the existing HD-map	▪ Tunnel		x		x	50-80 km/h	ADF function is already activated before tunnel entry with good localization	N
M.ADF10	▪ Localization for interchanging from one motorway to next motorway following navigation info ▪ Automated lane change	▪ Motorway with traffic and sunlight or light rain ▪ On-ramp/Off-ramp (motorway interchange)		x			0 – 130 km/h	▪ Navigation info available ▪ No road construction crossing	N
M.ADF11*	▪ Driver monitoring (enabler in shadow mode)	▪ Motorway with traffic and sunlight or light rain ▪ Peri-urban separated carriageways with traffic and sunlight				x	0-130 km/h 0-60 km/h (applicable only in urban motorway)	▪ No automated lane change ▪ No lane merging ▪ No road construction sites ▪ No tunnels	Y
M.ADF12*	▪ On-ramp merging (ADF and enabler in shadow mode)	**f)** Motorway with traffic and sunlight or light rain **g)** On-ramp				x	0-100 km/h	N/A	N

Table 3.2: Technology enabler groups supported by each Motorway ADF instance

TECH ENABLER THEMATIC AREA	TECH ENABLER GROUP	ADF instances											
		1	2	3	4	5	6	7	8	9	10	11	12
VEHICLE COMMUNICATION	E.2.3.1 V2V Vehicle-to-Vehicle Communication	x	x	x	x	x							
	E.2.3.2 V2I Vehicle-to-Infrastructure and Infrastructure-to-Vehicle Communication				x	x		x					
	E.2.3.3 Vehicle to Cloud (Edge and Core)					x	x	x					
	E.2.3.4 Vehicle Intention Communication												
VEHICLE HIGH-PRECISION POSITIONING & LOCALIZATION	E.2.4.1 Geo-referenced Cloud Services							x					
	E.2.4.2 Sensor Fusion for Localization				x	x		x		x	x		
VEHICLE COMMUNICATION CYBERSECURITY	E.2.5.1 TARA Threat Analysis and Risk Assessment			x	x								
	E.2.5.2 V2X Cyber-Risk Mitigation				x								
VEHICLE MACHINE LEARNING	E.2.6.2 CAD ML Perception, Object Detection and Classification								x	x			x
	E.2.6.3 CAD ML Decision Making							x					
	E.2.6.4 CAD ML Driver Monitoring				x			x				x	

3.3 Urban Hi-Drive Functions

In Hi-Drive, various existing Urban-chauffer ADF instances have been upgraded by integrating a set of enabler technologies developed within the project leading to nine advanced ADF instances and two shadow-mode AD subsystems outlined in Table 3.3, focusing on the ADF system under test: its advanced features, its target OD, the enabler technology integrated, its speed range, and any SuT limitation (see second to sixth columns). The last column indicates whether the operation is also targeting user aspects.

Information about enabler technology clusters adopted by each ADF instance is provided in Table 3.4 below. A more detailed description for each Urban ADF, providing full ODD description, activation/de-activation conditions, and other ADF features, defined by the ADF instance description template presented in 2.3.3.2.1, is provided in Annex A1.2.

Table 3.3: Summary of Urban ADF instances (for colouring of technology enabler groups, please refer to Section 2.2.4 or the next table)

ADF instance ID	Advanced AD feature under test	Target OD condition (where AD performance / AD availability can be measured)	Technology enabler group active				Speed range (km/h)	SuT limitation (when applicable)	User aspects (Yes/No)
U.ADF1	Green Light Optimized Speed Assist (GLOSA)	Smart traffic light zone	x				0-60 km/h	High acceleration not allowed.	N
U.ADF2	Non-signalized intersection crossing using info generated from local infrastructure (ETSI CPM)	Urban non-signal. intersections	x				0-50 km/h	V2X/GNSS coverage depends a lot on the environment.	N
U.ADF3	▪ Automated lane change, on-ramp/off-ramp driving to/from peri-urban 'motorway' ▪ Roundabouts and intersections with 'yield' or 'stop' traffic signs within city ▪ Signalized intersection crossing via I2V within city	▪ Peri-Urban 'motorways' - On-ramp - Off-ramp ▪ Suburban roads ▪ Urban non-signalized intersections ▪ Urban signalized intersections ▪ Urban roundabouts	x	-	x	-	0-60 km/h	Road construction zones can be included only if known *a priori*.	N
U.ADF4	▪ GLOSA support ▪ Localization under GNSS disturbances	▪ Urban roads ▪ Urban signalized intersections ▪ GNSS signal interruption	x	x			0-50 km/h	Connectivity continuum lane marker quality must be good. Low vehicle speed for re-localization.	N
U.ADF5	Cooperative speed/route adaptation responding to V2V info/notifications from a vehicle ahead (ETSI CAM/DENM)	▪ B-Roads incl. high curvature and slippery road segments ▪ Road hazard beyond FoV ▪ Traffic jam beyond FoV	x				0-50 km/h	▪ No road construction sites. ▪ V2V / GNSS coverage depends a lot on the environment.	N
U.ADF6	Cooperative signalized intersections crossing via V2I (ETSI CAM/DENM/MAPEM/SPATEM)	▪ Urban signal. Intersections equipped with I2V capabilities	x				0-60 km/h	▪ Smart intersection availability.	N

ADF instance ID	Advanced AD feature under test	Target OD condition (where AD performance / AD availability can be measured)	Technology enabler group active				Speed range (km/h)	SuT limitation (when applicable)	User aspects (Yes/No)
U.ADF7	Vision-based AD incl. automated lane change	▪ Urban straight and curvy roads ▪ Non-signal. intersections left and right turns / Roundabout ▪ Crossroads with traffic lights ▪ Rain				x	0-70 km/h	Available HD map.	N
U.ADF8	▪ Communication by lighting eHMI to crossing pedestrian ▪ Communication by lighting eHMI to following driver (frequent stops)	▪ Urban roads ▪ Urban non-signal. pedestrian crossing ▪ Daylight, low ambient lighting and artificial light illumination conditions	x				0-50 km/h	Unfavourable combination of high ambient illumination and sunlight	Y
U.ADF9	▪ Cooperative roundabout crossing ▪ Cooperative re-routing due to hazard notification (Via collective perception offered by ETSI CPM/CAM/DENM)	▪ Urban single carriageway (two lanes) with good lane markings ▪ Pedestrian crossings with and without roadside signals ▪ Roundabouts with low traffic	x			x	0-30 km/h	Availability of I2V communication throughout the manoeuvre	N
U.ADF10*	Modelling human driver intention in pedestrian crossings to later support implicit communication of AV to VRUs. (Enabler in shadow mode, manual driving)	▪ Pedestrian crossings				x	0-70 km/h	N/A	Y
U.ADF11*	▪ Localization under GNSS disturbances ▪ Forecasting satellite availability (Enabler in shadow mode, manual driving)	▪ GNSS signal interruption		x				N/A	

Table 3.4: Technology enabler groups supported by each Urban ADF instance

TECH ENABLER THEMATIC AREA	TECH ENABLER GROUP	ADF instances										
		1	2	3	4	5	6	7	8	9	10	11
VEHICLE COMMUNICATION	E.2.3.1 V2V Vehicle-to-Vehicle Communication					x						
	E.2.3.2 V2I Vehicle-to-Infrastructure and Infrastructure-to-Vehicle Communication	x		x	x		x					
	E.2.3.3 Vehicle to Cloud (Edge and Core)		x							x	x	
	E.2.3.4 Vehicle Intention Communication								x			
VEHICLE HIGH-PRECISION POSITIONING & LOCALIZATION	E.2.4.1 Geo-referenced Cloud Services											x
	E.2.4.2 Sensor Fusion for Localization				x							x
VEHICLE MACHINE LEARNING	E.2.6.2 CAD ML Perception, Object Detection and Classification			x				x		x	x	
	E.2.6.3 CAD ML Decision Making											
	E.2.6.4 CAD ML Driver Monitoring											

3.4 Rural Hi-Drive Functions

In Hi-Drive, two existing Rural-chauffer ADF instances have been upgraded by integrating a set of enabler technologies developed within the project, leading to two advanced ADF instances outlined in Table 3.5, focusing on the ADF system under test: its advanced features, its target OD, the enabler technology integrated, its speed range, any SuT limitation (see second to sixth columns). The last column indicates whether the operation is also targeting user aspects. Information about enabler technology clusters adopted by each ADF instance is provided in Table 3.5 below. A more detailed description of each Rural ADF is provided in Annex 1.

Information about enabler technology clusters adopted by each ADF instance is provided in Table 3.6 below. A more detailed description of each Rural ADF instance providing full ODD description, activation/de-activation conditions, and other ADF features defined by the ADF instance description template presented in 2.3.3.2.1, is provided in Annex A1.3.

Table 3.5: Summary of Rural ADF instances (for colouring of technology enablers, please refer to Section 2.2.4 or the next table)

ADF instance ID	Advanced AD feature under test	Target OD condition (where AD performance / AD availability can be measured)	Technology enabler group active				Speed range (km/h)	SuT limitation (when applicable)	User aspects (Yes/No)
R.ADF1	▪ Automated lane change ▪ On-ramp/off-ramp driving to/from urban to rural section	▪ Peri-urban - On-ramp - Off-ramp ▪ Suburban roads		-	x	-	0-60 km/h	Road construction zones can be included only if known *a priori*.	N
R.ADF2	Cooperative overtaking via V2V (ETSI CAM, CPM from vehicle in front)	▪ Two-lane/two-directional road ▪ Cooperation with vehicle and/or truck	x				0-60 km/h	V2X/GNSS coverage depends a lot on the environment	N
R.ADF3	▪ Accurate positioning in arctic conditions via error correction service of satellite positioning. Adapting vehicle speed according to jitter related to error correction. ▪ Support of 5G connectivity for cross-border driving testing 5G mobile operator handover Connecting to weather services and reading information from public sources (e.g.m Local Meteorological Institute) in order to tune the CAV environment perception system accordingly.	▪ Rural road affected by heavy snow (snowing or surface with snow)	x	x		x	0-50 km/h	Low traffic volume expected on test routes.	N

Table 3.6: Technology enabler groups supported by each Rural and Parking ADF instance

TECH ENABLER THEMATIC AREA	TECH ENABLER GROUP	Rural ADF instances			Parking ADF instances	
		1	2	3	1,2	3
VEHICLE COMMUNICATION	E.2.3.1 V2V Vehicle-to-Vehicle Communication		x			
	E.2.3.2 V2I Vehicle-to-Infrastructure and Infrastructure-to-Vehicle Communication					
	E.2.3.3 Vehicle to Cloud (Edge and Core)			x		
	E.2.3.4 Vehicle Intention Communication					x
VEHICLE HIGH-PRECISION POSITIONING & LOCALIZATION	E.2.4.1 Geo-referenced Cloud Services			x		
	E.2.4.2 Sensor Fusion for Localization				x	
VEHICLE MACHINE LEARNING	E.2.6.2 CAD ML Perception, Object Detection and Classification	x		x		
	E.2.6.3 CAD ML Decision Making					
	E.2.6.4 CAD ML Driver Monitoring					

3.5 Parking Hi-Drive Functions

In Hi-Drive, three existing Parking-chauffer ADF instances have been upgraded by integrating a set of enabler technologies developed within the project, leading to three advanced ADF instances outlined in Table 3.7, focusing on the ADF system under test: its advanced features, its target OD, the enabler technology integrated, its speed range, any SuT limitation (see second to sixth columns). The last column indicates whether the operation is also targeting user aspects.

Information about enabler technology clusters adopted by each ADF instance is provided in Table 3.8 below. A more detailed description of each Parking ADF instance, providing full ODD description, activation/de-activation conditions, and other ADF features, defined by the ADF instance description template presented in 2.3.3.2.1, is provided in Annex A1.4.

Table 3.7: Summary of Parking ADF instances (for colouring of technology enabler groups, please refer to Section 2.2.4 or the next table)

ADF instance ID	Advanced AD feature under test	Target OD condition (where AD performance / AD availability can be measured)	Technology enabler group active				Speed range (km/h)	SuT limitation (when applicable)	User aspects (Yes/No)
			(dark grey-green)	(green)	(light grey)	(lavender)			
P.ADF1 **P.ADF2**	• Seamless transitioning between outdoor/indoor • Full parking (and un-parking for P.ADF2) manoeuvre execution despite low or no GNSS coverage (SAE Level 4)	• Approaching parking area • Indoor parking site		x			4-8 km/h	Vehicle speed must be particularly low to execute the manoeuvre safely.	N
P.ADF3	▪ eHMI Safety zone ▪ Communicate the vehicle's intentions while manoeuvring to other vulnerable road users	▪ Indoor and ourdoor parking area ▪ VRUs in proximity	x				0-15 km/h	Good weather is mandatory for outdoor parking	Y

3.6 Notes on the Target Operational Domain

In Table 3.1, Table 3.3, and Table 3.5 above, the OD was briefly described for all ADF instances. Annex 1 provides further details on each OD under the field "ODD specification" within each ADF instance card. During the Hi-Drive operations, all listed road environments, namely motorway, urban motorway, rural, urban, and parking will be considered for open road testing or controlled testing on test tracks. Special emphasis will be put on covering new ODD conditions (not previously handled by Hi-Drive prototype ADFs, see e.g., Figure 3.1). Based on the ODD specification files collected by all ADF owners (see Annexes A2.1, A2.2, and A2.3 for the full list of ODD attributes), a set of attributes that extend the nominal ODD of the Hi-Drive ADFs have been collected and are listed in Table 3.8. As shown in the table,

- Around 30 different OD conditions (i.e., child attributes from the adopted ODD taxonomy introduced in Section 2.3.3.1) in which integration of Hi-Drive enablers extends the nominal ODD of the ADFs will attempt to be covered in the Hi-Drive operations. These attributes belong to the three major classes of the ODD taxonomy, namely Roads, Environmental conditions, and Characteristics of other road users.
- OD attributes supported by more than five ADFs (totals shown in bold) are, in order of popularity: Adverse weather/ambient illumination, urban intersections, on-ramps, temporary or special road structure/road hazard/dynamic signage, challenging road conditions (deteriorated lane markings, slippery condition), and GNSS interference zone.
- OD attributes supported by five or less ADF instances are, in order of popularity: Reduced visibility due to road curvature or visibility blockage due to nearby traffic, buildings or road furniture, off-ramps, smart traffic lights, pedestrians, and high traffic density.
- With the exception of cross-border, all other target OD conditions are supported by at least three Hi-Drive advanced ADF instances.

Table 3.8: Summary of challenging ODD conditions targeted

	Number of ADF instances					
	Type of ADF					
OD (where Enablers extend nominal ODD)	**Motorway /Urban Motorway**	**Urban**	**Rural**	**Parking**	**Total**	**ODD attributes considered in ODD "extension" (indicative)**
On-ramp	7	1	-	N/A	**8**	Roads/Drivable Area/Ramps/OnRamp
Off-ramp	2	1	-	N/A	**3**	Roads/DrivableArea/Ramps/OffRamp
Intersection/ Roundabout	2	7			**9**	Roads/DrivableArea/Intersection/Unsignalized Roads/DrivableArea/Intersection/Signalized Roads/DrivableArea/Roundabout
Smart traffic lights	-	3	-	-	**3**	Roads/Zones/Traffic-management/ConnectedTrafficLight
Temporary or special road structure or road hazard or dynamic signage	6	2	-	-	**8**	Roads/DrivableArea/ActTrafficMng/DynamicSignage Roads/SpecialStructure/BridgeAbove; Roads/SpecialStructure/Tunnel; Roads/TemporaryRoadStructure/RoadWorks Roads/Zones/LocalOnRoadHazard/TrafficIncident Roads/Zones/LocalOnRoadHazard/UnusualObject Roads/RoadSigns/InformationSigns/DynamicSignage
Adverse weather (rain, fog or snow) or ambient illumination	5	3	1	-	**9**	EnvConditions/Illumination/Cloudiness EnvConditions/Illumination/PositionOfSun/InFront EnvConditions/Weather/Rainfall/ModerateRain EnvConditions/Weather/Snowfall/ (+turbulent snow) Roads/Road_surface/Damp Roads/Road_surface/Snow EnvConditions/Illumination/artificial/StreetLight; EnvConditions/Illumination/artificial/OncomingVeh
Challenging road condition (e.g., deteriorated lane markings)	3	3	-	-	**6**	LaneSpecificaiton/LaneMarkerQual/Poor Roads/RodwayEdge/solid_barriers Roads/Zones/ZoneAffectedByHazard/SlippyRoad
New type of traffic agent	-	3	-	1	**4**	Road users/Pedestrian
Traffic density medium/high	-	3	1	-	**4**	Road users/volume-of-traffic/Increased
Reduced visibility due to road curvature or visibility blockage due to nearby traffic or buildings or road furniture.	N/A	5	-	-	**5**	Roads/Geometry/Horiz/Curves Roads/Geometry/Vert/Upslope; Roads/Geometry/Vert/Downslope Roads/Fixed_on-road_structures FixedRoadStructures/Buildings FixedRoadStructures/NonStaticRoadsideObject (trashcan)
GNSS interruption	3	2	-	2	**7**	Roads/Zones/InterferenceZones
Cross-border network handover	-	N/A	1	N/A	**1**	V2I-weather info

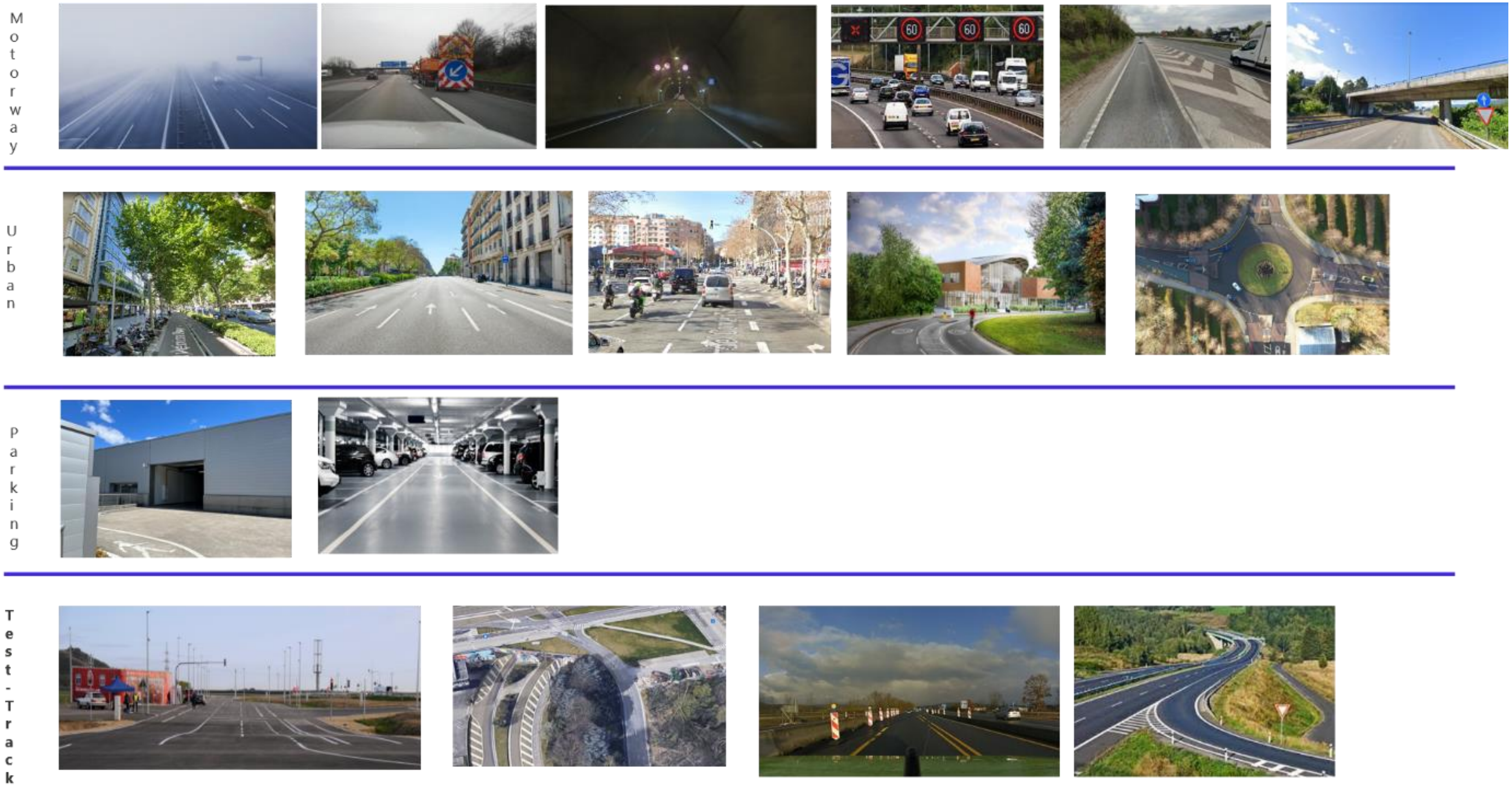


Figure 3.1: Snapshots from challenging ODs to be targeted when testing Hi-Drive UCs

4 Hi-Drive UC/Test scenario catalogue

4.1 Introduction

The UC/Test scenario catalogue per ADF type is presented in the four sections that follow, dedicating one UC/TS visual card for each UC described (see Section 4.2 for Motorway catalogue, Section 4.3 for Urban catalogue, Section 4.4 for Rural catalogue and Section 4.5 for Parking catalogue).

Guidelines on how to read and utilize the UC/TS cards that follow (see Tables of Section 4.2 to Section 4.5) are given below.

1. Each UC visual card consists of three parts, following the defined template (see Table 2.5) a) Test scenario (TS) description consisting of one or multiple 'trigger' conditions and a set of actions; b) photo(s) or graphical sketch(es) describing the scene or the test scenario for each UC or TS; and c) the ADF instance IDs which support the UC (IDs are defined in Chapter 3).

   Note: Additional information that has been provided with respect to the TS execution domain (i.e., whether the test environment is set to 'Open Road', 'Test Track', or 'Virtual'), although not part of the visual cards, is reported in the UC catalogue table, see Table 4.41.

2. Regarding the formulation of test scenarios (TS) in the Hi-Drive context, it is recommended first to read Table 2.6.

3. In all UC/TS descriptions, the ego vehicle is always assumed to be the only AV in the scenario, although in a few Hi-Drive tests the prototype ADF is in shadow mode. Hence we use the terms AV and ego vehicle interchangeably. An exception occurs in a very small number of UCs (see M2 and M3) where we have two AV actors in the same TS. This is clearly stated in each corresponding TS sketch caption.

4. On each UC card, TS enumeration starts from 1 and grows sequentially. Even if only one TS is proposed this is enumerated, since the goal is to have a unique identifier for each test scenario within each UC (the future user of the Hi-Drive UC catalogue may add their own test scenarios to those defined in this work).

5. During information collection, the design guidelines for the TS graphical sketches were not very strict. Thus the level of detail in the sketches varies, depending on the level of information each ADF owner had at the time of collecting the information. Additionally, if one TS was supported by several ADF owners, we had to select the most representative

sketch for the TS description card. Finally, not all TS are represented by sketches, as a written description was considered sufficient in some cases. Due to the limited space, the sketches are best viewed in zoom mode.

6. Graphical sketches on the UC cards should make it easier to grasp the TS description at a "functional" level [see ISO DIS 34501 (2022)]. Should a more detailed representation of each TS (e.g., including allowed trajectories) be required (e.g., for reproducing a TS in a simulation tool), more detailed sketches can be constructed. Important usage note: Sources of graphical sketches that are not created within the project are referenced as footnotes.

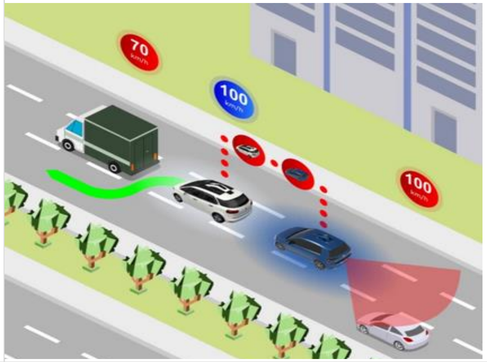
7. ADF IDs referred to in the last column of the UC/TS card correspond to the ADF IDs used in Chapter 3 and Annex 1. If an ADF ID is reported as supporting a specific UC, this means that one or more of its TS are expected to occur during testing of this ADF instance.

Hint: Each Hi-Drive UC and consequently UC/TS may be supported by more than one Hi-Drive ADF owner, which is desired since the idea is to be able to cluster data from multiple operations during our scenario-based analysis in the latter stage of the project where the data-driven technical evaluation is performed.

4.2 Motorway and Peri-urban Motorway UC catalogue

4.2.1 Cooperative Overtaking

Table 4.1: Visual card of UC M1 "Cooperative Overtaking via V2V with rear vehicle"

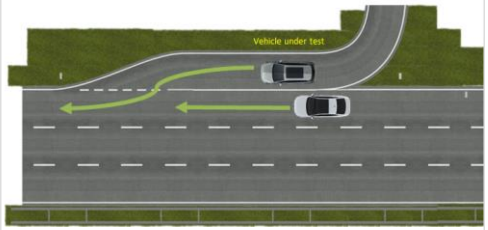
M1- Cooperative Overtaking via V2V with rear vehicle			
Test scenarios (TS)	Scene/Test scenario sketch		ADF ID(s)
Trigger: Ego vehicle's (AV) speed is higher than the speed from the vehicle driving ahead. 1. The (faster) left lane is available for the AV to perform an overtaking manoeuvre based on V2V info exchanged with a vehicle behind. 2. The (faster) left lane is unavailable, based on V2V info exchanged with a vehicle behind, so the AV postpones the manoeuvre.		TS1&2 Cooperative overtaking scenario implementing cooperation with vehicle in the rear.	*M.ADF4*

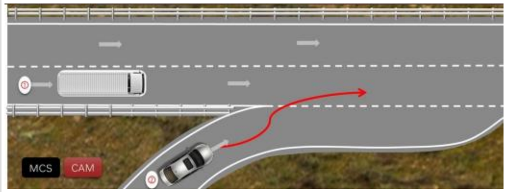
4.2.2 Cooperative lane management in merging or diverging areas

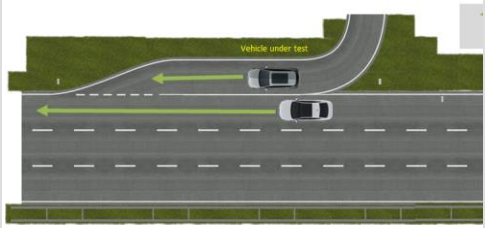
Table 4.2: Visual card of UC M2 "Cooperative Lane Merging on motorway entry via V2V"

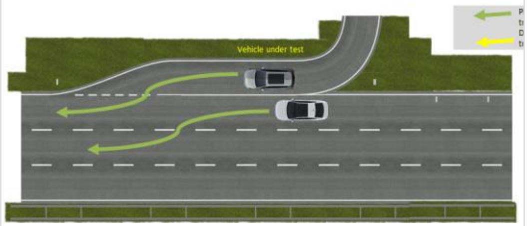
<table>
<tr><td colspan="4">M2 - Cooperative Lane Merging at motorway entry via V2V [AV drives on the on-ramp area (2 actors)]</td></tr>
<tr><td>Test scenarios (TS)</td><td colspan="2">Scene/Test scenario sketch</td><td>ADF ID(s)</td></tr>
<tr><td rowspan="2">Trigger: The on-ramp AV plans to merge and broadcasts its desired trajectory (both connected actors may continuously broadcast their current and desired trajectories). The motorway vehicle evaluates the merging vehicle's current and intended trajectory and acts as follows:

The motorway vehicle driving in the rightmost lane of the motorway decelerates in order to open a gap. The on-ramp AV merges.
Alternative-actor: Same as TS1 but now the motorway vehicle is a truck (TS supported by M.ADF3 for speeds up to 60 km/h).
The motorway vehicle continues without decelerating. The on-ramp AV evaluates the situation as not having a sufficient gap to merge and therefore merges after the motorway vehicle has passed.
The motorway vehicle changes lane in order to create a space for the merging vehicle (supported by M.ADF2&M.ADF5). The on-ramp AV merges into the rightmost lane, which is now free.

Technical note: In Hi-Drive implicit coordination is pursuit among AVs (i.e. each vehicle decides how to resolve the situation without explicitly notifying the other actor). However, different implementations of Manoeuvre Coordination Messages (MCM) allowing CAVs to explicitly declare acceptance/rejection of the merging request and confirmation are possible. It is important to stress that each CAV may adopt its own strategy but all CAVs involved in the execution of a TS will adopt a common MCM implementation to be interoperable.</td>
<td>

TS1 The on-ramp vehicle merges – in Hi-Drive both vehicles are in AD mode (Figure © C2C-CC)</td>
<td>

TS1-Alternative actor: The motorway truck decelerates (in Hi-Drive the truck is not in AD mode)</td>
<td rowspan="2">M.ADF1
M.ADF2
M.ADF3
M.ADF5</td></tr>
<tr><td>

TS2 The motorway vehicle has to let the other vehicle pass and then merge – in Hi-Drive, both vehicles are in AD mode. (Figure © C2C-CC)</td>
<td>

TS1.3 The motorway vehicle accepts the merge request and changes lane – in Hi-Drive, both vehicles are in AD mode. (Figure © C2C-CC)</td></tr>
</table>

Table 4.3: Visual card of UC M3 "Cooperative Merging Awareness on Motorway entry via V2V"

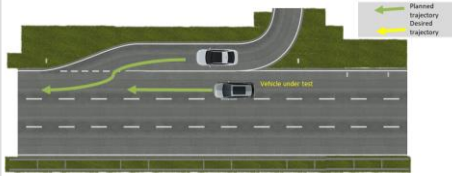
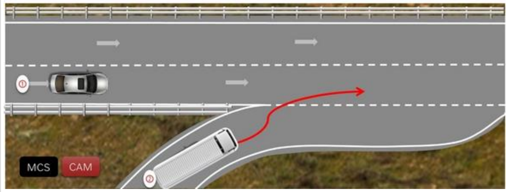
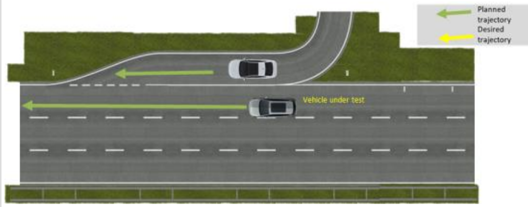
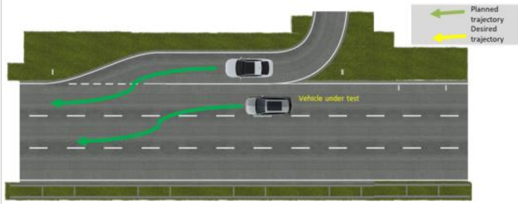
M3 - Cooperative Merging Awareness on Motorway entry via V2V [AV drives on the motorway (2 actors)]			
Test scenarios	Scene/Test scenario sketch		*ADF ID(s)*
Trigger: Motorway AV has to evaluate a conflicting trajectory from another vehicle that desires to merge (both connected actors may continuously broadcast their current and desired trajectories). 1. The AV decelerates in order to open a gap. The on-ramp vehicle merges (not supported by M.ADF3) Alternative actor: Same as TS1 but now the on-ramp vehicle is a truck (TS supported by M.ADF3 for speeds up to 60 km/h). 2. The motorway vehicle continues without decelerating. The on-ramp AV evaluates the situation as no sufficient gap to merge. The on-ramp vehicle postpones merging. 3. The motorway vehicle changes lane in order to create a space for the merging vehicle (supported by M.ADF2&M.ADF5). The on-ramp AV merges into the rightmost lane, which is now free. Technical note: In Hi-Drive implicit coordination is pursuit among AVs (i.e. each vehicle decides how to resolve the situation without explicitly notifying the other actor). However, different implementations of Manoeuvre Coordination Messages (MCM) allowing CAVs to explicitly declare acceptance/rejection of the merging request and confirmation are possible. It is important to stress that each CAV may adopt its own strategy but all CAVs involved in the execution of a TS will adopt a common MCM implementation to be interoperable.	 TS1 The motorway vehicle accepts the merge request and decelerates – in Hi-Drive both vehicles are in AD mode (Figure © C2C-CC).	 TS1.alternative-actor The motorway vehicle decelerates.	*M.ADF1* *M.ADF2* *M.ADF3* *M.ADF5*
	 TS2 The motorway vehicle rejects the merge request and continues without decelerating – in Hi-Drive, both vehicles are in AD mode (Figure © C2C-CC).	 TS3 The motorway vehicle accepts the merge request and changes lane – in Hi-Drive, both vehicles are in AD mode (Figure © C2C-CC).	

Table 4.4: Visual card of UC M4 "Cooperative Lane Merging on Motorway entry in between two trucks via V2V"

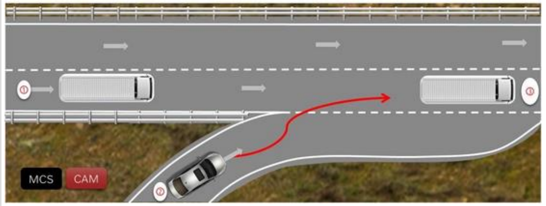
M4 - Cooperative Lane Merging at Motorway entry in between two trucks via V2V [AV drives on the on-ramp area (3 actors)]		
Test scenarios (TS)	Scene/Test scenario sketch	ADF ID(s)
Trigger: The on-ramp AV wants to merge and broadcasts its desired trajectory (all three connected actors may continuously broadcast their current and desired trajectories). 1. The second motorway truck is notified with a warning to adapt its speed due to a merging vehicle downstream and decelerates. The lead motorway truck maintains course. Both announce their status via MCS. The on-ramp vehicle merges behind the lead motorway truck as depicted in the sketch on the right.	 TS1 The AV merges in between two connected trucks	*M.ADF3*

Table 4.5: Visual card of UC M5 "Truck Cooperative Merging Awareness on Motorway entry with lead AV vehicle via V2V"

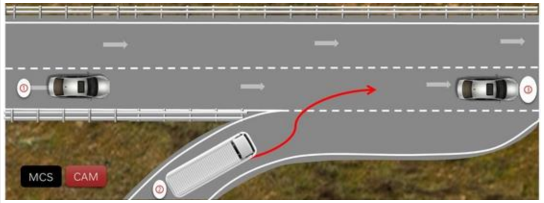
M5 - Cooperative Merging Awareness on Motorway entry with lead AV vehicle via V2V – AV drives on the motorway (3 actors, merging actor is a truck)		
Test scenarios (TS)	Scene/Test scenario sketch	ADF ID(s)
Trigger: A motorway AV following another lead AV has to evaluate a speed decrease warning due to a vehicle that desires to merge downstream (please refer to the sketch on the right). 1. The second motorway AV is notified with a warning to adapt its speed and decelerates. The lead motorway AV maintains its course. Both announce their status via MCS. The on-ramp truck merges behind the lead motorway AV as depicted in the sketch on the right.	 TS1 The AV follows a lead vehicle on the motorway and opens a gap for a truck to merge	*M.ADF3*

Table 4.6: Visual card of UC M6 "Cooperative Lane Exiting via I2V"

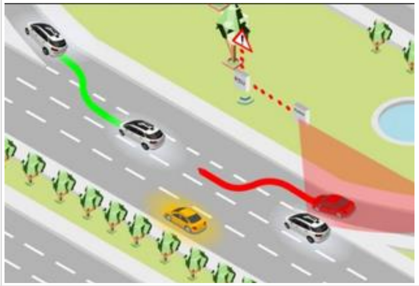
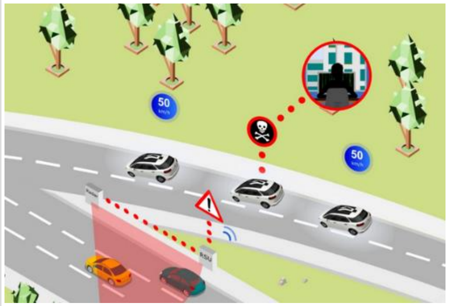
M6 - Cooperative Lane Exiting via I2V		
Test scenarios (TS)	Scene/Test scenario sketch	ADF ID(s)
Trigger: The ego vehicle is heading towards an off-ramp motorway segment and needs to handle a motorway on-ramp merging section that precedes the off-ramp segment (please see sketch on the right). 1. The off-ramp is available to take it. The AV executes the green trajectory depicted in the sketch on the right. 2. There is a vehicle merging from the right. Based on the infrastructure transmitted info about the merging vehicle (red trajectory depicted in the sketch on the right), the AV decelerates.	 TS1&2 Handling an on-ramp/off-ramp segment	*M.ADF4*

Table 4.7: Visual card of UC M7 "Cooperative Lane Merging and cyber-attack"

M7 - Cooperative Lane Merging and cyber-attack		
Test scenarios (TS)	Scene/Test scenario sketch	ADF ID(s)
Trigger: On-ramp AV heading to merge. Cyber-attack via V2I/V2V channel is detected. 1. Countermeasures applied to avoid the cyber-attack, no effect on AV course. 2. Countermeasures are not effective, conditional action to be performed: a) If the driver monitoring system detects that the driver is attentive, ADF issues a *TOR to the driver*. b) If the driver monitoring system detects that the driver is not attentive, ADF executes a Minimum Risk Manoeuvre (MRM).	 TS1&2 Cyber-attack mitigation during motorway merging	*M.ADF4*

4.2.3 Cooperative hazard/dynamic signage awareness

Table 4.8: Visual card of UC M8 "Cooperative Hazard Awareness and Avoidance"

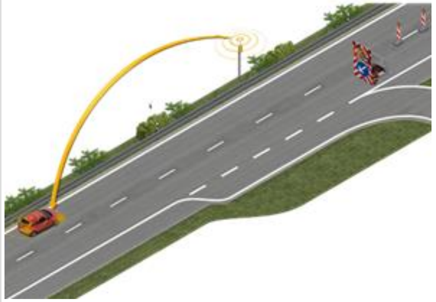
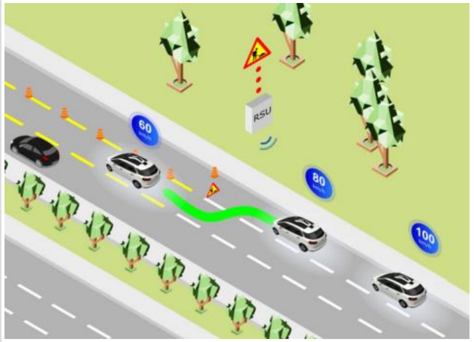
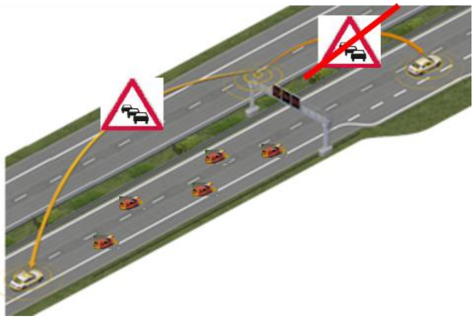
<table>
<tr><th colspan="4">M8 - Cooperative Hazard Awareness and Avoidance (lane changing or speed adaptation required)</th></tr>
<tr><th>Test scenarios (TS)</th><th colspan="2">Scene/Test scenario sketch</th><th>ADF ID(s)</th></tr>
<tr>
<td rowspan="2">Trigger: A hazard warning message is received via I2V or N2V for a situation applicable downstream (beyond the AV's FoV).
1. The notification is about roadworks or a stationary vehicle or an accident and does not specify the lanes affected by the event and thus unavailable for driving. The ego vehicle slows down, issues a take-over request (TOR) that, if not accepted, activates an MRM.
2. The notification is about roadworks or a stationary vehicle or an accident, and specifies the lanes affected by the event and thus unavailable for driving. The ego vehicle slows down (e.g., to the speed limit in the roadwork area) and, if needed, changes lane to drive on the lanes available for driving. The ego vehicle keeps driving in automated mode until the end of the area affected by the hazardous situation (e.g., end of roadworks).
3. The notification is about the end of a traffic jam. The ego vehicle slows down and prepares to stop. When in the traffic jam, a start-and-stop behaviour begins.
4. The notification is about new weather conditions. The ego vehicle adapts its speed, if necessary, to handle the new weather situation.
5. [Interaction with the driver] In any of the scenarios Nos. 2-4, and when AV enters the hazard zone, the pre-active HMI warns the driver if inattentive so he/she is ready to intervene if needed (supported by M.ADF4)
6. [Interaction with the driver] In any of the scenarios Nos. 2-4, an early ToR to the driver is applied based on the diagnosis by the driver monitoring system (supported by M.ADF7).</td>
<td>
TS1&2: Lane blockage notification – speed adaptation required (Figure © C2C-CC)</td>
<td>
TS2&5 Lane blockage notification – lane change and speed adaptation required</td>
<td rowspan="2">M.ADF4
M.ADF5
M.ADF7</td>
</tr>
<tr>
<td>
TS2 End of a traffic jam (Figure © C2C-CC)</td>
<td>
TS4 Adverse weather condition notification (Background figure © C2C-CC)</td>
</tr>
</table>

Table 4.9: Visual card of UC M9 "Cooperative Dynamic Signage Awareness"

M9 - Cooperative Dynamic Signage Awareness (lane changing or speed adaptation required)			
Test scenarios (TS)	Scene/Test scenario sketch		ADF ID(s)
Trigger: A signage information is received via I2V or N2V for a change in speed limit applicable downstream (beyond the AV's FoV). 1. The signage information is about dynamic speed limit. The ego vehicle adapts its speed to meet the enforced speed limit in its area of relevance. 2. The signage information is about dynamic lane management. The ego vehicle executes lane changes to the lanes available for driving in the area of relevance. 3. If the AV cannot manage the dynamic event, a preventive take-over request is triggered.	  TS1 Dynamic speed information for increasing speed again (left figure, © C2C-CC) or for reducing speed downstream (right figure)	 TS2 Dynamic lane management information (Figure © C2C-CC)	*M.ADF7* *M.ADF8*

4.2.4 Special or temporary road infra crossing (tunnel, road construction site)

Table 4.10: Visual card of UC M10 "Driving through a tunnel"

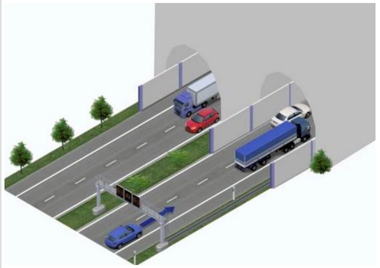
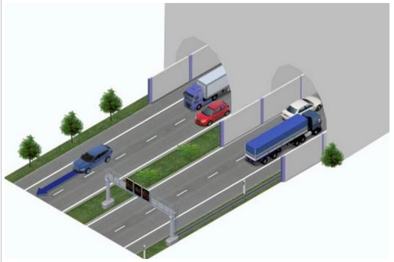
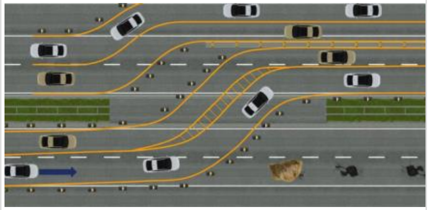
M10 – Driving through a tunnel (AD localization is challenged)				
Test scenarios (TS)	Scene/Test scenario sketch			ADF ID(s)
Trigger*: AV position is calculated to be 500m before a tunnel while the AV is in Lane Keeping mode (approximate distance to the tunnel entry is known to AD system by comparing current GPS position against HD maps). 1. Tunnel entry 2. Inside tunnel 3. Tunnel exit *The trigger here is an OD change = tunnel presence.	 TS1 Scene for tunnel entry	 TS1 Scene for driving inside a tunnel	 TS3 Scene for tunnel exit	*M.ADF7* *M.ADF8* *M.ADF9*

Table 4.11: Visual card of UC M11 "Driving through a road construction zone"

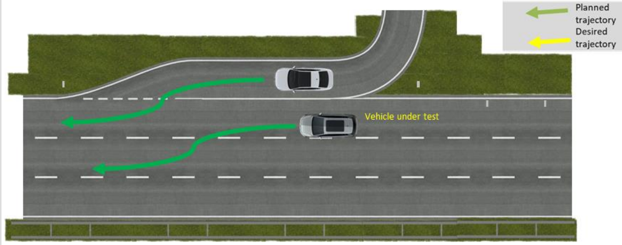
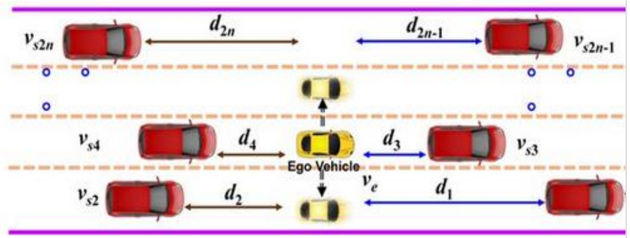
M11 – Driving through a road construction zone (AD perception and decision making is challenged)				
Test scenarios (TS)	Scene/Test scenario sketch			ADF ID(s)
Trigger*: AV position is calculated to be 500m before a road construction zone (approximate distance to the road construction zone is known to AD system by comparing current GPS position against HD maps). 1. Road construction entry 2. Inside road construction 3. Road construction exit *The trigger here consists of an OD change = road construction site presence	 UC M.11 Road construction crossing	 TS1 Scene for road construction zone entry (front view with adverse sunlight and rear view)	 TS1 Scene for road construction zone crossing (alternative topology)	*M.ADF8* *M.ADF9*

4.2.5 Lane management under nominal ODD conditions

Table 4.12: Visual card of UC M12 "Support of basic set of scenarios in lane-keeping mode"

M12 – Support of basic set of scenarios in lane keeping mode: Free Driving, Car following, Passive cut-in				
Test scenarios (TS)	Scene/Test scenario sketch			ADF ID(s)
Trigger: AV in lane-keeping mode. 1. Absence of lead vehicle – free driving. 2. Presence of lead vehicle – lead vehicle following. 3. While in TS1 or TS2, a vehicle from an adjacent lane cuts-in in front of the ego vehicle, possibly causing the AV to temporarily decelerate. 4. HMI: In any of the above scenarios, an early TOR to the driver is applied based on the diagnosis by the driver monitoring system (supported by M.ADF7).	 TS1 Free driving scene	 TS2 Following lead vehicle scene	 TS3 Passive cut-in scene	*M.ADF4* *M.ADF6* *M.ADF7* *M.ADF10* *M.ADF11*

Table 4.13: Visual card of UC M13 "Lane change"

M13 – Lane change			
Test scenarios (TS)	Scene/Test scenario sketch		ADF ID(s)
Trigger: The AV wants to change lane to follow its route. **Alternative Trigger:** The AV wants to change lane near a motorway entry to allow for another vehicle to merge. 1. The (faster) left lane is available for the AV to perform a lane change. 2. The (faster) left lane is unavailable, so the AV postpones the manoeuver.	 TS1 Free lane change near a motorway entry to create space for a vehicle merging from the ramp	 TS2 Difficult lane change due to other traffic (image source[2])	*M.ADF2* *M.ADF7* *M.ADF10*

2 Liu, Teng & Huang, Bing & Deng, Zejian & Wang, Hong & Tang, Xiaolin & Wang, Xiao & Cao, Dongpu. (2020). Heuristics-oriented overtaking decision making for autonomous vehicles using reinforcement learning. IET Electrical Systems in Transportation. 10. 10.1049/iet-est.2020.0044.

4.2.6 Lane Keeping under challenging ODD conditions

Table 4.14: Visual card of UC M14 "Driving in lane under rain/fog/heavy rain"

M14 – Driving in lane keeping mode under rain/fog/heavy rain		
Test scenarios (TS)	Scene/Test scenario sketch	ADF ID(s)
Trigger: The vehicle enters rainy conditions while in ACC mode. 1. Continue in ACC mode during moderate rain. 2. Continue in ACC mode during heavy rain.	 UC M14 Two examples of driving through rain (left image source[3], right image source AdobeStock)	*M.ADF4* *M.ADF6* *M.ADF8*

3 https://www.mappusinsurance.com/drive-safely-strong-wind-rain/

Table 4.15: Visual card of UC M15 "Approaching elevated bridge"

M15 - Approaching elevated bridge (AD object detection and classification is challenged)		
Test scenarios (TS)	Scene/Test scenario sketch	ADF ID(s)
Trigger: The AV approaches a static road element that it is known as safety hazard for one perception sensor, in this case an elevated bridge while in radar-based ACC mode. 1. Approaching bridge 2. Crossing underneath the bridge	 UC M15 Scene for driving under an elevated bridge	*M.ADF4* *M.ADF8*

Table 4.16: Visual card of UC M16 "Driving through areas affected by GNSS interruption or map inconsistencies or deteriorated lane markings"

M16 – Driving through areas affected by GNSS interruption or map inconsistencies or deteriorated lane markings (AD localization is challenged)		
Test scenarios (TS)	Scene/Test scenario sketch	ADF ID(s)
Trigger: The AV is crossing an area where AV localization capability is challenged due to: 1. Missing lane markings. 2. GNSS signal degradation. 3. Map inconsistencies.	 M12 Scene for driving through challenging lane-localization conditions	*M.ADF4* *M.ADF6* *M.ADF7*

4.2.7 Lane merging/diverging (non-cooperative)

Table 4.17: Visual card of UC M17 "Lane exit/interchange from one motorway to next motorway"

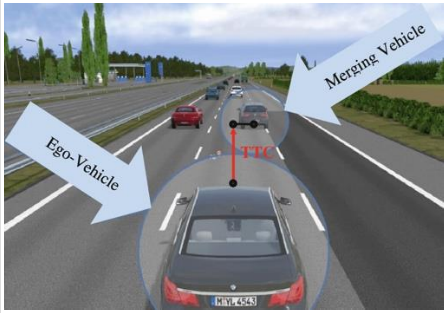
M17 – Lane exit/interchange from one motorway to next motorway (navigation system available)		
Test scenarios (TS)	Scene/Test scenario sketch	ADF ID(s)
Trigger: Navigation system alerts to a lane exit or interchange ahead. 1. AV in rightmost lane. AV keeps moving in the rightmost lane. AV leaves the motorway and takes the lane exit. 2. AV in rightmost lane. AV keeps moving in the rightmost lane. AV leaves the motorway and takes the lane exit/interchange ramp. AV leaves the interchange ramp and merges onto the next motorway. 3. AV not in rightmost lane. AV moves to the rightmost lane. Scenario continues as TS1 or TS2.	 UC M.15 Lane exit scene (left, image source[4]), cloverleaf interchange scene (right, image source[5])	*M.ADF6* *M.ADF10*

Table 4.18: Visual card of UC M18 "Lane Merging on motorway entry"

M18 – Lane Merging on motorway entry		
Test scenarios (TS)	Scene/Test scenario sketch	ADF ID(s)
Trigger: On-ramp entry 1. No vehicle in adjacent lane 2. Faster vehicle in adjacent lane 3. Slower vehicle in adjacent lane 4. Adjacent lane is blocked by multiple vehicles *Note: The difference with M2 is the absence of any cooperative function*	 TS1 Examples of a motorway entry in the UK (left) and Spain (right)	*M.ADF12*

[4] https://www.seetao.com/details/132047.html
[5] https://hmmh.com/markets/highway/

Table 4.19: Visual card of UC M19 "Passing motorway entry and allowing other vehicle to merge"

M19 – Passing motorway entry and allowing other vehicle to merge		
Test scenarios (TS)	Scene/Test scenario sketch	ADF ID(s)
Trigger: AV is approaching a motorway entry. 1. An on-ramp vehicle attempts to merge; AV decelerates and allows the other vehicle to merge. 2. An on-ramp vehicle is waiting to merge; AV maintains its speed and does not allow the other vehicle to merge. *Note: The difference with M3 is the absence of any cooperative function.*	 TS1 Example of passive merging scenario (image source[6])	*M.ADF6* *M.ADF7* *M.ADF10* *M.ADF11*

[6] https://www.researchgate.net/publication/318154763_How_Automation_Level_and_System_Reliability_Influence_Driver_Performance_in_a_Cut-In_Situation/figures?lo=1

4.3 Urban UC catalogue

4.3.1 Cooperative non-signalized intersection crossing

Table 4.20: Visual card of UC U1 "Cooperative non-signalized intersection crossing via V2I"

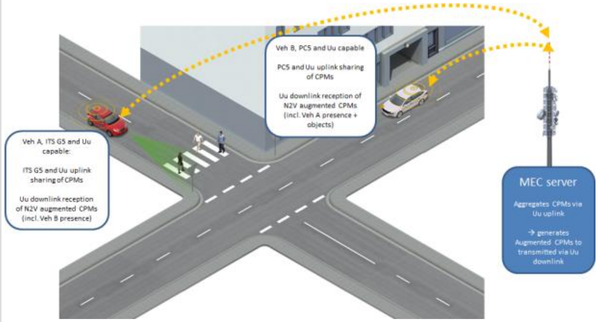
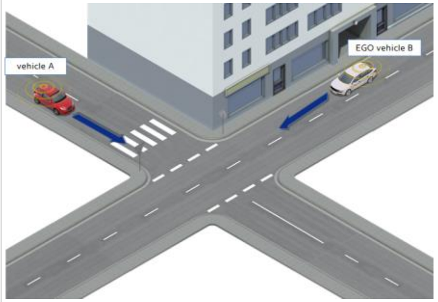
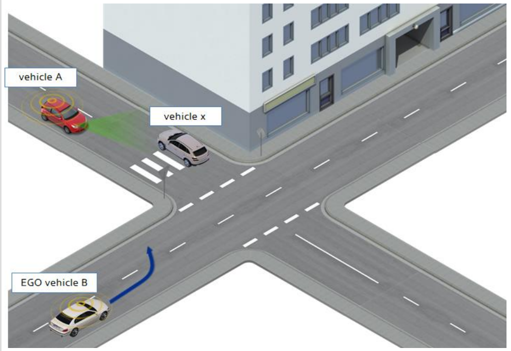
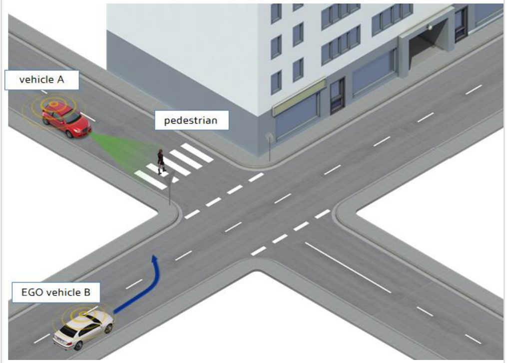
<table>
<tr><th colspan="4">U1 – Cooperative non-signalized intersection crossing via V2I</th></tr>
<tr><th>Test scenarios (TS)</th><th colspan="2">Scene/Test scenario sketch</th><th>ADF ID(s)</th></tr>
<tr><td rowspan="2">Trigger: The AV drives on a two-directional road approaching an intersection and receives an aggregated cooperative sensing information from the MEC server.
1. The AV (ego vehicle B in the sketch) plans to cross straight ahead when it receives information that another vehicle, A, is also crossing straight with dynamics that are detected by the ego vehicle as leading to a potential collision. The AV slows down and possibly stops to avert a collision.
2. The AV plans to turn left. The received information indicates that vehicle X is blocking its route and that a potential collision has been detected. The ego vehicle slows down smoothly and waits for vehicle X to move away before moving into the intersection conflict area.
3. The ego vehicle plans to turn left. The received information indicates that a pedestrian is crossing the street along its route and that a potential collision has been detected. Ego vehicle B slows down smoothly and waits for the pedestrian to cross before moving into the intersection conflict area.</td><td>
UC U.1 Communication approach and type of exchanged information (Figure © C2C-CC)</td><td>
TS1 Straight crossing (Figure © C2C-CC)</td><td rowspan="2">U.ADF2</td></tr>
<tr><td>
TS2 Turning left (Figure © C2C-CC)</td><td>
TS3 Turning left with presence of pedestrian (Figure © C2C-CC)</td></tr>
</table>

Table 4.21: Visual card of UC U2 "Cooperative non-signalized roundabout crossing via V2I"

U2 – Cooperative non-signalized roundabout crossing via V2I (focus on conflicts between CAV and other vehicles)			
Test scenarios (TS)	Scene/Test scenario sketch		ADF ID(s)
Trigger: The ego vehicle approaches a roundabout and receives additional information about the junction and other road users via the infrastructure. 1. The roundabout entry is free, and the vehicle enters the junction and takes the desired exit. 2. The roundabout entry is not free, and the vehicle does not enter the junction and waits for an appropriate time to enter. 3. The ego vehicle approaches the roundabout entry alongside a large vehicle and has its view obscured. a) If there are objects behind the occlusion, the ego vehicle will wait for an appropriate gap to enter the junction. b) Otherwise, it will enter the roundabout.	 TS1 Scene from a smart roundabout entry in a Hi-Drive test field	 TS3 Entering a roundabout when a bigger vehicle reduces the ADF's FoV (note: for safety reasons this UC will be tested with the ADF in shadow mode)	*U.ADF9*

4.3.2 Cooperative Signalized Intersection Crossing

Table 4.22: Visual card of UC U3 "Smart intersection crossing (RSU and connected vehicles)"

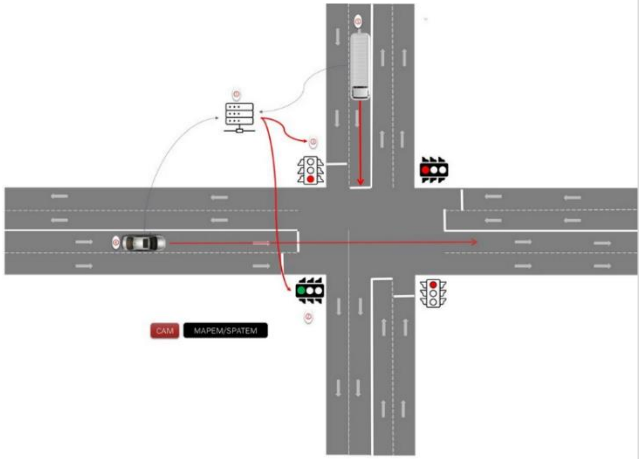
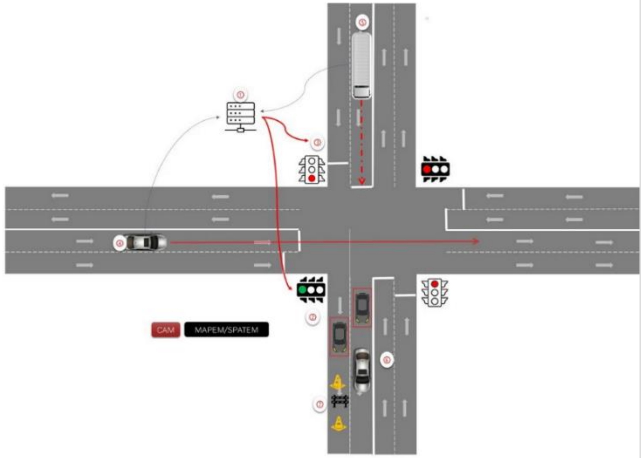
U3 – Smart intersection crossing (RSU and connected vehicles)			
Test scenarios (TS)	Scene/Test scenario sketch		ADF ID(s)
Trigger: Two connected vehicles (an AV and a truck) approaching a smart intersection. A smart traffic light (STL), AV, and truck broadcast their state. 1. STL decides priority based on predefined conditions and broadcasts the decision (via SPATEM/MAPEM), which the two vehicles must follow. 2. Another connected vehicle that just passed the intersection reports the presence of roadworks or a breakdown (via CAM or DENM). Based on this piece of info, the STL gives priority to the AV instead of the truck to prevent congestion due to the roadworks/breakdown ahead & high traffic volume. The AV continues, the truck stops at the intersection.	 TS1 Smart traffic intersection without traffic jam	 TS2 Smart traffic intersection with traffic jam	*U.ADF6*

Table 4.23: Visual card of UC U4 "Smart traffic light crossing"

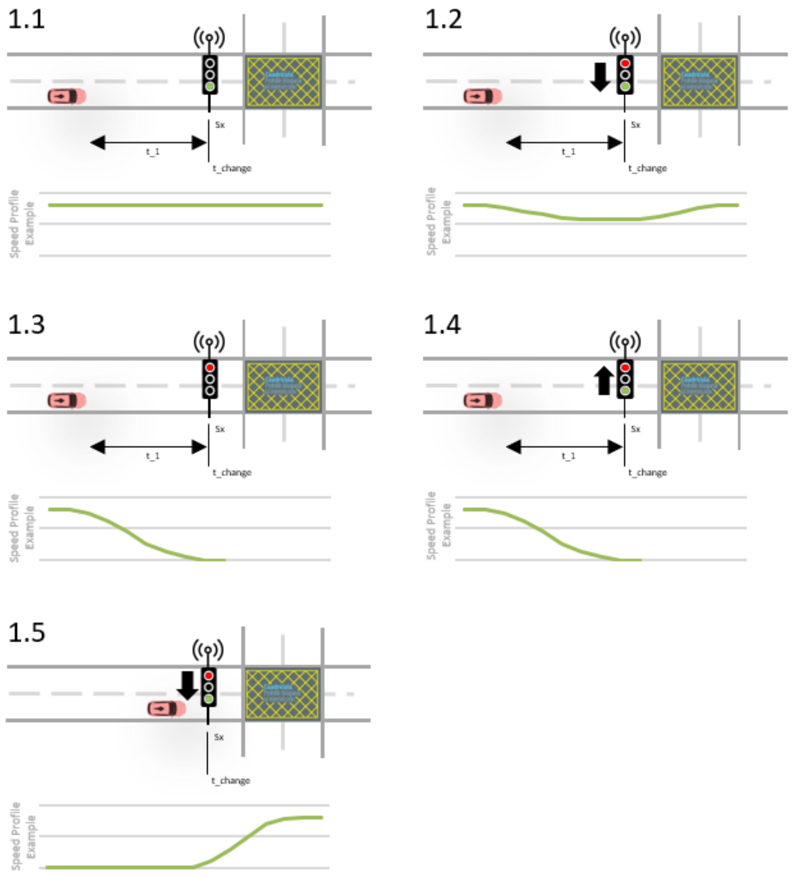
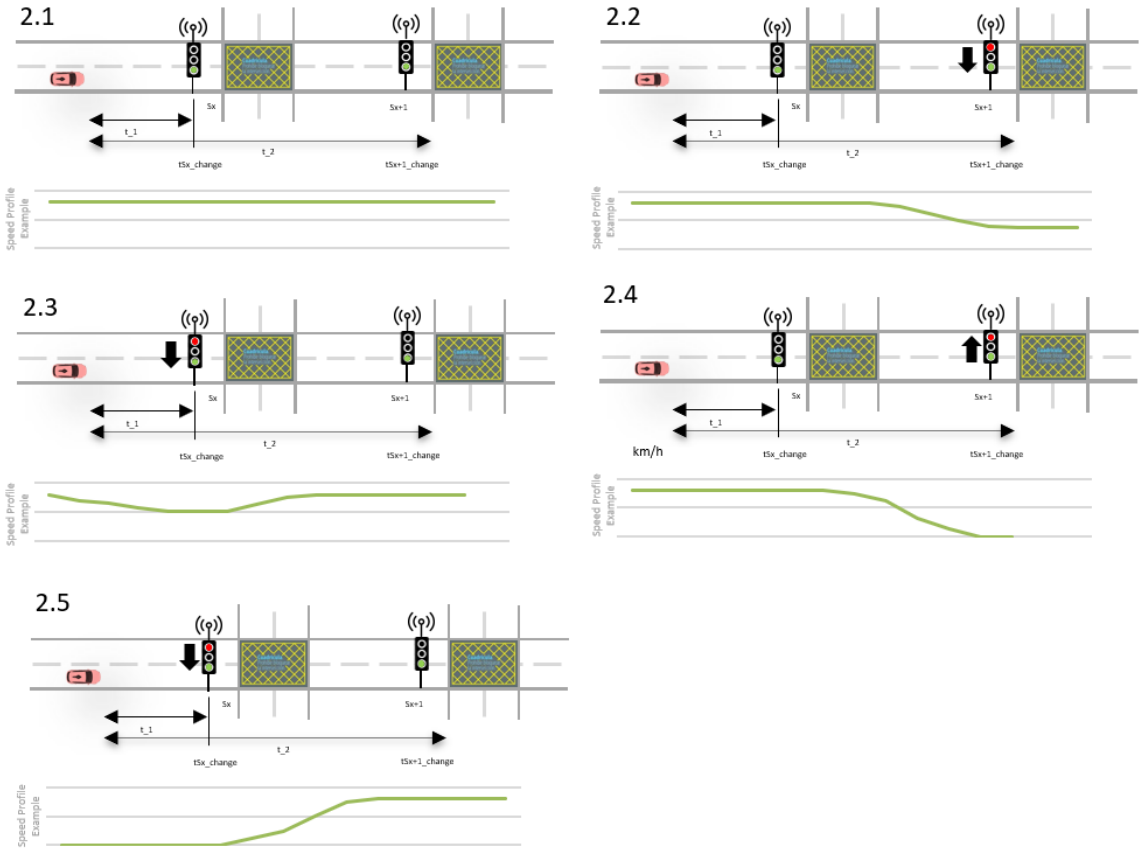
U4 – Smart traffic light crossing		
Test scenarios (TS)	Scene/Test scenario sketch	ADF ID(s)
Trigger: Ego vehicle receives a MAPEM with the position and corridor of the traffic light and a SPATEM indicating a need for action. 1. Maintain speed to cross the traffic light (see sketch 1.1). 2. Adapt speed to cross the traffic light (see sketch 1.2). 3. Stop the vehicle at the traffic light if necessary (see sketch 1.3 or 1.4). 4. Start the vehicle if the traffic light turns to green after a stop (see sketch 1.5). Note: The AV should avoid stopping in prohibited or dangerous areas.	 UC U.5 Speed profiles applicable to the four TS (work in progress)	*U.ADF1* *U.ADF3* *U.ADF4*

Table 4.24: Visual card of UC U5 "Consecutive traffic light crossing"

U5 - Consecutive traffic light crossing		
Test scenarios (TS)	Scene/Test scenario sketch	ADF ID(s)
Trigger: AD Mode activated and multiple consecutive traffic light messages received. 1. Maintain speed and cross the multiple traffic lights (see sketch 2.1). 2. Adapt speed for best performance (see sketch 2.1). 3. Stop the vehicle at the traffic light if necessary (see sketch 2.1). 4. Start the vehicle if the traffic light goes green after a stop (see sketch 2.1). Note: The AV shouldavoid stopping in prohibited or dangerous areas.	 UC U6 Speed profiles applicable to the four TS (work in progress)	*U.ADF4*

4.3.3 Cooperative traffic/hazard awareness

Table 4.25: Visual card of UC U6 "Cooperative re-routing to avoid congestion or hazard in front"

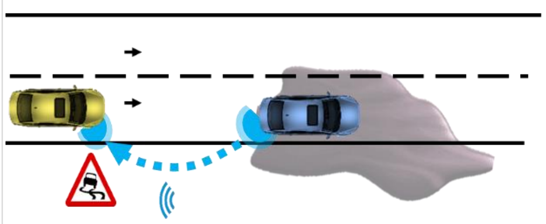
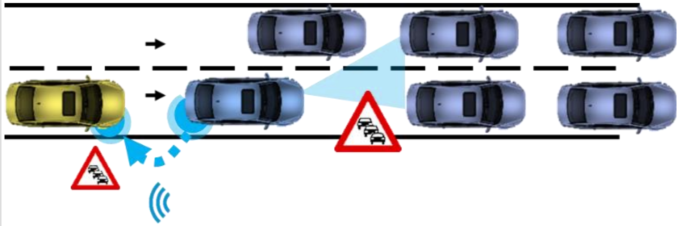
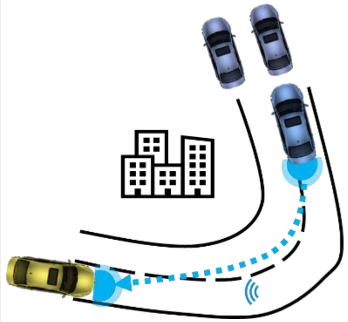
U6 – Cooperative re-routing to avoid congestion or hazard in front		
Test scenarios (TS)	Scene/Test scenario sketch	ADF ID(s)
Trigger: Ego vehicle receives road blockage notification (about 200m earlier) via an infrastructure node (V2I) (supported by U.ADF5). 1. Ego vehicle stays on its route and adapts speed. 2. Ego vehicle changes lane to avoid the hazard. 3. Ego vehicle performs re-routing. **Alternative Trigger:** Front connected vehicle sends slippery road notification (V2V is used) 4. Ego vehicle reduces speed to go through slippery road segment (supported by U.ADF9).	 TS4 AD vehicle receives information on slippery road location	*U.ADF5* *U.ADF9*

Table 4.26: Visual card of UC U7 "Cooperative speed adaptation applicable downstream via V2V"

U7 – Cooperative speed adaptation applicable downstream via V2V			
Test scenarios (TS)	Scene/Test scenario sketch		ADF ID(s)
Trigger: Reduced speed message is received by front connected vehicle (due to slippery road surface or traffic jam or curved road ahead, see sketches a and b on the right). 1. AV reduces speed based on notification of applicable condition downstream.	 UC U8a Stop and go traffic as 'Trigger'	 UC U8b Vehicle after curve awareness as 'Trigger'	*U.ADF5*

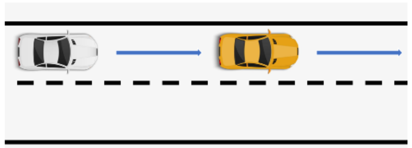
4.3.4 Lane Keeping Under Nominal ODD Conditions

Table 4.27: Visual card of UC U8 "Signalized intersection crossing"

U8 – Signalized intersection crossing		
Test scenarios (TS)	Scene/Test scenario sketch	ADF ID(s)
Trigger: AV is approaching a signalized intersection. 1. AV reads the traffic light and acts accordingly.	  Scene examples for U8 (images obtained from web article[7])	*U.ADF3* *U.ADF7*

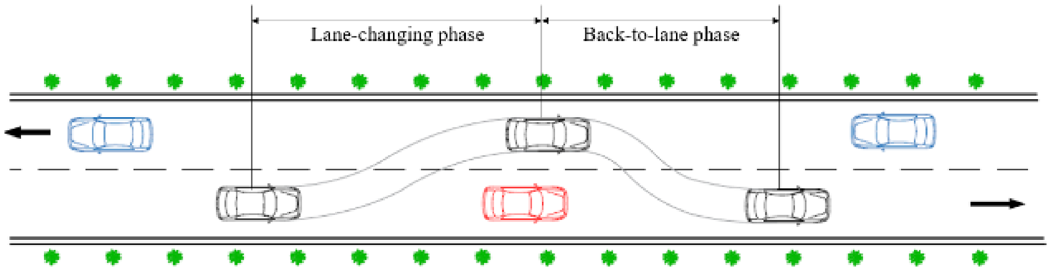
[7] (left image source) https://cyclingsolutions.info/signal-controlled-intersections-safe-cycling-solutions/#pp[gal]/0/; (right image source) https://www.emove360.com/right-turn-assist-system-for-passenger-cars-protects-cyclists-and-pedestrians/.

Table 4.28: Visual card of UC U9 "Support of basic set of scenarios: Free driving / Car-Follow / Cut-in"

U9 – Support of basic set of scenarios: Free driving / Car-Follow / Cut-in		
Test scenarios (TS)	Scene/Test scenario sketch	ADF ID(s)
Trigger: No lead vehicle 1. AV drives in lane-keeping mode. 2. While in lane-keeping mode another vehicle cuts in from the left or right. **Alternative Trigger:** Lead vehicle identified by the AV. 3. AV follows the lead vehicle. 4. While in car-follow mode, another vehicle cuts in from the left or right.	  (left) TS1,2 Free-driving scene example (right)TS3,4 Car-follow scenario (image obtained from cited publication[8])	*U.ADF3* *U.ADF7* *U.ADF9*

[8] Zhu Y, Wang J, Meng F, Liu T. Review on Functional Testing Scenario Library Generation for Connected and Automated Vehicles. *Sensors*. 2022; 22(20):7735. https://doi.org/10.3390/s22207735.

Table 4.29: Visual card of UC U10 "Lane changing / Overtaking"

U10 – Lane changing / Overtaking		
Test scenarios (TS)	Scene/Test scenario sketch	ADF ID(s)
Trigger: No lead vehicle, AV drives in lane-keeping mode. 1. AV changes lane to the left or right. **Alternative Trigger:** Lead vehicle identified by the AV. 2. AV changes lane to the right. 3. AV changes lane to the left. 4. AV changes lane to the left and back to the right to perform an overtake of the lead vehicle.	 TS4 Example of an overtaking manoeuvre on a two-directional road (image obtained from cited publication[9])	*U.ADF7*

[9] Pan J, Shen Y. Assessing Driving Risk at the Second Phase of Overtaking on Two-Lane Highways for Young Novice Drivers Based on Driving Simulation. *International Journal of Environmental Research and Public Health*. 2022; 19(5):2691. https://doi.org/10.3390/ijerph19052691

4.3.5 Lane Keeping Under Challenging ODD Conditions

Table 4.30: Visual card of UC U11 "Urban canyon driving"

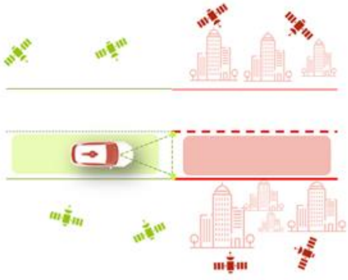
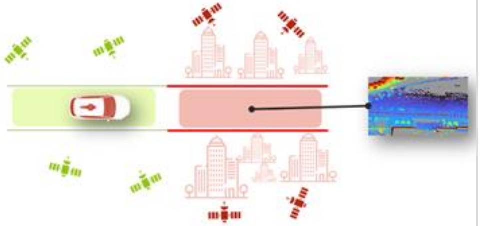
U11 – Urban canyon driving			
Test scenarios (TS)	Scene/Test scenario sketch		ADF ID(s)
Trigger: AV entering a GNSS interruption area or GNSS transition from one zone to another. 1. AV continuous in AD mode despite GNSS disturbances. 2. Intersection crossing in AD mode	 TS1 GPS signal from RTK to DGPS, detection of line markings and vehicle well located on HD Map	 TS2 GNSS signal from well covered GNSS area to a weak area, pre-recorded obstacle map available and vehicle well located on HD Map	*U.ADF4* *U.ADF11*

Table 4.31: Visual card of UC U12 "Driving in rainy weather or with missing lane markings"

U12– Driving in rainy weather or with missing lane markings		
Test scenarios (TS)	Scene/Test scenario sketch	ADF ID(s)
Trigger: AV reaches section with insufficient lane markings or wet road surface. 1. AV continues in AD mode. 2. AV continues in AD mode in moderate rain. 3. AV continues in AD mode in heavy rain (optionally supported). 4. AV continues in AD mode with deteriorated lane markings.	 TS3 Urban driving in heavy rain (Shutterstock image)	*U.ADF9* *U.ADF7* *U.ADF3*

4.3.6 Non-signalized intersection crossing

Table 4.32: Visual card of UC U13 "Pedestrian crossing (w/wo zebra crossing)"

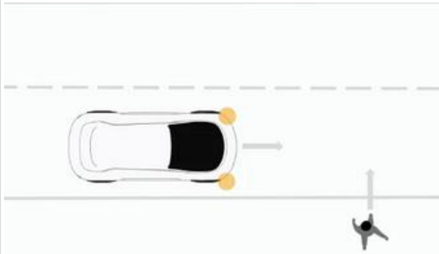
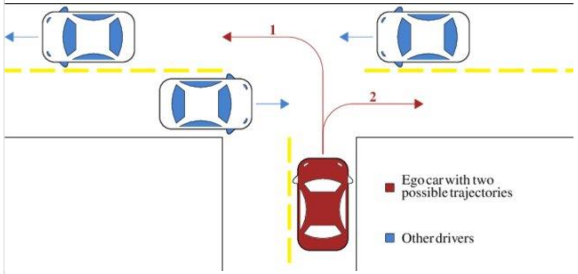
U13 – Pedestrian crossing (w/wo zebra crossing)		
Test scenarios (TS)	Scene/Test scenario sketch	ADF ID(s)
Trigger: AV approaching an area with a pedestrian detected on the pavement (no zebra crossing). 1. Pedestrian wants to cross the road. 2. Pedestrian does not want to cross the road. **Alternative Trigger:** AV approaching pedestrian detected on the pavement at a zebra crossing. 3. Pedestrian wants to cross the road. 4. Pedestrian does not want to cross the road.	 TS1. Pedestrian wants to cross the road perpendicular to the AV's route (2-directional single lane road)	*U.ADF7* *U.ADF10*

Table 4.33: Visual card of UC U14 "Crossing intersection with left or right turn"

U14 – Crossing intersection with left or right turn		
Test scenarios (TS)	Scene/Test scenario sketch	ADF ID(s)
Trigger: AD vehicle enters an intersection in order to turn left. 1. No vehicle/VRU on intersection; intersection crossing with left turn. 2. AV has to give way to vehicle/VRU. 3. Vehicle/VRU has to give way to AV; intersection crossing with left turn. **Trigger:** AD vehicle enters an intersection in order to turn right. 4. No vehicle/VRU on intersection; intersection crossing with right turn. 5. AV has to give way to vehicle/VRU. 6. Vehicle/VRU has to give way to AV; intersection crossing with right turn.	 Scene for UC U14 (figure obtained from cited publication[10])	*U.ADF7* *U.ADF3* *U.ADF11*

[10] https://www.researchgate.net/publication/316163263_Belief_State_Planning_for_Autonomously_Navigating_Urban_Intersections

4.3.7 Road user interaction zone (eHMI)

Table 4.34: Visual card of UC U15 "eHMI interaction on straight road segment towards the driver of the following vehicle"

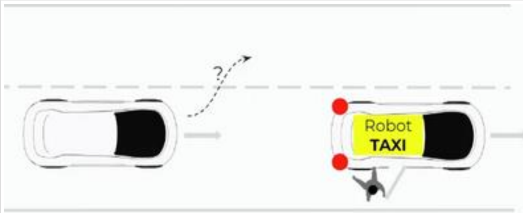
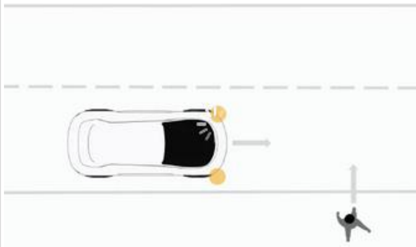
U15 – eHMI interaction on straight road segment towards the driver of the following vehicle		
Test scenarios (TS)	Scene/Test scenario sketch	ADF ID(s)
Trigger: A robot taxi is stationed on the side of the road where a passenger intends to exit the vehicle. A second vehicle with driver is approaching from behind. 1. The robot taxi communicates the situation to the following vehicle via its e-HMI.	 TS1, A robot taxi communicates the situation to the following vehicle via its e-HMI	*U.ADF8*

Table 4.35: Visual card of UC U16 "Interaction with VRU via eHMI on straight road segment (w/wo zebra crossing)"

U16 – Interaction with VRU via eHMI on straight road segment (w/wo zebra crossing)		
Test scenarios (TS)	Scene/Test scenario sketch	ADF ID(s)
Trigger: The AV vehicle (Host vehicle) detects pedestrian on conflicting path with AV's trajectory. 1. The pedestrian is not sure if he/she hasbeen detected by the AV. The AV communicates its 'yield behaviour via the eHMI, i.e., that it will wait for the pedestrian to cross the road. After that, the AV will continue driving.	 TS1, AV communicates its intention to wait to the pedestrian via its e-HMI	*U.ADF8*

4.4 Rural UC catalogue

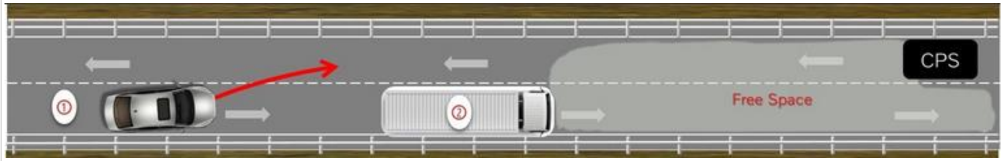
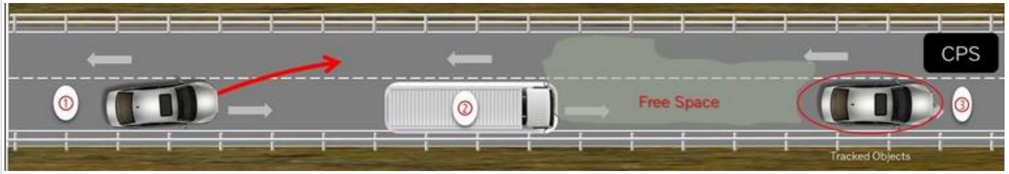
4.4.1 Urban-to-Rural Transition

Table 4.36: Visual card of UC R1 "Urban-to-rural transition"

R1 – Urban-to-rural transition		
Test scenarios (TS)	Test scenario sketch (optional)	ADF ID(s)
Trigger: AV transitions from urban to rural ODD. The speed limit and general traffic rules change in comparison to the urban areas. 1. The AV drives without following a lead vehicle. 2. The AV drives in car-following mode. 3. The AV performs a lane change.	 Rural section, connecting two urban areas for UC R1	*R.ADF1*

4.4.2 Cooperative Overtaking

Table 4.37: Visual card of UC R2 "AV-Truck cooperative overtaking on 2-directional road via V2V"

R2 – AV-Truck cooperative overtaking on 2-directional road via V2V object info sharing from truck		
Test scenarios (TS)	Test scenario sketch (optional)	ADF ID(s)
Trigger (2 actors): The AV (actor 1) intends to overtake a truck in front (actor 2) and receives information from the truck on adjacent lane status (2-directional road). 1. The ego vehicle bases its decision on CAM and CPM transmitted by the truck and performs, or does not perform, the overtaking manoeuvre. **Alternative trigger (3 actors):** The AV (actor 1) intends to overtake a truck in front (actor 2) while another vehicle is driving in front of the truck (actor 3). 2. The ego vehicle bases its decision on CAM and CPM transmitted by the truck and performs, or does not perform, the overtaking manoeuvre (no communication capabilities are required from actor 3)	 TS1, Overtaking scenario implementing cooperation with vehicle in front - no lead vehicle present and no oncoming traffic	*R.ADF2*
	 TS2, Overtaking scenario implementing cooperation with vehicle in front - lead vehicle present and no oncoming traffic	

4.4.3 (Cooperative) Arctic Driving

Table 4.38: Visual card of UC R4 "(Cooperative) Arctic driving on road covered by snow"

R3 – (Cooperative) Arctic driving on road covered by snow		
Test scenarios (TS)	Test scenario sketch (optional)	ADF ID(s)
Trigger: The AV drives on a road with invisible lane markings due to snow and/or the drivable area is affected by snowbanks. 1. Lane keeping despite decreased visibility range and without lane markings. 2. Speed adaptation according to actual environment perception range. **Alternative Trigger:** The AV drives through a cross-border area where handover between networks occurs. 3. AV driving before border point connected to the operator in Finland, retrieving weather info from FMI. 4. AV crosses border point. 5. AV is driving after border point connected to the operator in Norway, retrieving weather info from FMI. (V2N used additionally for on-board perception for landmark awareness based on historic data)	 TS1,2: Driving with invisible lane markings or area affected by snowbanks	*R.ADF3*

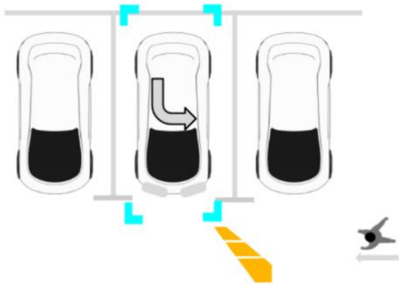
4.5 Parking catalogue

4.5.1 Automated Valet Parking (Indoor/Outdoor)

Table 4.39: Visual card of UC P1 "Automated Valet Parking via seamless positioning"

P1 – Automated Valet Parking via seamless positioning		
Test scenarios (TS)	Test scenario sketch (optional)	ADF ID(s)
Trigger: The AV is driving when it receives a user request to park in a selected indoor parking. 1. The ego vehicle leaves the urban zone and enters the indoor parking zone, where it performs the parking manoeuvre safely and stops correctly and aligned within the parking spot. 2. The ego vehicle is in the indoor parking zone, where it performs the parking manoeuvre safely and stops correctly and aligned within the parking spot. **Alternative Trigger:** The AV is parked and receives a summon request. 3. The ego vehicle leaves the indoor parking slot and performs an unparking manoeuvre in order to navigate to the driver's pick-up point. *Note: Transition between zones that have different conditions of GNSS coverage must be seamless and unnoticeable.*	 TS1: Ego vehicle will perform a parking manoeuvre safely and stop correctly and aligned within the parking spot	*P.ADF1* *P.ADF2*

Table 4.40: Visual card of UC P2 "Automated Valet Parking with risk of pedestrian passing (unparking manoeuvre)"

P2 –Automated Valet Parking with risk of pedestrian passing (unparking manoeuvre)		
Test scenarios (TS)	Test scenario sketch (optional)	ADF ID(s)
Trigger: A VRU is detected via local sensors of the vehicle while the AV is driving out of a perpendicular parking space. 1. The AV communicates its intention to perform an unparking manoeuvre to the VRU via its eHMI. *Note: The parking location can be either indoors or outdoors.*	 TS1: AV vehicle detects risk of collision warning with a pedestrian. It communicates its intention to unpark via its eHMI	*P.ADF3*

4.6 Hi-Drive UC catalogue overview

Listing all the UCs described in the previous sections, we ended up with the following final synthesis of UCs applicable to HI-Drive operations: 19 Motorway, 16 Urban, 3 Rural, and 2 Parking, as described in Table 4.41. The last two columns in this table show auxiliary information that is needed for other tasks within the project.

Table 4.41: Hi-Drive UC catalogue overview

UC ID	UC title	Enabler group involved	Test scenarios execution domain	ADF ID
M1	Cooperative Overtaking via V2V with rear vehicle	E.2.3.1 V2V Vehicle-to-Vehicle Communication	Open Road, Controlled Track	M.ADF4
M2	Cooperative Lane Merging on motorway entry via V2V [AV drives on the on-ramp area (2 actors)]	E.2.3.1 V2V Vehicle-to-Vehicle Communication E.2.4.2 Sensor Fusion for Localization E.2.5.1 TARA Threat Analysis and Risk Assessment	Controlled Track Virtual	M.ADF1, M.ADF2, M.ADF3, M.ADF5
M3	Cooperative Merging Awareness on Motorway entry via V2V [AV drives on the motorway (2 actors)]	E.2.3.1 V2V Vehicle-to Vehicle-Communication	Controlled Track	M.ADF1, M.ADF2, M.ADF3, M.ADF5
M4	Cooperative Lane Merging on Motorway entry with lead vehicle via V2V [AV drives on the on-ramp area (3 actors)]	E.2.3.1 V2V Vehicle-to Vehicle-Communication	Controlled Track	M.ADF3
M5	Cooperative Merging Awareness on Motorway entry with lead AV vehicle via V2V – AV drives on the motorway (3 actors)	E.2.3.1 V2V Vehicle-to Vehicle-Communication	Controlled Track	M.ADF3
M6	Cooperative Lane Exiting via I2V	E.2.3.2 V2I Vehicle-to-Infrastructure and Infrastructure-to-Vehicle Communication	Open Road Controlled Track	M.ADF4
M7	Cooperative Lane Merging and cyber-attack	E.2.5.1 TARA Threat Analysis and Risk Assessment E.2.5.2 V2X Cyber-Risk Mitigation E.2.6.4 CAD ML Driver Monitoring	Open Road Controlled Track	M.ADF4
M8	Cooperative Hazard Awareness and Avoidance (lane changing or speed adaptation required)	E.2.3.2 V2I VehicletoInfrastructure and Infrastructure-to Vehicle-Communication E.2.3.3 Vehicle to Cloud (Edge and Core) E.2.6.4 CAD ML Driver Monitoring	Open Road Controlled Track	M.ADF4, M.ADF5, M.ADF7

UC ID	UC title	Enabler group involved	Test scenarios execution domain	ADF ID
M9	Cooperative Dynamic Signage Awareness (lane changing or speed adaptation required)	E.2.3.2 V2I Vehicle-to-Infrastructure and Infrastructure-to-Vehicle Communication	Open Road	M.ADF5, M.ADF7
M10	Driving through a tunnel	E.2.4.2 Sensor Fusion for Localization E.2.6.2 CAD ML Perception, Object Detection and Classification	Open Road	M.ADF7, M.ADF8, M.ADF9
M11	Driving through a road construction zone	E.2.4.2 Sensor Fusion for Localization E.2.6.2 CAD ML Perception, Object Detection and Classification	Open Road Virtual	M.ADF8, M.ADF9
M12	Support of a basic set of scenarios in lane keeping mode: Free Driving, Car following, Passive cut-in	E.2.3.3 Vehicle to Cloud (Edge and Core) E.2.4.1 Geo-referenced Cloud Services E.2.4.2 Sensor Fusion for Localization E.2.6.3 CAD ML Decision Making E.2.6.4 CAD ML Driver Monitoring	Open road Virtual	M.ADF4, M.ADF6, M.ADF7, M.ADF10, M.ADF11
M13	Lane change	E.2.4.2 Sensor Fusion for Localization E.2.6.3 CAD ML Decision Making E.2.6.4 CAD ML Driver Monitoring	Open road	M.ADF7, M.ADF10
M14	Driving in lane under rain/fog/heavy rain	E.2.6.2 CAD ML Perception, Object Detection and Classification	Open Road	M.ADF4, M.ADF6, M.ADF8, M.ADF12
M15	Approaching elevated bridge	E.2.6.2 CAD ML Perception, Object Detection and Classification	Open Road	M.ADF4, M.ADF8
M16	Driving through areas affected by GNSS interruption or map inconsistencies or deteriorated lane markings	E.2.3.3 Vehicle to Cloud (Edge and Core) E.2.4.1 Geo-referenced Cloud Services E.2.4.2 Sensor Fusion for Localization	Open Road Controlled Track Virtual	M.ADF4, M.ADF6 M.ADF7
M17	Interchange from one motorway to next motorway (navigation system available)	E.2.3.3 Vehicle to Cloud (Edge and Core) E.2.4.2 Sensor Fusion for Localization	Open road Controlled Track	M.ADF6, M.ADF10
M18	Lane Merging on motorway entry	E.2.6.2 CAD ML Perception, Object Detection and Classification	Open road Controlled Track	M.ADF12

UC ID	UC title	Enabler group involved	Test scenarios execution domain	ADF ID
M19	Passing motorway entry and allowing other vehicle to merge	E.2.3.3 Vehicle to Cloud (Edge and Core) E.2.4.2 Sensor Fusion for Localization E.2.6.2 CAD ML Perception, Object Detection and Classification E.2.6.3 CAD ML Decision Making	Open road Controlled Track	M.ADF6, M.ADF7, M.ADF10, M.ADF11
U1	Cooperative non-signalized intersection crossing via V2I	E.2.3.3 Vehicle to Cloud (Edge and Core)	Controlled track	U.ADF2
U2	Cooperative non-signalized roundabout crossing via V2I (focus on conflicts between CAV and other vehicles)	E.2.3.3 Vehicle to Cloud (Edge and Core) E.2.6.2 CAD ML Perception, Object Detection and Classification	Controlled Track Open Road Virtual	U.ADF9
U3	Smart intersection crossing (RSU and connected vehicles)	E.2.3.2 V2I Vehicle-to-Infrastructure and Infrastructure-to-Vehicle Communication	Controlled Track Virtual	U.ADF6
U4	Smart traffic light crossing	E.2.3.2 V2I Vehicle-to-Infrastructure and Infrastructure-to-Vehicle Communication	Open Road Controlled Track	U.ADF1, U.ADF3, U.ADF4
U5	Consecutive Traffic Light crossing	E.2.3.2 V2I Vehicle-to-Infrastructure and Infrastructure-to-Vehicle Communication	Open Road Controlled Track	U.ADF4
U6	Re-routing to avoid congestion or hazard in front	E.2.3.1 V2V Vehicle-to-Vehicle Communication E.2.3.3 Vehicle to Cloud (Edge and Core) E.2.6.2 CAD ML Perception, Object Detection and Classification	Controlled Track Open Road Virtual	U.ADF5, U.ADF9
U7	Cooperative speed adaptation applicable downstream via V2V	E.2.3.1 V2V Vehicle-to-Vehicle Communication	Controlled Track	U.ADF5
U8	Signalized intersection crossing	E.2.6.2 CAD ML Perception, Object Detection and Classification	Open Road	U.ADF3 , U.ADF7
U9	Support of basic set of scenarios: Free driving / Car-Follow / Cut-in	E.2.6.2 CAD ML Perception, Object Detection and Classification E.2.3.3 Vehicle to Cloud (Edge and Core) E.2.4.1 Geo-referenced Cloud Services E.2.4.2 Sensor Fusion for Localization	Open road	U.ADF3, U.ADF7, U.ADF9, U.ADF11

UC ID	UC title	Enabler group involved	Test scenarios execution domain	ADF ID
U10	Lane changing / Overtaking	E.2.6.2 CAD ML Perception, Object Detection and Classification	Open Road	U.ADF7
U11	Urban canyon driving	E.2.4.1 Geo-referenced Cloud Services E.2.4.2 Sensor Fusion for Localization	Open Road Controlled Track	U.ADF4, U.ADF11
U12	Driving in rainy weather or with missing lane markings	E.2.6.2 CAD ML Perception, Object Detection and Classification E.2.3.3 Vehicle to Cloud (Edge and Core) E.2.4.1 Geo-referenced Cloud Services E.2.4.2 Sensor Fusion for Localization	Open Road	U.ADF9, U.ADF7, U.ADF3
U13	Pedestrian crossing (w/wo zebra crossing)	E.2.6.2 CAD ML Perception, Object Detection and Classification	Open Road	U.ADF7, U.ADF9, U.ADF10
U14	Crossing intersection with left or right turn	E.2.6.2 CAD ML Perception, Object Detection and Classification	Open Road	U.ADF7, U.ADF3, U.ADF9, U.ADF11
U15	eHMI interaction at straight road segment towards the driver of the following vehicle	E.2.3.4 Vehicle Intention Communication	Controlled Track	U.ADF8
U16	Interaction with VRU via eHMI on straight road segment (w/wot zebra crossing)	E.2.3.4 Vehicle Intention Communication	Controlled Track	U.ADF8
R1	Urban-to-rural transition	N/A	Open Road	R.ADF1
R2	AV-Truck Cooperative Overtaking on 2-directional road via V2V object info sharing from truck	E.2.3.1 V2V Vehicle-to-Vehicle Communication	Controlled Track	R.ADF2
R3	(Cooperative) Arctic driving on road covered by snow	E.2.4.1 Geo-referenced Cloud Services E.2.3.3 Vehicle to Cloud (Edge and Core)	Open Road	R.ADF3
P1	Automated Valet Parking via seamless positioning	E.2.4.2 Sensor Fusion for Localization	Controlled Track	P.ADF1, P.ADF2
P2	Automated Valet Parking with risk of pedestrian passing (unparking manoeuvre)	E.2.3.4 Vehicle Intention Communication	Controlled Track	P.ADF3

5 Summary

Figure 5.1 visualizes the whole D3.1 process of ADF/UC listing, grouping, and indexing, illustrating how the initial 71 UCs contributed by the 20 Hi-Drive prototype owners have been analysed and then grouped in order to create the proposed Hi-Drive UCs and associated test scenarios catalogue presented in Chapter 4.

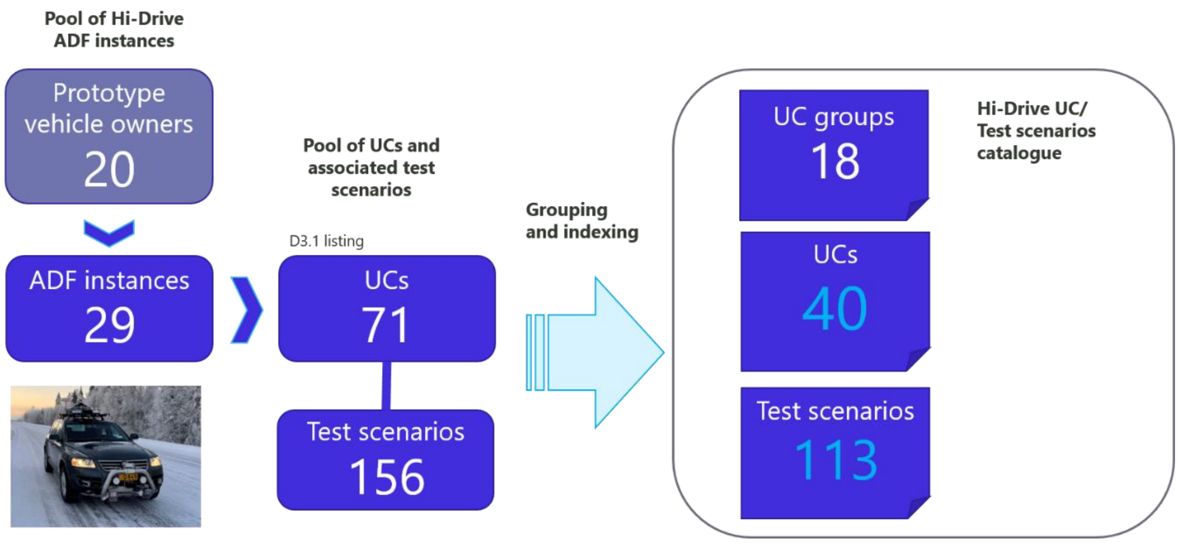


Figure 5.1: D3.1 in numbers

As seen in Chapter 4, the Hi-Drive UCs collected from the four ADF UC pools, namely Motorway and Urban Motorway, Urban, Rural, and Parking, were further grouped into finer groups as outlined in Table 5.1, i.e.,

- Seven (7) UC groups for Motorway, consisting of nineteen (19) UCs and fifty-one (51) associated Test Scenarios.
- Seven (7) UC groups for Urban, consisting of sixteen (16) UCs and forty-eight (48) associated Test Scenarios.
- Three (3) Rural clusters consisting of three (3) UCs and ten (10) associated Test Scenarios.
- One (1) Parking cluster consisting of two (2) UCs and four (4) associated Test Scenarios.

In total forty (40) UCs are included in the Hi-Drive UC catalogue. Most of the UCs described have two or three test scenarios each, the total number of UC catalogue test scenarios described reaching one hundred and thirteen (113).

Table 5.1: Hi-Drive UC catalogue in numbers

ADF type	UC clusters	Number of UCs generated	Number of TS generated	Supported by 'x' ADF instances
Motorway (and peri-urban Motorway)	Cooperative overtaking	1	2	1
	Cooperative lane management in merging or diverging areas	6	12	5
	Cooperative hazard/dynamic signage awareness	2	9	4
	Special or temporary road infra crossing (tunnel, road construction site)	2	6	3
	Lane management under nominal ODD conditions	2	6	6
	Lane Keeping under challenging ODD conditions	3	7	4
	Lane merging/diverging (non-cooperative)	3	9	5
	Motorway-Total	**19**	**51**	
Urban	Cooperative non-signalized intersection transit	2	6	5
	Cooperative signalized intersection transit	3	10	6
	Cooperative traffic/hazard awareness	2	5	2
	Lane Keeping under nominal ODD conditions	3	9	3
	Lane Keeping under challenging ODD conditions	2	6	5
	Non-signalized intersection crossing	2	10	5
	VRU interaction zone (eHMI)	2	2	1
	Urban-Total	**16**	**48**	
Rural	Urban to rural transition	1	3	1
	Cooperative overtaking via V2V	1	2	1
	Arctic uninterrupted driving against specific conditions	1	5	1
	Rural-Total	**3**	**10**	
Parking	Automated Valet Parking	2	4	3
	Parking-Total	**2**	**4**	
	Total	**40**	**113**	

Important note: as the operation for each ADF testing is work in progress by the project, small changes might occur w.r.t the test execution details, i.e. support of test scenarios by specific vehicles integrating an ADF instance.

Table 5.2: Enabler technology types involved in Hi-Drive UCs testing

TECH ENABLER THEMATIC AREA	TECH ENABLER GROUP	In Motorway UCs	In Urban UCs	In Rural UCs	In Parking UCs	In Total UCs
VEHICLE COMMUNICATION	E.2.3.1 V2V Vehicle-to-Vehicle Communication	5	2	1	-	**8**
	E.2.3.2 V2I Vehicle-to-Infrastructure and Infrastructure-to-Vehicle Communication	2	3	-	-	**5**
	E.2.3.3 Vehicle to Cloud (Edge and Core)	5	5	1	-	**11**
	E.2.3.4 Vehicle Intention Communication	-	2	-	1	**3**
Total (Vehicle Communication)		**12**	**12**	**2**	**1**	**27**
VEHICLE HIGH-PRECISION POSITIONING & LOCALIZATION	E.2.4.1 Geo-referenced Cloud Services	2	3	1	-	6
	E.2.4.2 Sensor Fusion for Localization	8	3	-	1	12
Total (Vehicle High-Precision Positioning)		**10**	**6**	**1**	**1**	**18**
VEHICLE COMMUNICATION CYBERSECURITY	E.2.5.1 TARA Threat Analysis and Risk Assessment E.2.5.2 V2X Cyber-Risk Mitigation	2	-	-	-	2
Total (Vehicle communication cybersecurity)		2	0	0	0	**2**
VEHICLE MACHINE LEARNING	E.2.6.2 CAD ML Perception, Object Detection and Classification	6	8	-	-	**14**
	E.2.6.3 CAD ML Decision Making	3	-	-	-	**3**
	E.2.6.4 CAD ML Driver Monitoring	4	-	-	-	**4**
Total (Vehicle Machine Learning)		**13**	**8**	**0**	**0**	**21**

The type and appearance frequency of the technology enabler groups involved in the Hi-Drive UCs are listed in Table 5.2. As the table outlines, the most popular group of technology enabler is Connectivity, with 27 appearances in Hi-Drive UCs, followed by AD stack Machine Learning, with 21 appearances, followed by High Precision Positioning, with 18 appearances.

We can also observe that a) within the group of UCs supported by Connectivity enablers, integration of Vehicle-to-Cloud enablers comes first in popularity (11 occurrences), followed by Vehicle-to-Vehicle (8 occurrences), then Vehicle-to-Infrastructure (5 occurrences), and b) within the group of UCs supported by Machine Learning enablers, ML for the Perception layer is predominant (14 occurrences), followed by ML for Driver Monitoring (4 occurrences) and ML for Decision Making layer (3 occurrences).

Table 5.3 outlines the number of UCs per test execution domain (i.e., 'controlled track', 'open road', 'virtual' as reported in Table 4.41). As seen in the table, 'Open Road' experiments form the majority (29 occurrences), followed by 'Controlled Track' experiments (25 occurrences). It should be noted that based on individual ADF testing information, for a small subset of ADF instances both 'Open Road' and 'Controlled Track' is employed, i.e., the Controlled Track experiments come first and the operations are then transferred to the Open Road environment.

Table 5.3: Experiment execution environment adopted in Hi-Drive UC testing

Number of UCs to be tested in specific test environment / **Type of experiment execution environment**	**Motorway UCs**	**Urban UCs**	**Rural UCs**	**Parking UCs**	**All UCs**
Controlled Track	12	10	1	2	**25**
Open Road	16	11	2	0	**29**
Virtual [11]	4	3	0	0	**7**

Hint: Experimental procedures on how to collect data for the test scenarios described in the Hi-Drive UC catalogue in each of the three types of execution environments, as well as guidelines for optimal OD coverage, are provided in Hi-Drive deliverable D4.3 (Sintonen, 2023).

[11] this is applied before testing in controlled track or open road and not standalone

6 Conclusions and outlook

This deliverable presents the work on the cataloguing and grouping of Hi-Drive use cases and test scenarios as derived based on the analysis of the Hi-Drive ADF instances and associated ODDs, spanning various types of ODD-challenging conditions. This work sets the scenario-based context that will allow the project to analyse with scenario-based performance indicators how the ADFs' ODDs can be extended, compared to the SoA, avoiding ODD fragmentation while ensuring user acceptance, robustness, reliability, and functional safety of high-level automated driving functions.

Overall, 29 AD functions (by 20 Hi-Drive prototype owners) with their ODDs are described using an ODD specification format customized for the project in alignment with the project's research questions. After the grouping and indexing process, a catalogue of 40 UCs grouped in 18 UC clusters are produced, corresponding to the 113 test scenarios described.

The description of ADF instances and the associated UC catalogue are considered a significant result of the work of SP3 that will be used to guide the setup of the Hi-Drive operations, as well as the data-driven analysis methodology of the project soon to be derived (e.g., whereby UCs can be analysed together, and from which the results from different ADF operations may be pooled for statistical processing of the ADF performance indicators, etc.). In particular, this work is expected to be used primarily by:

- Hi-Drive WP4.3 *Research questions* and WP4.7 *Methods for effects evaluation*
- Hi-Drive WP4.5 *Experimental procedures* for producing the experimental procedure recommendations according to the test environments of the UCs.
- Hi-Drive WP4.6 *Methods for user evaluation*
- Hi-Drive WP4.7 *Methods for effects evaluation* and WP7.3 *Test case definition for scenarios* as relevant to the proper definition and preparation for evaluation.
- Hi-Drive WP5.3 *Operations* preparation descriptions and realized/tested by WP5.4 *Operations*
- Hi-Drive WP5.5 *Tools and Databases* as input for automated (data-driven) scenario extraction scripts.

The Hi-Drive UC/Test scenario catalogue demonstrates the project's broad test scenario coverage, and although it does not aim to be exhaustive for testing AD SAE L3 systems, it efficiently represents all the operational domains and test scenarios selected by the Hi-Drive team on which the Hi-Drive ADS prototypes will be evaluated by the project's technical evaluation pipeline. The authors also believe that the methodology for test scenario representation as well as the UC/Test scenario catalogue itself, can be useful outside Hi-Drive for supporting ongoing activities of describing, testing, and evaluating CAD functions in a big range of challenging operational domain conditions.

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List of abbreviations and acronyms

Abbreviation	Meaning
AD	Automated Driving
ADAS	Advanced Driver Assistance Systems
ADF	Automated Driving Function
ADS	Automated Driving System
AV	Automated Vehicle
CAD	Connected Automated Driving
eHMI	External Human Machine Interface
GLOSA	Green Light Optimized Speed Advisory
GNSS	Global Navigation Satellite System
ML	Machine Learning
OD	Operational Domain
ODD	Operational Design Domain
SuT	System under Test
ToR	Take-over Request (usually the system issues a ToR to the driver)
TS	Test Scenario
UC	Use Case
V2N	Vehicle-to-Network
V2V	Vehicle-to-Vehicle
V2X	Vehicle-to-Everything
VRU	Vulnerable Road User

Annex 1 One-page description of the Hi-Drive ADF instances

A1.1 Motorway on-board ADF instance description (12 cards in total)

<table>
<tr><td>M.ADF1</td><td colspan="3">Focus area: support of negotiation for on-ramp sections</td></tr>
<tr><td>ODD specification</td><td colspan="3">The targeted ODD geometry is defined by straight and slightly curved roads with physical separation between traffic directions (i.e., “divided” roads). For the on-ramp vehicle, the ADF will additionally operate on curvy roads. In terms of lanes, the supported ODD accounts for 2 lanes of standard width on the highway plus the on-ramp (which will have at least one lane) with good quality lane markings (both solid and dashed). The roadway edge is expected to be line-marked and the road surface uniform (asphalt). In terms of environmental conditions, the ADF is expected to operate also in presence of calm wind and light rain, under daytime illumination conditions, and irrespective of cloudiness or position of the sun. Finally, in terms of traffic, the ADF is expected to support ODDs of at least low flow rates.</td></tr>
<tr><td>Advanced ADF capabilities / MRM</td><td>The ADF is capable of driving on a motorway in the current lane and handling on-ramp sections via fusion of V2V communication information (ETSI MCS). In case of an unexpected failure, the system performs an MRM.</td><td>Speed range</td><td>60 -130 km/h on highway, 30 -100 km/h on on-ramp</td></tr>
<tr><td>Activation condition</td><td>• Environment requirements fulfilled (e.g., sufficiently good weather, lane markings are detected, curve is not too steep, no construction site, HD map material available).
• Driver is available.</td><td>Conditions for automated de-activation</td><td>• Environment requirements no longer fulfilled.
• Driver is no longer available.
• The motorway is exited.
• System malfunction.</td></tr>
<tr><td>List of ADAS active</td><td colspan="3">• Always on: All safety related ADAS.
• Active before ADS activation: ACC + LKAS.</td></tr>
<tr><td>Activation by user</td><td>The driver turns on ACC/LKAS and then, as soon as the activation conditions are fulfilled, the ADS switches to AD mode.</td><td>De-activation by the user</td><td>• Cancel button on steering wheel.
• Steering input.
• Pedal operation.</td></tr>
<tr><td>ToR activation</td><td colspan="3">If the system decides to de-activate the ADS, the ADS issues a ToR request to the driver. If the driver does not react to the ToR request, then the ADS performs an MRM.</td></tr>
<tr><td>Type/location/purpose of HMI used</td><td colspan="3">Auditory: Different sounds are played on activation, deactivation, and ToR request.
Haptic: The belt tensioner tugs on the driver's seat belt if the driver does not respond to a ToR request.
Visual: The status of the ADS, warnings, and ToRs are shown in the instrument cluster, on the steering wheel, and on the centre display.</td></tr>
<tr><td>Driver role</td><td colspan="3">The driver must be available for take-over. The driver must look either to the front at the road or at the centre display. If the driver looks elsewhere, then, after a few seconds, the driver will be asked to focus on the road in front or on the centre display again. The only allowed side task for the driver is to use the vehicle infotainment system on the centre console.</td></tr>
<tr><td>Safety driver seat position and role</td><td colspan="3">The driver must be a trained safety driver. Annotation of interesting events is not an option for the driver. Annotation is done by a mandatory operator in the rear seat via a keyboard.</td></tr>
<tr><td>Optional features activation (if applicable)</td><td colspan="3">N/A</td></tr>
</table>

M.ADF2	Focus area: support of negotiation for on-ramp sections		
ODD specification	The targeted ODD geometry is defined by straight and slightly curved roads with physical separation between traffic directions (i.e., “divided” roads). For the on-ramp vehicle, the ADF will additionally operate on curvy roads. In terms of lanes, the supported ODD accounts for 2 lanes of standard width on the highway plus the on-ramp (which will have at least one lane) with good quality lane markings (both solid and dashed). The roadway edge is expected to be line-marked and the road surface uniform (asphalt). In terms of environmental conditions, the ADF is expected to operate also in the presence of calm wind and light rain, under daytime illumination conditions, and irrespective of cloudiness or position of the sun. Finally, in terms of traffic, the ADF is expected to support ODDs of at least low flow rates.		
Advanced ADF capabilities / MRM	The ADF is capable of driving on a motorway in the current lane and handling on-ramp sections via fusion of V2V communication information (ETSI MCS). It can also handle lane changes. In case of an unexpected failure, the system performs an MRM.	**Speed range**	60 km/h - 130 km/h on highway; 30 km/h - 100 km/h on on-ramp.

Activation condition	• Environment requirements fulfilled (e.g., sufficiently good weather, lane markings are detected, curve is not too steep, no construction site.).
	• Driver is available.
	• Vehicle is switched on; then there is a switch at the left side of the trunk that needs to be turned on. There is a similar button next to the gear selector in the front of the vehicle which needs to be released (also called emergency stop button). Individual component power buttons are in the armrest and should be turned on.
	  ○ Individual component power buttons are in the armrest and should be turned on.
	  ○ The software for the Traffic Jam Chauffeur should be started by clicking on the button ‘Traffic Jam Chauffeur’ located on the desktop.
	  ○ Two buttons on the steering wheel must be pressed at the same time. Pressing the two buttons simultaneously provides an extra layer of safety and avoids accidental activation of the Traffic Jam Chauffeur.
		Conditions for automated de-activation	• Environment requirements no longer fulfilled.
			• Driver is no longer available.
			• The motorway is exited.
			• System malfunction.

List of ADAS active	There is no ADAS features active apart from the Traffic Jam Chauffeur.		
Activation by user	The driver turns on TJC and then, as soon as the activation conditions are fulfilled, the ADS switches to AD mode.	**De-activation by the user**	• Cancel button on steering wheel. • Steering input. • Pedal operation. • Emergency stop button.
ToR activation	If the system decides to de-activate the ADS, the ADS issues a ToR request to the driver. Our system assumes the availability of an immediate fall-back ready driver.		
Type/location/purpose of HMI used	• Auditory: Different sounds are played on activation, deactivation, and ToR request. • Visual: The status of the ADS, warnings, and ToR requests are shown on the centre display.		
Driver role	The driver must be available for take-over.		
Safety driver seat position and role	The driver must be a trained safety driver. Annotation of interesting events is not an option for the driver. Annotation is done by a mandatory co-driver via a keyboard.		
Optional features activation (if applicable)	N/A		

M.ADF3/U.ADF6/R.ADF2	**Focus area: Cooperative merging, cooperative overtaking, and cooperative intersection transit**		
ODD specification	For Cooperative Merging, the target ODD is Motorway and Motorway to Urban transition with clear lane markings. Vulnerable road users are not expected. For Cooperative Overtaking, road segments with multiple lanes in Motorway (without physical separation) and Motorway to Urban transition (rural roads with 70-90 km/h speed limit) with clear lane markings and without hard separation between lanes/oncoming traffic. For Cooperative Traffic intersections crossing, Urban environment with clear lane markings. Vulnerable road users are not expected. In terms of environmental conditions, the ADF is expected to operate also in the presence of calm wind and light rain, under daytime illumination conditions and irrespective of cloudiness or position of the sun. Finally, in terms of traffic, the ADF is expected to support ODDs of at least low flow rates.		
Advanced ADF capabilities / MRM	Cooperative merging, cooperative overtaking, and cooperative intersection transit.	**Speed range**	Up to 120 km/h
Activation condition	Deemed to be present in ODD. Lead vehicle present.	**Conditions for automated de-activation**	Driver Override, Successful take-over on ODD exit, deactivated by driver via dedicated means.
List of ADAS active	All standard ADAS functions.		
Activation by user	Info is presented to the driver about the availability of the function in HMI.	**De-activation by the user**	Via dedicated interface (driver can override the function).
ToR activation	ToR request is issued.		
Type/location/purpose of HMI used	(Work in progress)		
Driver role	Perform DDT before activation. Free to engage in secondary activities when active but as a 'fallback-ready user'.		
Safety driver seat position and role	Safety driver: Person in the co-driver seat. Logging Trigger and annotation via dedicated trigger, separately mounted next to the driver.		
Optional features activation (if applicable)	N/A		

M.ADF4	**Focus area: Extend and improve the motorway driving chauffeur ADF during ODD challenging sections**
ODD specification	The ODD will consider highway lanes within a straight road with at least 3.5m width, solid, dashed, or yellow lane markers, traffic lanes, right hand, good, fair, or poor lane marker quality. Information, regulatory and warning signs. Roadway edge limited by line markers, gravel, grass or solid barriers and road surface which could be slippery due to water. The area could present different GPS quality zones which should not affect to the operation. The weather could be slightly windy or rainy, during day or night, irrespective of sun position or cloudiness grade. The legacy vehicles could be cars, light commercial vehicles or tracks, the road vulnerable users could be motorcycles, all of them in a low or normal level of traffic, which will be handled by the ADF.
Advanced ADF capabilities / MRM	• Merge to motorway on the same level plane without obstacles that occlude ego-vehicle sensors, • Perform an automated overtaking with no obstacles that occlude ego-vehicle sensors, • Perform lane changes when the ego-vehicle sensors are not occluded, • Keep driving within the lane when there are no errors of positioning signal on HD Map. **Speed range**: Min/max speed range: 0-120 km/h
Activation condition	• System checks that there are no errors (object detection, road description, cooperative system, HMI system, positioning system...), and • The ADF receives an activation request from the user. **Conditions for automated de-activation**: • The AD function is automatically de-activated when a system malfunction is detected while the ADF is active. • Also, an automated de-activation is executed when the system checks that the ego vehicle is not driving within the ODD.
List of ADAS active	ACC/Speed Limiter, LKA, AEB, ISA, TJA.
Activation by user	The HMI system informs the user about ADF availability via IC (instrument cluster) messages and/or icons. The user presses a button on the steering wheel to activate the ADF. **De-activation by the user**: • Pressing a button on the steering wheel, or • Pressing the brake/gas pedal, or • Applying some torque on the steering wheel.
ToR activation	Depending on the reason that triggers the ADF de-activation, the system issues a ToR to the driver or performs an MRM. In case the system requests the user to take back control, the TOR must last approx 5 seconds. If the user does not take the control, or if the risk is too high, the system executes an MRM to reach a safe status.
Type/location/purpose of HMI used	HMI definition will evolve during the project. However, the initial architecture proposed includes: • Auditory advice to communicate notifications and popups and to communicate a TOR situation. An acoustic HMI based on audio tracks that will be emitted through the audio system of the vehicle and additional speakers specifically oriented. • Visual HMI interface to include visual feedback to communicate to the driver all the necessary information to manage the different use cases. It will consist of a digital instrument cluster with a specific HMI prototyped to fulfil user needs.
Driver role	The driver must activate the ADF when the HMI system informs that the function is available. The driver must be ready to take control after a request to intervene issued by the ADF.
Safety driver seat position and role	The safety driver sits in the driver's seat and monitor the environment.
Optional features activation (if applicable)	N/A

<table>
<tr><td>M.ADF5</td><td colspan="3">Focus area: Extend and improve the motorway driving chauffeur ADF on merging sections, as well as on areas affected by hazardous situations or where dynamic signage is provided.</td></tr>
<tr><td>ODD specification</td><td colspan="3">The targeted ODD geometry is defined by straight roads (motorways) with physical separation between traffic directions (i.e., “divided” roads). Partial road obstruction by e.g., crossing bridges, gantry signs or trees are possible. For on-ramp vehicles, the ADF will additionally operate on curvy roads, possibly. In terms of lanes, the supported ODD accounts for 3 lanes of standard width on the motorway (the on-ramp will have at least one lane) with good quality lane markings (both solid and dashed). The roadway edge is expected to be line-marked and the road surface uniform (e.g., asphalt, concrete). A certain set of static, fixed landmarks (e.g., lane markings, traffic signposts, road dividers, bridges, buildings) is required, the minimum number and shape of such landmarks will be investigated during the implementation phase. In terms of environmental conditions, the ADF is expected to operate also in the presence of calm wind/breeze and light rain, under daytime illumination conditions and irrespective of cloudiness or position of the sun. Finally, in terms of traffic, the ADF is expected to support ODDs of at least low flow rates.</td></tr>
<tr><td>Advanced ADF capabilities / MRM</td><td>• Driving on a motorway as well as on the on-ramp (lane and distance keeping).
• Dxecuting automated lane changes.
• Merging with motorway traffic.
• (Automated) execution of minimum risk manoeuvres (available but not operated in any of the UCs given below).</td><td>Speed range</td><td>60-130 km/h</td></tr>
<tr><td>Activation condition</td><td>• Vehicle will detect when it is driving inside of the ODD (map data & positioning).
• System will signalize to the driver that the ADF is available.
• Driver needs to activate the ADF by pressing two paddles on the steering column.</td><td>Conditions for automated de-activation</td><td>• Detection of ODD end (parameters like road geometry, road signage, map coverage).
• Detection of component/system malfunction (e.g., component stops working, no transmission/reception of sensor data, component shutdown).
• V2X triggered take-over request.
• User initiated take-over request (but this is not really an automated de-activation).</td></tr>
<tr><td>List of ADAS active</td><td colspan="3">• ADAS sensors (Camera, Radar, Lidar, V2X, DGPS with IMU) always on.
• (Modified) ADAS functions used (as integral part of the ADF): Lane keeping/following, forward collision warning / auto emergency braking, blind spot detection, speed limiter / smart cruise control.</td></tr>
<tr><td>Activation by user</td><td>• Visual (instrument panel/cluster) indication of availability, audible signals announcing availability.
• User must follow the instructions on the cluster display (pulling two paddles on the steering column to activate the system).</td><td>De-activation by the user</td><td>• User can take over control by pulling the two paddles on the steering column.
• In emergency cases the driver can take back control by a slight counter-steering manoeuvre (pulling the steering wheel) or use the gas or brake pedal.
  • Hitting an emergency knob in the cup-holder area.</td></tr>
<tr><td>ToR activation</td><td colspan="3">• Visual (instrument panel/cluster) indication and audible signals announcing system de-activation (in case ODD termination is imminent). In case the driver does not follow instructions to take back control within a ToC (Transition of Control) period an MRM will be executed
• ToR is issued on time by the system to the driver in case of error or when the ADF journey is completed / ODD terminated.
• ToR is situation/environmental based, but 10 seconds is the current time.</td></tr>
<tr><td>Type/location/purpose of HMI used</td><td colspan="3">A dedicated HMI research/enabler is not part of the Hi-Drive work, but the test vehicle will be equipped with an HMI to support the driver/user of the test vehicle.
• Auditory: Warning/information signals (beeps, alarms) as secondary input for the driver. To support the situation awareness, sounds will be played using in-cabin speakers (either instrument</td></tr>
</table>

	panel or in-cabin speakers from the audio/navigation system (e.g., availability of ADF, de-/activation of ADF, take-over request, minimum risk manoeuvre). • Visual: Warning/information primary source for the driver. The instrument panel (cluster display) will provide information to the driver (e.g., availability of ADF, ADF status, de-/activation of ADF, take-over request, minimum risk manoeuvre, executed manoeuvres, surrounding traffic information, current vehicle speed, V2X information). • Other: A dedicated screen in front of the safety co-driver seat will provide debug information to the safety co-driver. Information presented can be the system/component (e.g., sensor, ECU) status, planned trajectory, sensor raw/fused data, selected route, vehicle state. The co-driver is also able to reconfigure certain parameters (e.g., route planning and driven speeds) of the ADF as well as able to start, stop, or execute certain manoeuvres or functions (e.g., trigger a lane change, change the vehicle speed).
Driver role	• The driver activates the ADF; before and during the activation phase the driver is in full control of the vehicle (and responsible for driving) • The target is that the driver can be (partially) disengaged from the monitoring task to do other tasks (e.g., changing radio station, checking smartphone).
Safety driver seat position and role	The safety driver is located next to the vehicle driver (co-driver seat) and monitors the system status using a display mounted on the dashboard. This monitoring includes informing the driver about upcoming manoeuvres initiated by the vehicle/ADF as well as system errors/malfunctions needing intervention by the driver. The safety driver also configures the test scenario and starts/stops the ADF. The system should continuously log the requested data. Additionally, aux video cameras will be used to record front facing traffic as well as i-cabin activities (e.g., using action cameras).
Optional features activation (if applicable)	Debug features (not really for the driver/user), which can be changed/adapted by the safety driver: • De-/activation of lateral control. • De-/activation of longitudinal control. • Selection of test scenario (e.g., route selection). • Triggering of lane changes.

M.ADF6*	**Focus area: Field monitoring (enablers in shadow mode)**		
ODD specification	Motorway with or without traffic.		
Advanced ADF capabilities / MRM	Our ADF is a basic one and can just follow a lead vehicle; it cannot handle lane changes, merging to motorway traffic, intersection, or roundabout.	**Speed range**	0 – 130 km/h
Activation condition	Lead vehicle is not a prerequisite, but we should have a driver alert. We can activate the function when the vehicle proposes it, i.e., when roads are allowed.	**Conditions for automated de-activation**	ODD exit detection criteria: GNSS end of availability. System malfunction: bad sensor reception; roadworks; driver unavailable.
List of ADAS active	-		
Activation by user	Professional driver pushes a specific button if ADF is available.	**De-activation by the user**	Specific button: steering wheel or brakes allow the driver to take back control.
ToR activation	The system asks the driver to take back control. After a few seconds (20sec?) the system deactivates itself.		
Type/location/purpose of HMI used	N/A		
Driver role	Professional driver: responsible for the drive, activates the ADF when it is allowed and deactivates when necessary. We also have a professional co-driver for all other activities in the car.		
Safety driver seat position and role	The professional co-driver is next to the driver, and may have to annotate interesting events via a dedicated screen in the vehicle.		
Optional features activation (if applicable)	Special sensors for data acquisition only.		

M.ADF7	Focus area: L3 Pilot demonstrator extended to manage challenging environments: positioning problems, lack of road infrastructure, temporary variations of the road (e.g., roadworks)		
ODD specification	The enabler will mainly focus on high-speed roads where the infrastructure is typically well maintained. Motorway, extra-urban road but also applicable to high-speed urban roads (with well-defined lane markings) and merging sections (motorway to urban transition).		
Advanced ADF capabilities / MRM	Motorway chauffeur vehicle to increase the amount of time with L2/L3 ADF active, thanks to lane-level positioning accuracy in difficult driving conditions, preventive manoeuvres (e.g., speed reduction, lane change). HC or TJP, according to velocity. The transition from HC to TJP and vice versa is automatic.	**Speed range**	min/max speed range 0-130 km/h
Activation condition	Perception layer always active, vehicle control in motorway only. For SAE-L3 when driver is attentive. (Is lead vehicle existence a prerequisite? Is driver alert status a prerequisite?) Depending on the UC.	**Conditions for automated de-activation**	Unsolvable inconsistencies among perception sensors, absolute position, and map.
List of ADAS active	Highway Assist system (ACC, Lane-centring).		
Activation by user	HMI	**De-activation by the user**	HMI or brake intervention.
ToR activation	ADS issues a ToR to the driver in case of DDT fallback.		
Type/location/purpose of HMI used	Visual: central cluster.		
Driver role	Driver is the safety driver (see row below).		
Safety driver seat position and role	Safety driver in the driver's seat. The driver must accept the ADS. suggestions before triggering any safety manoeuvre.		
Optional features activation (if applicable)	-		

M.ADF8*	Focus area: Front free area estimation by radar for advanced ACC		
ODD specification	Motorway that is not limited by illumination of the scene such as tunnel, construction, bridge, and harsh weather conditions.		
Advanced ADF capabilities / MRM	Longitudinal control.	Speed range	max 110 km/h
Activation condition	• ADF function will be activated by safety driver. • ADF function will be activated while lateral manoeuvre is controlled by safety driver.	Conditions for automated de-activation	De-activation from safety driver, system malfunction, AEB activation.
List of ADAS active	ACC L2 function.		
Activation by user	Clear indication on HMI of the vehicle.	De-activation by the user	Emergency shut-off by pressing an Estop button, Manual intervention by brake pedal
ToR activation	N/A		
Type/location/purpose of HMI used	N/A		
Driver role	Controlling lateral manoeuvre during ACC with radar perception.		
Safety driver seat position and role	Safety driver position is in the driver's seat. • Awareness environment and vehicle surrounding ego vehicle. • HMI status check. Prepare for immediate handover with driver's hands on the steering wheel.		
Optional features activation (if applicable)	N/A		

M.ADF9	Focus area: Support of GPS-denied regions and construction areas		
ODD specification	GNSS-denied areas. A typical use case for GNSS occlusion is a tunnel while piloting on a motorway. The targeting tunnel has a length of approximately 8 km, with an average speed of 80 km/h; the GNSS will not be available for more than 6 minutes. Motorway construction zone.		
Advanced ADF capabilities / MRM	The demonstration vehicle will localize itself inside the tunnel and will be well positioned in the correct lane to make sure that a manual take-over scenario in automated and driving mode is not requested. A localization error at the tunnel exit, today typically caused by an IMU error as soon as the GNSS signal is available, will be reduced to a tolerable minimum and ensure an ongoing automated driving operation after leaving the tunnel exit. The demonstration vehicle will localize itself inside the construction area and will be well positioned in the right lane to make sure that a manual take-over scenario in automated driving mode is not requested.	**Speed range**	50-80 km/h
Activation condition	• Prerequisite: ADF is already activated before tunnel entry with clear localization and in ODD.	**Conditions for automated de-activation**	ADF will be de-activated in case of • ODD exit detection criteria (e.g., critical situations: accident, construction area, fire engine, emergency ambulance, ...). • De-activation from safety driver (e.g., unexpected manoeuvres from other road users, traffic jam, ...). • System malfunction.
List of ADAS active	N/A		
Activation by user	Clear identification on HMI of the automated driving vehicle.	**De-activation by the user**	• Manual intervention will result in de-activation. • Emergency shut-off by pressing a button.
ToR activation	ToR activation in case of system malfunction will de-activate the ADF.		
Type/location/purpose of HMI used	• Auditory: Acoustic signals for transition from Manual to ADF and back. • HMI Location: Centre stack. • HMI Content: Situation awareness.		
Driver role	Safety driver is responsible for taking care of the vehicle and other road users. No other tasks are allowed.		
Safety driver seat position and role	Driver is behind the steering wheel and always ready for a sudden take-over request from the automated driving vehicle.		
Optional features activation (if applicable)	-		

M.ADF10	Focus area: Support for motorway interchanges			
ODD specification	Interchange from one motorway to next motorway. The envisioned ODD geometry is defined by straight roads with physical separation between traffic directions (i.e., “divided” roads). For the on-ramp vehicle, the ADF will additionally operate on curvy roads, possibly. In terms of lanes, the supported ODD accounts for 3 lanes of standard width on the highway (the on-ramp will have at least one lane) with good quality lane markings (both solid and dashed). The roadway edge is expected to be line-marked and the road surface uniform (asphalt). In terms of environmental conditions, the ADF is expected to operate also in the presence of calm wind and light rain, under daytime illumination conditions and irrespective of cloudiness or position of the sun. Finally, in terms of traffic, the ADF is expected to support ODDs of at least low flow rates.			
Advanced ADF capabilities / MRM	ADF provides longitudinal and lateral control. The enabler (location and map and navigation) allows the ADF to follow another direction - that of the interchange. Without the enabler the vehicle with ADF would follow the existing lane inside the lane markings and respond to traffic around it.		Speed range	Up to 130 km/h
Activation condition	• ADF (long., lat.) is on. • BLIS is on. • Automated Lane change • Driver alert with a driver monitoring system from our series vehicles is planned. • Destination must be entered & findable. Route must be calculated and available. • Vehicle is on a path that is assumed by the navigation system. • Robust location information from sensor fusion is present.		Conditions for automated de-activation	• Mismatch of location and map, i.e., interchange is earlier or later than expected, or is missing entirely. • Driving on a street not considered for ADF (Tunnels etc.). • Driving out of ODD. • Driver has eyes off the road for longer than N seconds. For safety reasons hands-off driving is not allowed.
List of ADAS active	Lateral and longitudinal control is active, BLIS is active. Automated lane change is active.			
Activation by user	• In the prototype the status is on according to the L2-activation message (on the instrument panel, the steering wheel is green, lane markers are white or active). • User activation via Navigation. • User activation by L2-buttons on steering wheel.		De-activation by the user	The ADF can always be de-activated by braking, out-of-lane steering, L2-buttons.
ToR activation	Hands-off, Eyes-off warning. ToR activation. Braking to standstill if driver does not react.			
Type/location/purpose of HMI used	• Auditory: Escalating beep with Hands-off, Eyes-off warning. • Auditory: ADF deactivation warns with a beep if hands-on driving. • Haptic: Brake jerk under consideration. • Visual: Cluster information on status.			
Driver role	For safety reasons professional drivers are driving. Later trials with ordinary drivers and safety driver. They must not sleep; eyes need to be on the road. See above			
Safety driver seat position and role	Driver sits behind the steering wheel and is attentive (professional driver). For later trials a safety driver is provided in the passenger seat. Annotation is done with the passenger. They enter events in the data logging via notebook.			
Optional features activation (if applicable)	Navigation is pretty complex, and no other features are expected to be activated in addition.			

<table>
<tr><td>M.ADF11</td><td colspan="3">Focus area: User aspects testing via in-cabin driver monitoring</td></tr>
<tr><td>ODD specification</td><td colspan="3">The ODD addressed within Hi-Drive includes Level 3 automated driving on motorways (<130 km/h, M.1) and urban motorways (dual carriageways meaning structurally separated directions, <60 km/h, U.1, U.2).
For the operation of motorway chauffeur (M.1) and urban motorway chauffeur (U.1) with the L3Pilot vehicles, a safety driver is seated in the co-driver seat. In a new test vehicle for urban motorway (built-up is planned), the ODD will be the same as for U.1 but without needing a safety driver.
Since the enabler driver monitoring only requires a specific camera setup within the test vehicle and an according logging concept, it is not dependent on any other ODD specifications such as road types, environmental conditions, or traffic characterization.</td></tr>
<tr><td>Advanced ADF capabilities / MRM</td><td>• Motorway chauffeur: Level 3 driving on motorway up to 130 km/h, participant as driver (safety driver on co-driver seat)
• Urban motorway chauffeur: Level 3 driving on urban motorway up to 60 km/h, participant as driver (with/without safety driver in co-driver seat).</td><td>Speed range</td><td>Motorway chauffeur (M.1): 0-130 km/h
Urban motorway chauffeur (U.1, U.2): 0-60 km/h</td></tr>
<tr><td>Activation condition</td><td>• Motorway Chauffeur: Motorway excluding on-ramps and off-ramps as well as road construction sites and tunnels. Driver input by pressing button on steering wheel.
• Urban motorway Chauffeur: Urban motorway with separated carriageways excluding intersections. Lead vehicle is a pre-requisite. Driver input by pressing button on steering wheel.</td><td>Conditions for automated de-activation</td><td>Qualitatively insufficient information on driving environment. System malfunction (prototype).</td></tr>
<tr><td>List of ADAS active</td><td colspan="3">ACC + lane keeping</td></tr>
<tr><td>Activation by user</td><td>Acoustic signals and visual signals (in instrument cluster).</td><td>De-activation by the user</td><td>• Pressing button on steering wheel.
• Braking.
• Strong steering moment.
• Combination of hands on the steering wheel and using the gaspedal.</td></tr>
<tr><td>ToR activation</td><td colspan="3">A ToR activation is issued.
Fallback during on-road tests is the safety driver in the passenger seat in some UCs.</td></tr>
<tr><td>Type/location/purpose of HMI used</td><td colspan="3">N/A</td></tr>
<tr><td>Driver role</td><td colspan="3">The driver is responsible for activation and needs to supervise the activation process and stay attentive until the ADF is fully activated.
The driver is allowed to divert their attention from the driving task when the ADF is active and engage in other tasks such as vehicle infotainment or own device, etc. The driver is not allowed to sleep or move away from the driver seat and the relevant controls.</td></tr>
<tr><td>Safety driver seat position and role</td><td colspan="3">Safety driver is seated in the co-driver seat during the entire trip. The safety driver is responsible for supervising the functionality of the ADF and intervening in critical situations or malfunctions. Annotation of events is not intended.</td></tr>
<tr><td>Optional features activation (if applicable)</td><td colspan="3">No</td></tr>
</table>

M.ADF12*	Focus area: data collection and real-time testing of enablers in shadow mode for on-ramp merging (manually driven prototype vehicle)				
ODD specification	The envisioned ODD geometry is defined by motorways with an arbitrary number of lanes and merging ramps. The chosen route could contain a mixture of straight and curved roads. Lanes will feature good-quality lane markings (both solid and dashed). The route will have good GPS signal strengths/coverage. The test is supposed to be done under normal weather conditions (sunny, partly cloudy, or light rain). Other road users will likely include cars, motorcycles, and trucks.				
Advanced ADF capabilities / MRM	N/A (manual driven mode)			**Speed range**	0-70 mph
Activation condition	N/A (manual driven mode)	**Conditions for automated de-activation**	N/A (manual driven mode)		
List of ADAS active	N/A				
Activation by user	N/A		**De-activation by the user**	N/A	
ToR activation	N/A				
Type/location/purpose of HMI used	Visual: demonstrating real-time performance of the integrated enabler.				
Driver role	Manually driving according to relevant rules and regulations.				
Safety driver seat position and role	Vehicle is manually driven.				
Optional features activation (if applicable)	N/A				

A1.2 Urban on-board ADF instance description (10 cards in total)

U.ADF1	Focus area: Support for GLOSA (Green Light Optimized Speed Advisory)		
ODD specification	Urban intersection with signalized interface with a communicating traffic light. • Situation with two traffic lights. The above situation is a preconnected traffic light and active corridor given by MAP message. An ego vehicle comes from the left and detects the conditionally active TL. The permanent TL is only recognized after passing the first TL with a very short distance of 40m for adequate action. Both TL corridors must be detected and considered for smooth passage.		
Advanced ADF capabilities / MRM	ADF provides longitudinal and lateral control and responds to traffic lights, adapting the ego speed. Without the enabler the vehicle with ADF would follow the existing lane inside the lane markings and respond to traffic around it but not to traffic light signals.	Speed range	Up to 60 km/h
Activation condition	• In urban driving, lead vehicle is not necessary. • Timely traffic light information is necessary. • Driver alert status is not checked yet, driver but needs to be alert.	Conditions for automated de-activation	Deactivation if: • there is no traffic light information available, • quality of lane markings is inadequate (outside ODD), • the driver is informed that the automated approach is not working, • No warning device specified yet.
List of ADAS active	Lateral and longitudinal control is active, BLIS is active.		
Activation by user	Function is on when Longitudinal control is active.	De-activation by the user	The ADF can always be de-activated by braking.
ToR activation	Hands-off warning.		
Type/location/purpose of HMI used	• Auditory: Escalating beep with Hands-off warning. • Auditory: ADF deactivation warns with a beep if hands-on driving.		
Driver role	For safety reasons professional drivers are driving. Later trials with ordinary drivers and safety driver. They must not sleep, and eyes must be on the road.		
Safety driver seat position and role	Driver sits behind the steering wheel and is attentive (professional driver). For later trials a safety driver is provided in the passenger seat. Annotation is done with the passenger, entering events in the data logging via notebook.		
Optional features activation (if applicable)	None.		

U.ADF2	Focus area: Support for non-signalized intersections		
ODD specification	All operation tests are going to be performed on test tracks where the Hi-Drive enabler is expected to operate on sections emulating B-roads and unsignalized intersections. The envisioned ODD geometry is defined by straight roads without physical separation between traffic directions (i.e., “undivided” roads) joining at an intersection and possibly having pedestrian crossing structures. In terms of lanes, the supported ODD will account for at least one lane per driving direction with lane markings of good quality (both solid and dashed). The roadway edge is expected to be line-marked and the road surface uniform (asphalt). In terms of environmental conditions, the enabler is expected to operate also in presence of calm wind and light rain, under daytime illumination conditions and irrespective of cloudiness or position of the sun. Finally, in terms of traffic, the enabler is expected to support ODDs of at least low flow rates and presence of vulnerable road users as detectable objects.		
Advanced ADF capabilities / MRM	• Driving on B-roads (lane and distance keeping) and cross/turn at intersections. • Executing automated lane changes. • (Automated) execution of minimum risk manoeuvres (available but not operated in the UCs).	**Speed range**	0-50 km/h
Activation condition	• Vehicle will detect when it is driving inside of the ODD (map data & positioning). • System will signalize to the driver that the ADF is available.	**Conditions for automated de-activation**	• Detection of ODD end (parameters like road geometry, road signage, map coverage).

	• Driver needs to activate the ADF by pressing two paddles on the steering column.		• Detection of component/system malfunction (e.g., component stops working, no transmission/reception of sensor data, component shutdown). • Take-over request (please note, this function is part of the ADF safety concept, but will not be adopted as a studied feature in the UCs).
List of ADAS active	ADAS sensors (Camera, Radar, Lidar, V2X, DGPS with IMU) always on. (Modified) ADAS functions used (as an integral part of the ADF): Lane keeping/following, forward collision warning / auto emergency braking, blind spot detection, speed limiter / smart cruise control.		
Activation by user	• Visual (instrument panel/cluster) indication of availability, audible signals announcing availability. • User must follow the instructions on the cluster display (pulling two paddles on the steering column to activate the system).	**De-activation by the user**	• User can take over control by pulling the two paddles on the steering column. • In emergency cases the driver can take back control by a slight counter-steering manoeuvre (pulling the steering wheel) or use the gas or brake pedal. o Hitting an emergency knob in the cup-holder area.
ToR activation	• Visual (instrument panel/cluster) indication and audible signals announcing system de-activation (in case ODD termination is imminent). In case driver does not follow instructions to take back control within a ToC (Transition of Control) period a minimum risk manoeuvre (MRM) will be executed (same as stated in cell B.6 applies). • ToR is issued in time by the system to the driver in case of error or when the ADF journey is completed / ODD termination. • ToR is situation/environment based and adapted, but 10 seconds is the present time.		
Type/location/purpose of HMI used	A dedicated HMI research/enabler is not part of the Hi-Drive work, but the test vehicle will be equipped with an HMI to support the driver/user of the test vehicle. • Auditory: Warning/information signals (beeps, alarms) as secondary input for the driver. To support the situation awareness, sounds will be played using in-cabin speakers (either instrument panel or in-cabin speakers from the audio/navigation system (e.g., availability of ADF, de-/activation of ADF, take-over request, minimum risk manoeuvre). • Visual: Warning/information primary source for the driver. The instrument panel (cluster display) will provide information to the driver (e.g., availability of ADF, ADF status, de-/activation of ADF, take-over request, minimum risk manoeuvre, executed manoeuvres, surrounding traffic information, current vehicle speed, V2X information). • Other: A dedicated screen in front of the safety co-driver seat will provide debug information for the safety co-driver. Information presented can be the system/component (e.g., sensor, ECU) status, planed trajectory, sensor raw/fused data, selected route, vehicle state. The co-driver is also able to reconfigure certain parameters (e.g., route planning and driven speeds) of the ADF as well as able to start, stop or execute certain manoeuvres or functions (e.g., trigger a lane change, change the vehicle speed)		
Driver role	• The driver activates the ADF, before and during the activation phase the driver is in full control of the vehicle (and responsible for driving) • Target is that the driver can be (partially) disengaged from the monitoring task to do other tasks (e.g., changing radio station, checking smartphone). Note: Since a prototyping vehicle with prototype function implementation is under test, the test driver will need to continue with supervising the vehicle state to be able to take back control in case of a malfunction or unexpected risky situation.		
Safety driver seat position and role	The safety driver is located next to the vehicle driver (co-driver seat) and monitors the system status using a display mounted on the dashboard. This monitoring includes informing the driver about upcoming manoeuvres initiated by the vehicle/ADF as well as system errors/malfunctions that need intervention by the driver. The safety driver also configures the test scenario and starts/stops the ADF.		

	The system should continuously log the requested data. Additionally, aux video cameras to record front facing traffic and in-cabin activities (e.g., action cameras).
Optional features activation (if applicable)	Debug features (not really features for the driver/user), which can be changed/adapted by the safety driver: • De-/activation of lateral control • De-/activation of longitudinal control • Selection of test scenario (e.g., route selection) • Triggering of lane changes.

U.ADF3/R.ADF1	Focus area: urban driving and support for transition to rural and cross-border		
ODD specification	The ODD addressed in L3Pilot (Urban) is extended by rural sections and driving cross-border. The ADF is designed to operate in urban areas and rural sections <70 km/h. The ODD includes signalized and unsignalized intersections and roundabouts. Additionally, the ADF is designed to drive on urban motorways, exit- and entry-ramps. During operation a safety driver is required in the driving seat and an operator in the co-driver seat.		
Advanced ADF capabilities / MRM	The ADF is capable of driving in urban environments including roundabouts, signalized and unsignalized intersections. The ADF is capable of merging on an urban motorway and of performing lane changes on urban motorways as well as in urban traffic. Road construction zones are only included if they stay unchanged for a longer time and considered ahead of testing.	**Speed range**	Currently: 0-50 km/h (might be extended to 70 km/h)
Activation condition	Safety driver can activate the ADF on its designated route, if the ODD requirements are fulfilled (no extreme weather conditions, no emergency vehicles, no unexpected construction zones, all ADF modules are running). It is activated by pulling the steering column lever.	**Conditions for automated de-activation**	• System malfunction (prototype): e.g., low battery, missing sensor signals, general vehicle malfunction, … • Software: If malfunction of any software component is detected.
List of ADAS active	None, ADF replaces ADAS.		
Activation by user	Availability of ADF: Operator advises safety driver when to activate. Availability of vehicle control interface: visual and acoustic signals in instrument cluster.	**De-activation by the user**	• Lateral or longitudinal take-over: apply torque to steering wheel, apply pressure to accelerator or brake pedal, pull hand brake. • ADF deactivation: push steering column lever, push emergency-stops, …
ToR activation	Depending on deactivation cause, either MRM or ToR is performed. ToR request is a single acoustic and visual signal. Safety driver is at fallback level during testing.		

Type/location/purpose of HMI used	• Auditory: Simple “pling” to request driver to take over control. Located in instrument cluster.
	• Haptic: none.
	• Visual:
	  ○ Status of longitudinal and lateral vehicle control.
	  ○ Driving mode (automated driving mode vs. manual driving mode).		

Driver role	Driver = safety driver		
Safety driver seat position and role	Driver not allowed to engage in other tasks besides supervising ADF.		
Optional features activation (if applicable)	-		

U.ADF4	**Focus area: Support for GLOSA and handling of low GNSS sections**.
ODD specification	The ODD geometry is applicable on straight and curved roads with physical separation between traffic directions (i.e., “divided” roads). In terms of lanes, the supported ODD is applicable for 1 to 3 lanes of width between 2.5 and 4m on minor roads with good quality lane markings (including solid, dashed, and yellow), intended for right-hand traffic lanes. The roadway edge is expected to be line-marked and the road surface uniform (asphalt) and dry. Interference zones, e.g., dense foliage or loss of positioning signal due to tall buildings are applicable. Bridges, tunnels, and signalized intersections are accepted as well. In terms of environmental conditions, the ADF is expected to operate also in the presence of calm wind and breeze, under daytime or night illumination conditions and irrespective of cloudiness or position of the sun. Finally, in terms of traffic, the ADF is applicable for low flow rates.
Advanced ADF capabilities / MRM	The ADF is capable of keeping the lane and stopping in front of a traffic light if found on the HD map. The current ADF cannot yet handle signal phases or timing information of traffic lights.. **Speed range**: From 0 to 50 km/h
Activation condition	No system errors and ADF user request (user press button on steering wheel) **Conditions for automated de-activation**: • System malfunction. • Non-compliance of ODD. • TOR/MRM situation. • Gas, brake, or steering override.
List of ADAS active	• Before: Front Assist, PDC (Parking Distance Control), Manoeuvre AEB (Automatic Emergency Braking). • During ADF activation: ACC / Speed Limiter, Lane keeping, Traffic Jam Assistant, Front Assist, PDC, Manoeuvre AEB.
Activation by user	AD availability is indicated through a customized HMI in the instrument cluster. The driver activates the ADF by pushing the dedicated button placed in the interior zone of the steering wheel. **De-activation by the user**: Gas, brake, or steering wheel override, or pushing the dedicated button in the interior zone of the steering wheel.
ToR	If the system decides to automatically deactivate the ADF, a TOR request is sent to the driver. If there is no driver response in the next 5 seconds, an MRM will be executed (still not working, it will be prepared for Hi-Drive operations). In some risky situations, an MRM will be directly executed without a TOR request.

Type/location/purpose of HMI used	• Acoustic: definition in progress for
	  ○ AD connection/disconnection
	  ○ TOR situations.
	• Visual: definition in progress for instrument cluster with specific HMI to show
	  ○ AD availability
	  ○ AD connection/disconnection
	  ○ TOR
	  ○ Information about the related use cases.

Driver role	• ADF Activation. • During AD Mode, for safety reasons, the driver must be aware of any failure of the system and take control if requested or necessary.
Safety driver seat position and role	The safety driver seat position is the usual position of the driver. Annotation events could be generated by pushing a steering wheel button (TBD).
Optional features activation (if applicable)	N/A

U.ADF5	Focus area: Support for V2V for handling events beyond line of sight		
ODD specification	The envisioned ODD geometry is defined by an urban road. Maximum speed is 50 km/h and in any case equal to or lower than the posted speed limit. Roadwork zones are excluded as well as heavy rain, flooded or snowy roads.		
Advanced ADF capabilities / MRM	The vehicle drives in its lane or changes lane to follow the navigation route. It can detect vulnerable road users (VRUs) such as pedestrian, bicycle, etc.	Speed range	0-50 km/h
Activation condition	A safety driver will be always present in the car as well as an operator to check the car behaviour and the AD system. AD 'detects' compatible roads and proposes to the driver to switch to automated mode.	Conditions for automated de-activation	The driver can take control of the vehicle at any time either by applying sufficient torque on the steering wheel or by braking/accelerating with enough pressure that the vehicle detects it as a voluntary action. When the automated system is engaged but an error has occurred preventing the car from operating safely, then the system notifies the driver to take over.
List of ADAS active	PCS		
Activation by user	LEDs inform the driver of the system status. When the system is ready (green light), the driver can activate ADS by using the ACC button.	De-activation by the user	The driver can take control of the vehicle at any time either by applying a sufficient torque on the steering wheel or by braking/accelerating with enough pressure that the vehicle detects it is a voluntary action. The driver can press the "Cancel" ACC button to disengage as well.
ToR	When the automated system is engaged but an error has occurred preventing the car from operating safely, the system notifies the driver to take over.		
Type/location/purpose of HMI used	• Auditory: Beeps. • Visual: Coloured LEDs for system status.		
Driver role	The driver is the safety driver (see row below).		
Safety driver seat position and role	A safety driver will be always present behind the steering wheel for safety purposes. His task is to follow the vehicle behaviour and be ready to take over.		
Optional features activation (if applicable)	N/A		

U.ADF6 → see M.ADF3

U.ADF7	Focus area: Vision-based perception		
ODD specification	The ODD is defined by urban areas with available HD map. The environmental conditions are restricted to daylight and no heavy rain or snowfall. Crossroads with traffic lights, left and right turns are covered. Other road users can be passenger cars, busses, trucks, bicycles, and pedestrians. The ODD includes scenarios with a decreased reliability of LIDAR sensors, e.g., rainy weather or small objects (which cannot be detected due to the limited LIDAR measurement resolution).		
Advanced ADF capabilities / MRM	Straight and curvy roads, signalized intersection, left and right turns, roundabouts, lane changes.	**Speed range**	max. 70 km/h
Activation condition	(Work in progress)	**Conditions for automated de-activation**	(Work in progress)
List of ADAS active	-		
Activation by user	(Work in progress)	**De-activation by the user**	The ADF is deactivated when the safety driver takes over the steering wheel.
ToR activation	(Work in progress)		
Type/location/purpose of HMI used	N/A		
Driver role	See row below.		
Safety driver seat position and role	The safety driver is seated in the driver's seat. The safety driver supervises the reliability of the driving function and must be able to take over control of the vehicle at any moment.		
Optional features activation (if applicable)	N/A		

<table>
<tr><td>U.ADF8</td><td colspan="3">Urban chauffeur with communication by lighting</td></tr>
<tr><td>ODD specification</td><td colspan="3">Minor roads that are straight and can have some level of slope. Traffic lanes are separated by good quality dashed markings, with driving on the right side. The edge of the road has solid markings. The road surface is dry and uniform. The weather conditions are optimal, with calm wind and possible light rain. Any cloudiness is supported. Illumination conditions supported are the following: low ambient lighting and day illumination with some limitations towards the high end.</td></tr>
<tr><td>Advanced ADF capabilities / MRM</td><td>Our ADF will provide an eHMI to communicate the vehicle intentions while negotiating priority with other vulnerable road users. This ADF is expected to operate in urban areas. Our ADF will provide an eHMI to communicate the vehicle intentions to the following car. This ADF is expected to operate in urban areas with frequent stops.</td><td>Speed range</td><td>0-50 km/h</td></tr>
<tr><td>Activation condition</td><td>• Host vehicle is moving forward.
• Host vehicle has a safe stopping distance.
• ADF function is active,
• Pedestrian is detected and characterized (Pedestrian Position& Dynamics, intention, risk of collision, etc.) via vehicle sensor.
• Road conditions fulfilled (curve is not too steep, no construction site).
OR
• ADF function is activated.
• Following vehicle is detected via vehicle sensor and/or V2I connectivity.
Road conditions fulfilled (curve is not too steep, no construction site).</td><td>Conditions for automated de-activation</td><td>• Pedestrian no longer present (?)
• Road condition not fulfilled.
• System malfunction.
• Sensor data failure.</td></tr>
<tr><td>List of ADAS active</td><td colspan="3">TBD</td></tr>
<tr><td>Activation by user</td><td>Via car dashboard.</td><td>De-activation by the user</td><td>Cancel button.</td></tr>
<tr><td>ToR activation</td><td colspan="3">Yes, ToR in case of system will de-activate the ADS.
MRM (TBC)</td></tr>
<tr><td>Type/location/purpose of HMI used</td><td colspan="3">No specific HMI for the driver. The enablers are eHMIs (Display & 360 Near Field Projection) placed on the car body.</td></tr>
<tr><td>Driver role</td><td colspan="3">The driver must be available for take-over request.</td></tr>
<tr><td>Safety driver seat position and role</td><td colspan="3">The safety driver will be in the driver's seat.
Is annotation of interesting events an option via a handheld device or vehicle HMI? TBC.</td></tr>
<tr><td>Optional features activation (if applicable)</td><td colspan="3">N/A</td></tr>
</table>

<table>
<tr><th>U.ADF9</th><th colspan="3">Focus area: Support for smart intersections (collective perception)</th></tr>
<tr><td>ODD specification</td><td colspan="3">The ODD will consider low speed (~20mph) urban roads on the university campus. This chosen route could contain a mixture of straight and curved roads with connecting complex junctions:
○ Single carriageway (two lanes)
○ One-way traffic (one lane)
○ Shared space roads
○ Roundabouts
○ Speed bumps
○ Pedestrian crossing - traffic lights and zebra crossings.
Road lanes will feature good quality lane markings (both solid and dashed) with information, regulatory, and warning signs. The roadway edge is defined by line markers, gravel, grass, or solid barriers and the road surface will be dependent on weather. The route is likely to contain a range of GPS signal strengths/performance characteristics. The weather will be varied depending on the time of year and will likely include wind, rain, fog, and possibly snow with driving taking place in different lighting conditions. Other road users will likely include cars, motorcycles, e-scooters, light and heavy goods vehicles, pedestrians, and cyclists with a mixture of traffic densities.</td></tr>
<tr><td>Advanced ADF capabilities / MRM</td><td>• Driving on urban single carriageway (two lanes) with good lane markings.
• Driving with an onboard safety driver.
• Driving in good weather conditions with good to fair visibility.
• Driving through crossings with and without roadside signals.
• Driving through roundabouts with low traffic.</td><td>Speed range</td><td>0-20 mph</td></tr>
<tr><td>Activation condition</td><td>• Environment requirements are fulfilled (e.g., sufficiently good weather, lane markings are present).
• Driver is available.
• Vehicle is switched on.
• Individual components are switch on (sensor, GNSS, router, pc …).
• Execute software to start the ADF.</td><td>Conditions for automated de-activation</td><td>• The safety driver intervenes (brake or steering input from the safety driver).
• The requested manoeuvre is completed.
• Emergency stop button pressed.
• System malfunction.</td></tr>
<tr><td>List of ADAS active</td><td colspan="3">FCW & AEB</td></tr>
<tr><td>Activation by user</td><td>Vehicle indicates that automation is available through the visual UI.
The user must press a button to engage the ADF.</td><td>De-activation by the user</td><td>Any steering or breaking input from the driver will disengage the DBW system and return the vehicle to manual control.</td></tr>
<tr><td>ToR activation</td><td colspan="3">On triggering de-activation of the ADF, the system will perform a ToR to the safety driver.
In case of a ToR to the safety driver, the request should last approximately 5 seconds.</td></tr>
<tr><td>Type/location/purpose of HMI used</td><td colspan="3">• Distinct audible alerts will be played when the ADF is overridden by the safety driver.
• Custom visual HMI located near the centre console for displaying ADF availability and for ToR.</td></tr>
<tr><td>Driver role</td><td colspan="3">• The driver must always be alert to the driving situation and be ready to take over in a timely manner.
• The driver must activate the ADF when the function is available, as indicated on the HMI.</td></tr>
<tr><td>Safety driver seat position and role</td><td colspan="3">The safety diver will sit in the driver's seat and will be responsible for taking control of the vehicle in the event of an unsafe manoeuvre by the ADF or during a ToR.</td></tr>
<tr><td>Optional features activation (if applicable)</td><td colspan="3">N/A</td></tr>
</table>

U.ADF10	Focus area: Record Data for Driver Intention Prediction		
ODD specification	The envisioned ODD geometry is defined by an urban road with and without zebra crossings. Zebra crossings are clearly marked on the floor and additionally have traffic signs indicating the crossing area.		
Advanced ADF capabilities / MRM	Interpretation of an algorithm for driver intention prediction (current algorithm is based on neural networks) to propose a temporal behaviour of automated vehicles at pedestrian crossings (implicit communication). Therefore, we need to interpret the algorithm to know how it decides and what the clearest predictions are. These can be used to develop an automated vehicle's implicit communication in SP6 *Users*. The data needed is collected with manually driven vehicles.	Speed range	0-70 km/h
Activation condition	No activation of an ADF.	Conditions for automated de-activation	No de-activation of an ADF.
List of ADAS active	There could be ADAS active, but not necessarily.		
Activation by user	Only data collecting and evaluation.	De-activation by the user	Only data collecting and evaluation.
ToR activation	Only data collecting and evaluation.		
Type/location/purpose of HMI used	Visual feedback is not given at this stage but targeted for later implicit and explicit communication.		
Driver role	No other tasks in parallel allowed. The driver should act as normal as possible during data collection.		
Safety driver seat position and role	No safety driver.		
Optional features activation (if applicable)	N/A		

U.ADF10: Already described as part of M.ADF6.

A1.3 Rural on-board ADF instance description (3 cards)

R.ADF1 → Already described as part of U.ADF3

R.ADF2 → Already described as part of U.ADF6

R.ADF3	**Focus area: Driving in arctic conditions; Maintaining connectivity in a cross-border area.**		
ODD specification	Rural roads in all weather conditions including arctic winter. Cross-border section also considered.		
Advanced ADF capabilities / MRM	• Free driving on rural (two-lane) roads without lane markings and in urban areas, max speed 50 km/h • Car-follow function. • Non-signalized and signalized at-level intersection driving, turning, & passing through. • Non-signalized pedestrian crossing/obstacle avoidance. • Driving in good weather and winter (snowy) conditions.	Speed range	0-50 km/h
Activation condition	No special activation conditions when on test route.	Conditions for automated de-activation	When too far from the pre-programmed route.
List of ADAS active	ESP/ASR activated (manual driving, AD).		
Activation by user	No indication.	De-activation by the user	Brake pedal, emergency stop, HMI indication.
ToR activation	Visual indication of ToR, no MRM.		
Type/location/purpose of HMI used	Visual warning on HMI display located in central console of car.		
Driver role	Professional safety driver (see below).		
Safety driver seat position and role	Front seat behind the steering wheel. Safety driver is supervising obstacles in front and vehicle behaviour, monitoring of ADF performance, deactivation, and take-over when needed, no NDRA allowed during the drive.		
Optional features activation (if applicable)	N/A		

A1.4 Parking on-board ADF instance description (3 cards)

P.ADF1	Focus area: Automated valet parking		
ODD specification	ODD extended from outdoor parking to indoor parking without GNSS reception. Parking lots that are e.g., separated by line markings. Line markings should not be completely blocked by parked cars (i.e., wrong positioning of parked vehicles).		
Advanced ADF capabilities / MRM	The ADF is capable of performing an automated parking manoeuvre within an area with GNSS coverage which has been mapped before.	Speed range	Min/max speed range: 0-7 km/h
Activation condition	The ADF can be activated when: • The system checks that the prerequisites are met (within ODD, digital map available, no vehicle errors, ...). • The ADF receives a drive request (drop-off/pick-up) from the user.	Conditions for automated de-activation	• The AD function must be automatically de-activated when a system malfunction is detected while the ADF is active. • Also, an automated de-activation must be executed when the system checks that the ego vehicle is not driving inside the ODD.
List of ADAS active	There are no other ADAS functions active while the ADF is active.		
Activation by user	The ADF activation is triggered by the user via a smartphone app.	De-activation by the user	The user can cancel the automated driving mode via the smartphone app.
ToR activation	Depending on the reason that triggers the ADF de-activation, the system will perform an MRM and notify the driver on its smartphone app.		
Type/location/purpose of HMI used	HMI solution for Automated Valet Parking is a mobile app. The app shows the progress of parking and informs when the operation has stopped.		
Driver role	The driver activates and de-activates the ADF. Furthermore, the user can cancel the automated driving mode. After an MRM has been executed, the driver must get to the vehicle and take over control of the vehicle.		
Safety driver seat position and role	The safety driver is in the driver's seat and monitors the environment.		
Optional features activation (if applicable)	N/A		

<table>
<tr><td>P.ADF2</td><td colspan="3">Focus area: Automated valet parking</td></tr>
<tr><td>ODD specification</td><td colspan="3">The ODD will consider urban roads and parking within a straight or curved lane the dimensions of which should be between 2.5 and 4 m width, solid, dashed, or yellow lane markers, traffic lanes (when minor roads), right hand, good, fair or poor lane marker quality. Also, regarding the road geometry a level plane will be considered, and for a transverse plane divided or undivided road, pavements, barriers on road edges are included. Information, regulatory, and warning signs will be considered when urban road lanes. Roadway edge can be limited by line markers, gravel, grass, or solid barriers and road surface which could be slippery due to water. The area could present different GPS quality zones which should not affect to the operation. Within the fixed road structure will be included buildings, streetlights, street furniture (e.g., bollards), and vegetation. The weather could be slightly windy or rainy, during the day or night, irrespective of sun position or cloudiness grade. The legacy vehicles could be cars (a low rate of traffic would be considered, or normal level of traffic) and the VRUs would be pedestrians, bicyclists, scooters, motorcycles, and wheelchairs/wheeled mobility assistance vehicles.</td></tr>
<tr><td>Advanced ADF capabilities / MRM</td><td>Able to perform a full parking manoeuvre within an area with a constant condition of GNSS coverage.</td><td>Speed range</td><td>Min/max speed range: 4-8 km/h</td></tr>
<tr><td>Activation condition</td><td>• The system checks that there are no errors (object detection, road description, cooperative system, HMI system, positioning system...), and
• The ADF receives an activation request from the user.</td><td>Conditions for automated de-activation</td><td>• The AD function is automatically de-activated when a system malfunction is detected while the ADF is active.
• Also, an automated de-activation is executed when the system checks that the ego vehicle is not driving inside the ODD.</td></tr>
<tr><td>List of ADAS active</td><td colspan="3">ACC/Speed Limiter, LKA, AEB, ISA, TJA.</td></tr>
<tr><td>Activation by user</td><td>ADF activation is triggered by the user via a smartphone app.</td><td>De-activation by the user</td><td>ADF deactivation is automated when a failure is detected, and the user is informed via the smartphone app.</td></tr>
<tr><td>ToR activation</td><td colspan="3">Depending on the reason that triggers the ADF de-activation, the system shall perform an MRM.</td></tr>
<tr><td>Type/location/purpose of HMI used</td><td colspan="3">HMI solution for Parking will consist of:
• Visual HMI: from one side to the user, through a screen visualization and some lighting feedback. The purpose of this HMI is to inform the user about the different phases of Valet Parking. Furthermore, in the case of lighting, this will also be located on the exterior of the car to communicate information about the ADF status to other vehicles.
• Auditory: Using the speakers of the vehicle, auditory feedback will be used to get the attention of the user for specific UCs.
Also, this UC requires development of a connected application to manage the UC from the exterior of the car.</td></tr>
<tr><td>Driver role</td><td colspan="3">The driver activates the ADF when the smartphone app informs that the function is available.</td></tr>
<tr><td>Safety driver seat position and role</td><td colspan="3">The safety driver sits in the co-driver’s seat and monitors the environment.</td></tr>
<tr><td>Optional features activation (if applicable)</td><td colspan="3">N/A</td></tr>
</table>

<table>
<tr><td>P.ADF3</td><td colspan="4">Parking chauffeur with communication by lighting</td></tr>
<tr><td>ODD specification</td><td colspan="4">The parking chauffeur ADF is targeted at a parking lot (outdoor or indoor). The road surface is dry and uniform. The weather conditions are optimal in the case of outdoor parking, with calm wind.</td></tr>
<tr><td>Advanced ADF capabilities / MRM</td><td colspan="2">The ADF will provide an eHMI to create a safety zone around the vehicle and communicate the vehicle intentions while manoeuvring to other vulnerable road users. This ADF is expected to operate in parking areas.</td><td>Speed range</td><td>0-15 km/h</td></tr>
<tr><td>Activation condition</td><td>• ADF function is activated.
• Pedestrian is detected and characterized (Pedestrian Position& Dynamics, intention, risk of collision, etc.) via vehicle sensor.
• Road conditions fulfilled (curve is not too steep, no construction site).</td><td>Conditions for automated de-activation</td><td colspan="2">• Road condition not fulfilled.
• System malfunction.
• Sensor data failure.</td></tr>
<tr><td>List of ADAS active</td><td colspan="4">N/A</td></tr>
<tr><td>Activation by user</td><td>Via car dashboard.</td><td>De-activation by the user</td><td colspan="2">Cancel button.</td></tr>
<tr><td>ToR activation</td><td colspan="4">Yes, ToR in case of system will de-activate the ADS.
MRM (TBC)
How many seconds is ToR active? (TBD)</td></tr>
<tr><td>Type/location/purpose of HMI used</td><td colspan="4">No specific HMI for the driver. The enablers are eHMIs (Display & 360 Near Field Projection) placed on the car body.</td></tr>
<tr><td>Driver role</td><td colspan="4">The driver must be available for take-over request.</td></tr>
<tr><td>Safety driver seat position and role</td><td colspan="4">The safety driver is in the driver's seat.
Is annotation of interesting events an option via a handheld device or vehicle HMI? TBC</td></tr>
<tr><td>Optional features activation (if applicable)</td><td colspan="4">N/A</td></tr>
</table>

Annex 2 ODD specification template

General instructions for filling in the ODD spec excel file

Each Hi-Drive ADF owner is expected to create one ODD spec file for each ADF, considering the three sets of ODD attributes defined (i.e., nominal, performance, extended). Please follow the four steps listed hereafter:

1. Mark with 'x' the ODD attributes handled by your ADF before enabler integration (nominal ODD).
2. Based on the set of x marked in the previous step, now **mark with bold** font these attributes (from nominal ODD) that are actually going to be tested in your Hi-Drive Operation: Mark with '**x**'.
3. Now add**,** if applicable**,** red **x to new attributes** (i.e, not part of the nominal ODD) that you are able to handle due to a Hi-Drive enabler integration: Mark with **'x'**.
4. Add related UC IDs for all attributes marked in steps 2+3.

The Hi-Drive ODD taxonomy, see Section 2.2.4.1, includes three tables that are described in the following three subsections.

A2.1 Table for ODD specification Roads

Table A 2.1: Attributes of the ODD-spec "Roads"

Instructions >>>>> (Yellow background cells denote fields to be filled in)	PLEASE FILL IN with 'x' or **'x' or 'x'** or put a number in all applicable cells, i.e., column 'A' attributes that are handled (hence recognized) by your ADS.	PLEASE FILL IN with 'x' or **'x'** or **'x'** or put a number in the applicable cells, i.e., column 'B' attributes that are handled (hence recognized) by your ADS.	PLEASE FILL IN with 'x' or **'x'** or **'x'** or put a number in the applicable cells (i.e., column 'D' attributes that are handled (hence recognized) by your ADS).	PLS fill in related UC ID if bold **'x'** or **'x'** is denoted.
ROADS includes the following sub-structures: **1 Drivable area** **2 Geometry** **3 Lane specification** **4 Road signs** **5 Roadway edge** **6 Road surfaces** **7 Zones** **8 Special structures** **9 Fixed road structures** **10 Temporary road structures**				
1. Drivable area			Associated Speed Limit for this drivable area (if fixed)	Related UC ID
a) Motorway roads				
	With active traffic management (smart motorways);			
	Without active traffic management.			
b) Ramps (on/off motorway)				
c) Radial roads				
d) Distributor roads				
e) Minor roads				
f) Intersections				
	a. Signalized			
	ii. Unsignalized			
g) Roundabouts				
h) Parking				
k) Shared space				
2. Geometry				
a) Horizontal plane				
	a. Straight lines			
	b. Curves			
b) Transverse plane				
	a. Divided or undivided road			
	b. Pavements			

	c. Barriers on road edges			
	d. Types of lanes together			
c) Vertical plane				
	a. Up-slope			
	b. Down-slope			
	c. Level plane			
3. Lane specification				
a) Lane dimensions				
b) Lane markings				
	i) Solid			
	ii) Dashed			
	iii) Yellow			
c) Lane type				
	i) Bus lane			
	ii) Traffic lane			
	iii) Cycle lane			
	iv) Tram lane			
	v) Emergency lane			
	vi) Dedicated lane			
d) Number of lanes				
e) Direction of travel				
	i) Right-hand travel			
	ii) Left-hand travel			
f) Lane marker quality				
	i) Good			
	ii) Fair			
	iii) Poor			
4. Road signs				
a) Information signs				
b) Regulatory signs				
c) Warning signs				
5. Roadway edge				
a) lLne markers				
b) Shoulder (paved or gravel)				
c) Shoulder (grass)				
d) Solid barriers (e.g., grating, rails, curb, cones)				
e) Temporary line markers				
f) None				
6. Road surfaces				
a) Dry				
b) Damp				
c) Wet				
d) Snow-covered				
e) Icy				
f) Leaves				
c) Holes in the asphalt				
d) Type				
	i) Uniform (e.g., asphalt)			
	ii) Segmented (e.g., cobblestones)			
7. Zones				
a) Geo-fenced areas				
b) Traffic management zones				

c) School zones				
d) Interference zones, e.g., dense foliage or loss of positioning signal due to tall buildings				
e) Rush-hour affected zones				
f) Local on-road hazard affected zone				
	Traffic incident			
	Unusual object			
8. Special structures				
a) Automatic access control				
b) Bridges				
c) Pedestrian crossings				
d) Rail crossings				
e) Tunnels				
f) Toll plaza				
9. Fixed road structures				
a) Buildings				
b) Streetlights				
c) Street furniture (e.g., bollards)				
d) Vegetation				
e) Non-static roadside object like trashcans				
10. Temporary road structures				
a) Construction site detours				
b) Refuse collection				
c) Roadworks				

A2.2 Table for ODD specification Environmental Conditions

Table A 2.2: Attributes of the ODD-spec "Environmental conditions"

	PLEASE FILL IN with 'x' or '**x**' or '**x**' or put a number in the all applicable cells, i.e. column 'A' attributes that are handled (hence recognized) by your ADS.	PLEASE FILL IN with 'x' or '**x**' or '**x**' or put a number in the applicable cells (i.e. column 'B' attributes that are	PLS fill in related UC ID if bold '**x**' or '**x**' is denoted.
ENVIRONMENTAL CONDITIONS			
1 Weather			
2 Particulates			
3 Illumination			
*PAS 1883 Connectivity was ren			
(1) Weather			**Related UC ID**
a) Wind			
	i) calm: 0–0.2 m/s;		
	v) breeze: 5.5–13.8 m/s;		
	ix) gale: 17.2–24.5 m/s;		
	xi) storm: 24.5–28.4 m/s;		
b) Rainfall			
	i) light rain: when the precipitation rate is < 2.5 mm/h		
	ii) moderate rain: when the precipitation rate is between 2.5 mm/h and 7.6 mm/h		
	iii) heavy rain: when the precipitation rate is between 7.6 mm/h and 50 mm/h		
	iv) violent rain: when the precipitation rate is between 50 mm/h and 100 mm/h		
	v) cloudburst: when the precipitation rate is > 100 mm/h		
c) Snowfall			
	i) light snow, where visibility is greater than 1 km		
	ii) moderate snow, where visibility restrictions are between 0.5 km and 1 km		
	iii) heavy snow, where visibility is less than 0.5 km		
(2) Particulates (obscuration by non-precipitating water droplets and other particulates)			
a) Marine (coastal areas only)			
b) Non-precipitating water droplets or ice crystals (i.e. mist/fog)			
c) Sand and dust			
d) Smoke and pollution			
e) Volcanic ash			
(3) Illumination			
a) Day			
b) Night or low-ambient lighting condition			
c) Elevation of sun	degrees		
c) Position of sun			
	i) in front		
	ii) behind		
	iii) right side		
	iv) left side		
e) Artificial illumination			
	i) streetlights		
	ii) oncoming vehicle lights		
f) Cloudiness			
	i) clear – no possibility of cloud fully or partially obscuring the sun;		
	ii) partly cloudy – some possibility of a direct path of sunlight to the CAV between clouds;		
	iii) overcast – there are no breaks.		

A2.3 Table for ODD specification Road Users

Table A 2.3: Attributes of the ODD-spec "Road users"

	PLEASE FILL IN with 'x' or '**x**' or '**x**' or or put a number in all applicable cells, i.e. column 'A' attributes that are handled (hence recognized) by your ADS.	PLEASE FILL IN with '**x**' **or put a number** in the applicable cells (i.e. column 'B' attributes that are handled (hence recognized) by your ADS).		PLS fill in UC ID if bold '**x**' or '**x**' is denoted.
ROAD USERS				
1 Vehicles				
2 Vulnerable Road Users				
3 Intended ego vehicle category (*new, borrowed from MUSICC)				
*PAS 1883 defines traffic agents as element of Traffic. We did it differently. Moreover we added intended ego-vehcile category.				
			volume of traffic (optional, number of traffic agents passign a fixed point per hour)	**Related UC ID**
(1) Vehicles				
a) Cars				
b) Light Commercial Vehicles				
c) Trucks				
d) Emergency and rescue vehicles				
e) Other vehicles (garbage trucks, street sweepers,...)				
(2) Vulnerable Road Users				
a) Pedestrians				
b) Bicyclists				
c) Animals				
d) Scooters				
e) Motorcycles				
f) Wheelchairs/wheeled mobility assistance vehicles				
(3) Intended ego vehicle category				
a) Passenger car				
b) Truck				