EVENTS

ReliablE in-Vehicle pErception and decisioN-making in complex environmenTal conditionS

Grant Agreement Number: 101069614

D.2.1: User and System Requirements for selected Use-cases

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Executive Summary

The “D2.1: User and System Requirements for Selected Use-Cases” deliverable is a public report of the EVENTS project, which main goal is to provide the requirements (REQs) of the EVENTS systems and sub-systems, which are defined based on use cases (UCs) and experiments (EXPs). The latter are defined as the specific realizations of one or more UCs by each partner or by synergies of more than one partners. Having therefore as a basis the Grant Agreement (GA), in which three UCs were defined, the work carried out in WP2/Task T2.1 aimed at fine-tuning the UCs’ description and at defining the EXPs that are going to be conducted throughout the project.

Starting from these UCs and EXPs, this deliverable, that is part of WP2/Task 2.2, presents the collection of the requirements (REQs) that need to be satisfied by the EVENTS components, which will be described in the next deliverable about functional architecture (D2.2), as well as the analysis of these requirements collected by the partners of the consortium. A total of 135 requirements have been collected, categorized in General, Decision-Making, Perception, Operational and Actuation. The vast majority of the requirements refers to Perception, Operational and Decision-Making.

The activities of T2.1 and T2.2 are finalized with this deliverable; the project development continues with T2.3, which main goal is to define the EVENTS systems’ and sub-systems’ architecture and its specific instantiations in the project demonstrators.

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Abbreviations & Acronyms

Abbreviation / acronym	Description
ACC	Adaptive Cruise Control
AD(F)	Autonomous Driving (Function)
AL	Alert Limit
AV	Automated Vehicle
CA	Consortium Agreement
CAM	Cooperative Awareness Message
CAV	Connected Automated Vehicle
CPM	Collective Perception Messages
DDT	Dynamic Driving Task
EC	European Commission
EXPs	Experiments
GA	Grant Agreement
IR	Integrity Risk
ISO	International Organization for Standardization
MOP	Moving Object Prediction
MOT	Multi-Object Tracking
ODD	Operational Design Domain
PE	Position Error
PL	Protection Level
REQs	Requirements
SAE	Society of Automotive Engineers
SPaT message	Signal Phase and Timing message
SPECs	Specifications
TSs	Target Scenarios
UCs	Use Cases
VRU	Vulnerable Road User
WP	Work Package

1. Introduction

Deliverable D2.1 “User and System Requirements for selected Use-cases” presents the project’s Use Cases (UCs) and derives system and user requirements (REQs) for each subsystem described inside the UCs. The work on UCs starts with analyzing the three main UCs selected from the proposal phase for demonstrating perception and decision-making capabilities in different operational domain conditions. It then proceeds with breaking down these UCs into experiments (EXPs), where more detailed sub-UCs are described as well as how these sub-UCs will be tested and development of which (C)AD sub-systems they assume. Finally, based on the information from the UCs and the EXPs, the REQs of the EVENTS systems and subsystems are derived.

1.1 Aim of the Project

Driving is a challenging task. In our everyday life as drivers, we are facing unexpected situations we need to handle in a safe and efficient way. The same is valid for Connected and Automated Vehicles (CAVs), which also need to handle these situations, to a certain extent, depending on their automation level. The higher the automation level is, the higher the expectations for the system to cope with these situations are.

In the context of this project, these unexpected situations where the normal operation of the CAV is close to be disrupted (e.g. ODD limit is reached due to traffic changes, harsh weather/light conditions, imperfect data, sensor/communication failures, etc.), are called “events”.

Today, CAVs are facing several challenges (e.g. perception in complex urban environments, Vulnerable Road Users (VRUs) detection, perception in adverse weather and low visibility conditions) that should be overcome in order to be able to handle these events in a safe and reliable way.

Within our scope, and in order to cover a wide area of scenarios, these kinds of events are clustered under three main use cases: a) Interaction with VRUs, b) Non-Standard and Unstructured Road Conditions and c) Low Visibility and Adverse Weather Conditions.

Our vision in EVENTS is to create a robust and self-resilient perception and decision-making system for AVs to manage different kind of events on the horizon. These events result in reaching the CAV ODD limitations due to the dynamic changing road environment (VRUs, obstacles) and/or due to imperfect data (e.g. sensor and communication failures). The CAV should be able to operate safely in these challenging conditions. When the system cannot handle the situation, an improved minimum risk manoeuvre should be put in place.

1.2 Purpose of the Document

This deliverable is part of the work in Work Package 2 (WP2): “Use cases, requirements and system design” and its main objective is to illustrate in detail the use cases (UCs), the experiments (EXPs), as well as the requirements (REQs) of the EVENTS system. As the first deliverable of WP2, in which the UCs and REQs are described, it will directly influence the other technical documents in the project, since the included information is the basis for all technical developments and research activities in EVENTS. So, for example, the real-world observations and models, as well as the perception and decision-making algorithms of WP3 (“Perception and self-assessment”) and WP4 (“On-board decision-making for fail-safe automated vehicle motion”) will focus on the selected UCs. In these cases, solutions for the selection of the optimal and safe maneuver of the AV in harsh conditions are developed for the EVENTS systems. In WP5 “System integration and safety compliance”, the demonstrators are addressing the use cases described in this deliverable, satisfying the related requirements, to provide the final, integrated EVENTS solutions, for the evaluation work in WP6 (“Evaluation and cost-efficient sensor suites”), and to present the EVENTS achievements to the public in the demonstrator vehicles.

1.3 Related EVENTS Tasks and Terminology

There are two main terms to clearly define, Use Cases (UCs) and Experiments (EXPs). Use Cases (UCs) are the abstract use cases that were initially defined in the Grant Agreement (GA) and are described with refinements in this document (Section 2). More specifically, a UC is a collection of related aspects of the operational design in which the system will be deployed, along with the desired behaviour of the AV. Our UCs are described from the AV perspective, meaning that the AV needs to react to a certain traffic situation/condition.

Experiments (EXPs) are the specific realizations of one or more UCs by each partner or by synergies of more than one partners. EXPs are described in detail in Section 3.

An overview of the structure of WP2, which demonstrates the methodological workflow from the UCs to the EXPs definition (Task T2.1), to the REQs collection and analysis (Task T2.2), to the EVENTS systems’ and sub-systems’ architecture (Task T2.3) and finally, to the hazard analysis & risk assessment (Task T2.4) is shown in Figure 1. A more detailed figure, including the analysis of UCs, EXPs and REQs that follows, is shown in Annex 1.

Finally, three more terms that need to be defined are a scene, a scenario and a functional scenario. A scene represents a snapshot of the environment including the scenery, dynamic elements, and all actors’ and observers’ self-representations, and the relationships among those entities [3]. A scenario is a description of the temporal relationship between several scenes in a sequence of scenes, with goals and values within a specified situation [3]. A functional scenario is a scenario described in natural language on a conceptional level, in general without specific physical values [4]. More details can be found in [3] and [4], as well as in the "*interACT*" EU co-funded project (https://www.interact-roadautomation.eu/).

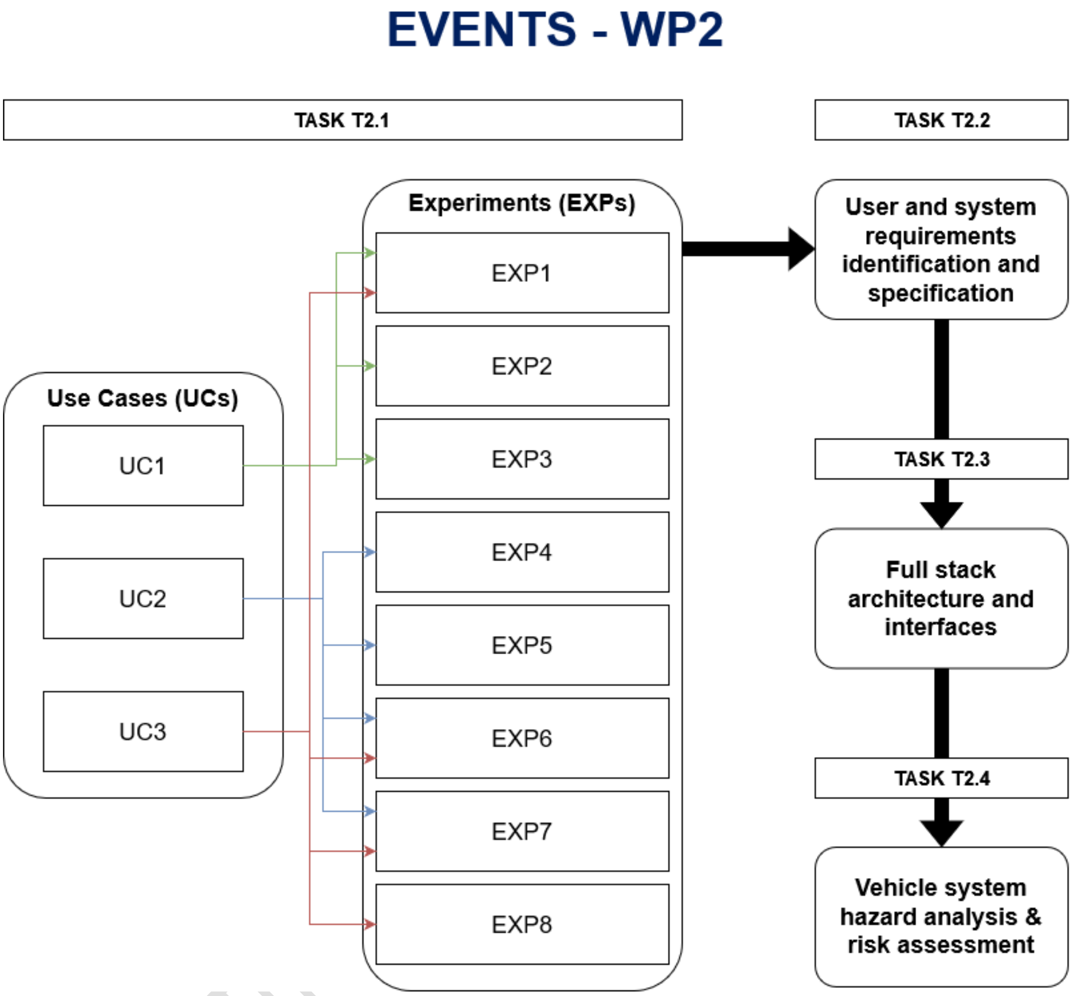


Figure 1: EVENTS WP2 structure

1.4 Intended Readership

This deliverable is addressed to any interested reader (i.e., PU dissemination level), wishing to know more in details how the EVENTS systems are specified. In addition to that, D2.1 can be practically useful for the consortium members, in particular for WP2 partners, who can use it as a basis for exchanging information as well as understand the UCs and high-level test scenarios in which partners will focus and the requirements of CAVs to operate on those scenarios. For WP3 and WP4 partners, the document will serve a general understanding of the different scenarios that will frame the experiments in which each partner will focus to demonstrate its technology. Finally, for WP6 partners, the document will help them start from the selected UCs to derive and then provide the test-scenarios for the evaluation activity.

1.5 Document Overview

The document is structured in seven sections. After a short introduction on the EVENTS project and the purpose of the current document, the UCs are described in detail, in Section 2. In Section 3, the eight EXPs that are going to be carried out throughout the project are defined. In Section 4, the methodology for eliciting the REQs is described. The REQs for each experiment and per partner are listed in Section 5. In Section 6, the collected REQs are analysed. Finally, in Section 7, final remarks are made with regards to this deliverable.

2. Use Cases (UCs) Description

This section describes the Use Cases (UCs), as described in the Grant Agreement (GA) of the EVENTS project and gives an overview of the challenges to be addressed in each of them with regards to the Perception and Decision-Making AD tasks.

2.1 UC1: Interaction with vehicles and VRUs in Complex Urban Environment

UC1 is concerned with the safe and resilient automated driving (AD) in complex urban environments, i.e., cluttered surroundings (occlusions), multiple road users, V2X-assisted intersections. Particular focus is given on interacting with Vulnerable Road Users (VRUs), e.g., pedestrians, cyclists. Urban roundabouts are also of interest in this UC with focus on V2V info integration and advanced control based on collective perception. The participating partners are (in alphabetical order): 1. ICCS, 2. TECN, 3.TUD and 4. UULM.

The perception challenges associated with UC1 are the following:

- Large variability in the appearance of VRUs (e.g. due to height, mass, clothes, articulated pose, and gazing direction).
- Cluttered surroundings and potential for (partially or fully) occluded vehicles and VRUs.
- Multiple VRUs with high possibility of maneuverability.

The decision-making challenge associated with UC1 is the safe, comfortable and time-efficient motion planning, while coping with the involved uncertainties regarding vehicles, connectivity and VRUs (high maneuverability, perception errors etc.).

The proposed approach for AD systems to interact with vehicles and VRUs in a complex urban environment includes:

- Multi-sensor data fusion for improved VRU detection and localization performance. Performance comparison of various sensor combinations (camera, radar, LiDAR).
- VRU motion prediction:
    - Identify which context cues and models to incorporate.
    - Consider the interpretability of motion models (“Explainable AI”).
    - Implement novel ML solutions to understand the intention of VRUs based on their body language.

- Use of V2X in addition to on-board perception to account for visibility obstructions in urban intersections.
- V2X info integrity checks before fusing it with perception.
- Use of V2V in addition to on-board perception to account for restricted FOV due to curvature or visibility obstructions in urban roundabouts (optional – if available). It is necessary a V2V info consistency check before fusing it with perception.
- Principled way of dealing with uncertainty due to imperfect sensing and future road user (inter)action. Sound propagation of uncertainties from the perception component to motion planning component.

2.2 UC2: Non-Standard and Unstructured Road Conditions

UC2 investigates non-standard and unstructured road conditions, for example, road works, accident-zones, or park areas with no lane markings. The participating partners are (in alphabetical order): 1. APTIV, 2. CRF, 3. HIT-FR, 4. HIT-UK, 5. TECN and 6. WMG.

The perception challenges associated with UC2 are the following:

- High precision localization in unstructured environment despite the absence of landmarks.
- Detection of non-standard and unstructured road conditions with typical supervised learning approaches (e.g., object detectors).
- Identification of zones related to road works or accidents, which will require a holistic scene understanding approach (detecting traffic beacons/poles, additional road markings, special-type vehicles like ambulances and police cars, uniformed personnel).
- Lack of communication makes the aforementioned challenges particularly hard.

The decision-making challenges associated with UC2 are the following:

- Decide the high-level maneuvers that a non-standard traffic condition requires, possibly in contradiction with normal traffic rules. Decide whether a minimum risk maneuver is necessary.
- Decide the trajectory that needs to be executed in the presence of uncertainties from perception and localization.
- Design overtaking maneuver for urban park open areas.

The proposed approach for AD systems to cope with non-standard and unstructured road conditions includes:

- Use of data augmentation techniques based on synthetic data (simulation).
- Multi-sensor data fusion for highly accurate 3D measurements.
- Model normative conditions with unsupervised learning, detect anomaly as deviation from norm. Self-assessment of perception and decision-making components.
- Modelling the decision-making process.

2.3 UC3: Low Visibility & Adverse Weather

UC3 aims to extend the environmental conditions of AD functions. The participating partners are (in alphabetical order): 1. APTIV, 2. HIT-FR, 3. HIT-UK, 4. ICCS, 5. S4 and 6. WMG.

The perception challenges associated with UC3 are the following:

- Detection of road users and other objects, under low visibility and adverse weather conditions.
- Prediction of other vehicles behavior (lane changing maneuver), under low visibility and adverse weather conditions.
- Self-assessment of localization and perception under adverse weather conditions.
- Estimation of the road friction.
- Robust localization when snow, fog or rain impair the LiDAR.

The decision-making challenge associated with UC3 is translating the adverse visibility and road conditions to appropriate vehicle motion planning, decision-making and control measures.

The proposed approach for AD systems to cope with low visibility and adverse weather conditions includes:

- Increase training data of object detectors (and their performance) in low visibility and adverse weather conditions by domain adaptation, self-supervision, and adding synthetic/simulated data.
- Multi-LiDAR SLAM for filtering snow/fog/rain in 3D mapping and maintain accurate localization.

- Multi-sensor (camera, LiDAR, radar) data fusion approaches for object detection and road condition estimation.
- Integration of V2X information (optional – if available).
- Optimization-based decision-making constrained by visibility/weather conditions. Such conditions are to be estimated online using specialized ML models trained to classify challenging visibility/weather events.
- Improvement and dynamic adaption of the motion planning algorithm based on slippery road conditions.
- Fail-safe planning despite occluded objects and incomplete data, e.g., missing lane markings. This may be achieved by combining traditional optimization-based approaches with modern data driven solutions.
- Adaptive and real-time emergency motion planning based on current road conditions.

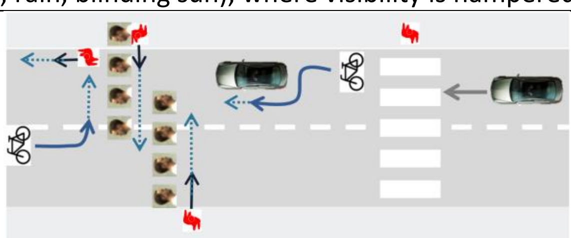
Based on the abovementioned described UCs, in the next Section, we illustrate the experiments carried out in the EVENTS project.

3. Experiments (EXPs) Description

In this section, the UCs are further detailed in finer groups that form the eight experiments where more detailed sub-UCs are described. Each experiment includes the following information:

- Sub-UC title, Reference UC and Leading Partner,
- AD System Under Test and targeted ODD,
- Functional scenarios to be tested including a graphical sketch description of the sub-UC,
- Experimental setup preliminary info including information on prototype vehicle, data needed and hints for Evaluation.

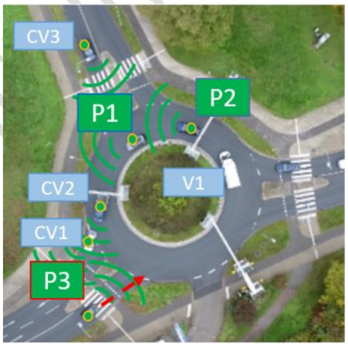
3.1 EXP1: Interaction with VRUs in complex urban environment

General Info	
Experiment Title	Interaction with VRUs in complex urban environment
Leading Partner	TUD
Partners Involved	---
Reference Use Case	UC1 & UC3
Associated Tasks	T3.2, T3.3, T3.5, T4.1, T4.2 & T4.3
AD SuT/ Target Operational Domain and Functional Scenario(s)	
Short Verbal Description	EXP1 is about safe, comfortable and time-efficient automated driving in complex urban environment while interacting with VRUs (e.g. pedestrians, cyclists). The environment perception, road user motion prediction, motion planning and vehicle control will be demonstrated in a single integrated system on-board TUD's own vehicle prototype. The experiment consists of the ego-vehicle driving on a two-lane road (i.e., one lane on each side) whereas several VRUs might (or might not) move into the vehicle's path (e.g., crossing, walk longitudinally, swerve), possibly from behind occlusions (e.g., parked vehicles). The question is whether to decelerate, accelerate or steer away. Experimentally, some VRUs will be real, while others will be realistic dummies (e.g., 4activeSystems). This experiment will include both benevolent and more challenging environmental/lighting conditions (e.g., night, rain, blinding sun), where visibility is hampered.
Detailed Graphical Description	 *Figure 2: EXP1 example*
Initial Assumptions	---

Partners' contribution	TUD will demonstrate in its prototype vehicle the interaction of a self-driving vehicle with VRU(s), "full stack". That is, environment perception, road user motion prediction, motion planning and vehicle control will be demonstrated in a single integrated system on-board a real vehicle (SAE level L2 and L3). This might include some type of handcrafted HD map.
Partners' synergies	TUD will be able to handle a few VRU experiment variants independently and share some related non-proprietary datasets. Also, it would be beneficial to share test equipment (e.g. realistic dummies) wherever possible between partners.
Traffic & Environment conditions	The overall experiment is that of the ego-vehicle driving on a two-lane road (i.e. one lane on each side) whereas several VRUs might (or not) move into the vehicle's path (crossing, walk longitudinally, swerve), possibly from behind occlusions (e.g. parked vehicles). The question is whether to decelerate/accelerate or to steer away. Experimentally, some VRUs will be real, while others will be realistic dummies (e.g. 4activeSystems). Some experiment variant will be in benevolent sensing conditions.
Traffic Participants' (TPs) Attributes	Environment perception will aim to extract intent-relevant cues like gaze/head orientation and body pose to improve VRU motion prediction.
Autonomous Vehicle's (AV) Attributes	---
Limitations	Vehicle speeds up to 30 km/h. In the direct vicinity of real pedestrians / cyclists probably lower.
Other relevant information	---
Vehicle Info	
Model	Toyota Prius
Communication	No V2X
Sensors	Currently: front facing stereo-camera, radar and 360° LiDAR 64-layer Velodyne. Sensor set-up might be upgraded.
Data	
Availability	To be discussed
Format	TUD specific initially. To be discussed if other formats are required. TUD uses ROS 1 as middleware.
Openness	To be discussed
Hints for Evaluation	
KPIs	Environment perception is assessed by detection quality (localization accuracy, correct vs. false positives) and tracking quality (id changes etc.). Motion execution of ego-vehicle is assessed along three dimensions: safety, comfort, and time efficiency. Safety and comfort to be assessed both objectively (e.g., safety metrics like time-to-collision (TTC), shortest distance or comfort metrics like maximum acceleration/deceleration) and subjectively (e.g. questionnaire).
Preliminary plan (if available)	---

3.2 EXP2: Re-establish platoon formation after splitting due to roundabout

<table>
<tr><th colspan="2">General Info</th></tr>
<tr><td>Experiment Title</td><td>Re-establish platoon formation after split due to roundabout</td></tr>
<tr><td>Leading Partner</td><td>TECN</td></tr>
<tr><td>Partners Involved</td><td>ICCS (T3.4, T3.5)</td></tr>
<tr><td>Reference Use Case</td><td>UC1</td></tr>
<tr><td>Associated Tasks</td><td>T3.4, T3.5, T4.1, T4.2 & T4.3</td></tr>
<tr><th colspan="2">AD SuT/ Target Operational Domain and Functional Scenario(s)</th></tr>
<tr><td>Short Verbal Description</td><td>In EXP2, a coordinated platooning planning is investigated via V2X info integration. A platoon ensemble composed by three CAVs (one CAV leader and two CAVs as followers) in an urban environment is assumed, which is split because of traffic when approaching and crossing a roundabout (driving rules in the roundabout are assumed to prioritize the vehicles inside the roundabout). The followers should be able to reach the leading vehicles ensuring string stability also under curved trajectories. Planning of re-joining the platoon takes advantage of Collective Perception Messages' (CPMs) fused info (and confidence) that is made available to the follower when entering the roundabout.</td></tr>
<tr><td>Detailed Graphical Description</td><td>The experiment incorporates perception augmentation via safe integration of collective perception info, predictive planning for the control of the platooning in an urban environment (T4.1), management of the platooning behavior (T4.2) and design of a safe operational model for when an attached vehicle is in the platoon (T4.3). AV control takes advantage of augmented perception (inside and outside CAVs' FOV) offered by fusion of cooperative awareness messages (CAM) and collective perception messages (CPM) (T3.4 and T3.5) shared by other road users and platoon members.



- Green dot denotes V2X capability of the traffic agent

P1: CAV platoon leader
P2: CAV platoon follower #1
P3: CAV platoon follower #2
(←this is the subject vehicle which tries to reconnect with the platoon via merging into the roundabout right after/before P1, P2, details of P1, P2, P3 choreography so that a platooning reconnection is realized to be specified later)
CV1, CV2, CV3: Connected vehicles able to share CAM, DENM, CPM info
V1: not connected vehicle

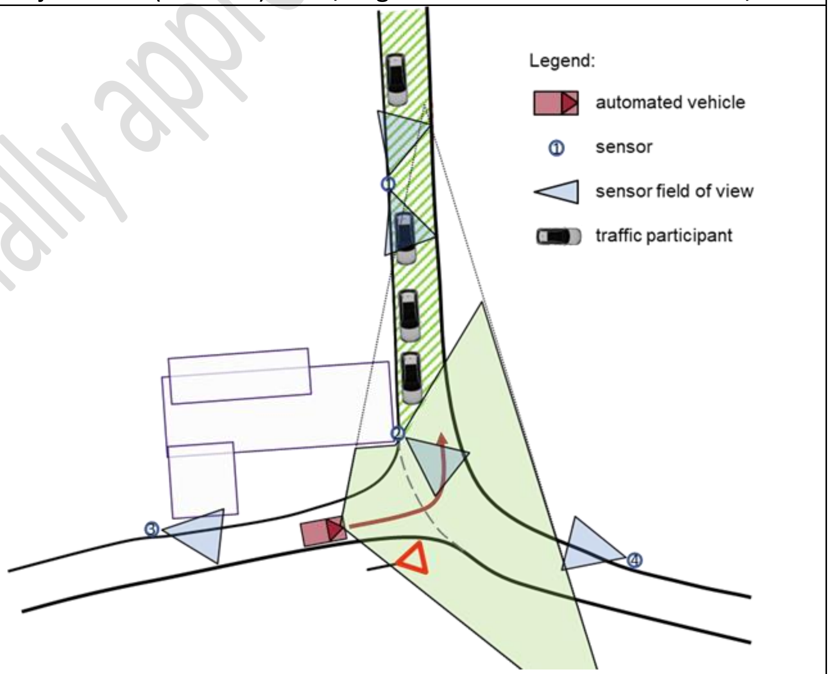
Figure 3: EXP2 example

<u>Platoon split/re-joining control strategy</u>: A platoon ensemble of 3 CAVs, P1, P2 and P3 approaches a roundabout. Due to traffic conditions at the entrance of the roundabout, the platoon formation splits into two disjoint groups: 1) inside the roundabout, and 2) waiting to enter the roundabout. The vehicle(s) that managed to enter the roundabout must remain at the roundabout until rejoined by the rest. This strategy for rejoining, will be the focus of development in T4.2. In order to rejoin the platooning safely, the vehicles will take into account the traffic conditions and obstacle definition in its surroundings, which will be</td></tr>
</table>

	augmented by the use of CPM. An example of such a maneuver is illustrated in Figure 3.
Initial Assumptions	Connected Autonomous Vehicular (CAV) platoon refers to a group of vehicles that coordinate their movements and operate as a single unit. The vehicle at the head acts as the leader of the platoon and determines the course of the vehicles following it. The follower vehicles utilize Vehicle-to-Everything (V2X) communication and automated driving support systems to automatically maintain a small fixed distance between each other. This experiment is based on the following assumptions: 1. The leader vehicle can be made aware of the gap opening in the rear. 2. Communication between vehicles is working at a rate that allows real-time processing during the experiment. 3. The vehicle(s) inside the roundabout adapt their speed and trajectories, in order to facilitate the lost follower(s) to re-join the platoon.
Partners' contribution	The experiment will be tested both in a virtual and a real environment. For the former, TECN will use a digital twin built in Carla simulator combined with a control architecture developed in C++. For the latter, TECN will use their own vehicle, which is equipped with LiDAR, GPS and communication capabilities. ICCS will contribute by setting up CPM fusion and CAVs' perception augmentation incorporating multi-source information plausibility checks using ROS and CARLA.
Partners' synergies	Perception object-level information is assumed available (virtually constructed) as the experiment focus on CAV perception augmentation and control. ICCS will deliver augmented perception info and object-level confidence to TECN's controller and adapt its development so that its modules can be integrated in TECN's experimental architecture.
Traffic & Environment conditions	ODD adapted to UC2. Good weather conditions in a low speed roundabout crossing.
Traffic Participants' (TPs) Attributes	Simulated connected vehicles members of the platoon with V2X capabilities. Simulated connected vehicles outside of the platoon with V2X capabilities. Simulated non-connected vehicles.
Autonomous Vehicle's (AV) Attributes	CAV platform capable of low speed maneuvers. CAV platform equipped with obstacle detection systems. All platoon vehicles are connected to each other via V2V.
Limitations	Perception layer is abstracted and hence is not tested here. Bad weather could be virtually tested but not the focus here.
Other relevant information	Vehicle platforms require safety drivers.
Vehicle Info	
Model	Renault Twizy
Communication	V2X/5G Modules of Commsignia + Antennas
Sensors	2 LIDARs + DGPS-RTK
Data	
Availability	Data in ROSbag (ROS2)
Format	CAM msgs; MQTT; ROS msgs (json)
Openness	Data public for partner of EVENTS
Hints for Evaluation	

KPIs (preliminary)	Augmented perception KPIs: • Objects' presence consistency checks (inside and outside FOV) success rate • FoV augmentation with time (percentage) Control KPIs: • Longitudinal and lateral errors (RMS) • Stabilization time (due to wave effect in platooning) • Distance for rejoining the platoon with min stabilization time
Preliminary plan (if available)	A hybrid SiL/ViL testing environment will be deployed including two real vehicles by TECN, deployed in a test track, which will interact in real time with other simulation-based virtual vehicles and a virtual intelligent Road Side Unit (iRSU), generated in the tested scenarios. Platoon strategy evaluation to be discussed later.

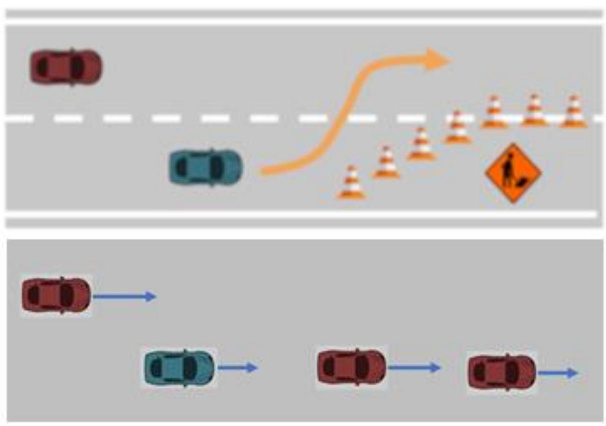
3.3 EXP3: Self-assessment and reliability of perception data with complementary V2X data in complex urban environments

General Info	
Experiment Title	Self-assessment and reliability of perception data with complementary V2X data in complex urban environments
Leading Partner	UULM
Partners Involved	---
Reference Use Case	UC1
Associated Tasks	T3.4 & T3.5
AD SuT/ Target Operational Domain and Functional Scenario(s)	
Short Verbal Description	EXP3 is concerned with safe automated driving in a complex urban environment with occlusion, in order to demonstrate the integration of reliability assessment outputs of environment state estimation (onboard self-assessment methods) and V2X data into an onboard perception system. The experiment will be conducted both in a virtual and a real environment. The former will be simulation-based, and it will be primarily concerned with developing a self-assessment layer for the perception data (T3.5) along with complementary V2X data (T3.4). The latter will be realized in UULM's vehicle, with safety drivers/marshals to account for the prototypical status of the developed system, and in UULM's V2X infrastructure pilot site, where the automated ego vehicle will face objects and (artificial) error/degradation in one of the sensors/V2X.
Detailed Graphical Description	 *Figure 4: EXP3 example*
Initial Assumptions	Single failure in data, not something like "everything delivers wrong data". For V2X: pilot site with compatible data interface available.
Partners' contribution	UULM develops and implements a self-assessment system of the perception

Partners' synergies	UULM will be able to handle the development and implementation of the self-assessment system independently
Traffic & Environment conditions	Good weather conditions, good road conditions, good lighting conditions, during the day, for V2X: pilot site with V2X data available.
Traffic Participants' (TPs) Attributes	There must be objects in the automated ego vehicle's environment to be detected and an error/degradation in one of the sensors (or V2X) must "occur" (or artificially realized).
Autonomous Vehicle's (AV) Attributes	Only in own UULM vehicle under above-described conditions, with safety drivers/marshals to account for the prototypical status of the developed system.
Limitations	UC implementation and testing will be based on UULM’s test track and equipment (topology, infrastructure, prototype AV).
Other relevant information	Demonstration of V2X reliability and perception self-assessment will be possibly performed in a SiL manner with recorded or synthetic data as input (real world demonstration with fault injection not foreseen as it is not safe).
Vehicle Info	
Model	Mercedes-Benz E-Class T-model
Communication	V2X
Sensors	Cameras, radars, LiDARs, ADMA
Data	
Availability	Within the vehicle and internally, including pilot site
Format	Rosbags
Openness	To be discussed/clarified (GDPR & IP issues)
Hints for Evaluation	
KPIs	To be developed/discussed (self-assessment and reliability of V2X augmented perception data need special care due to limited data)
Preliminary plan (if available)	---

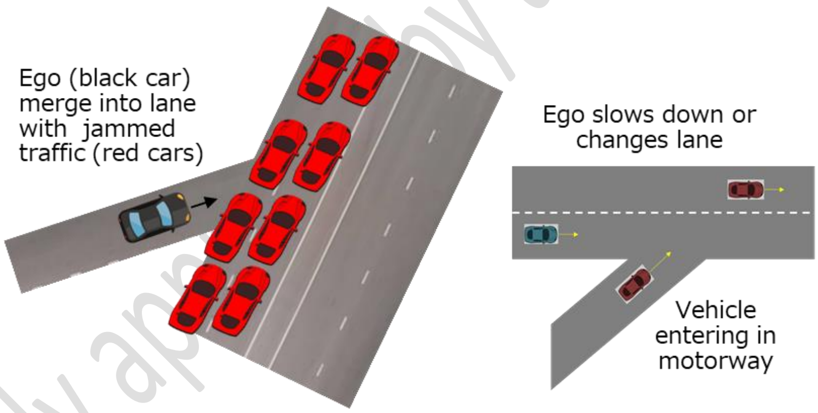
3.4 EXP4: Decision making for motion planning when faced with roadworks, unmarked lanes and narrow roads with assistance from perception self-assessment

General Info	
Experiment Title	Decision making for motion planning when faced with roadworks, unmarked lanes and narrow roads with assistance from perception self-assessment
Leading Partner	HIT-FR & HIT-UK
Partners Involved	CRF, TECN, WMG
Reference Use Case	UC2
Associated Tasks	T3.2, T3.3, T3.4, T3.5, T4.1, T4.2 & T4.3
AD SuT/ Target Operational Domain and Functional Scenario(s)	
Short Verbal Description	EXP4 is an end-to-end experiment starting with the precise vehicle localization, by defining a semantic representation of the environment (T3.2), and the motion prediction of dynamic objects in the scene (T3.3). The localization of the ego-vehicle will be further enhanced by using V2X information (CAM, CPM and SPAT messages, optional, if available), thus increasing the reliability of its position in case of a failure or sensor blockage (T3.4). Particularly in the context of roadworks, unmarked lanes and narrow roads, the ego-vehicle performs a self-assessment by deciding whether to trust its perception system (T3.5). Using CRF's demo vehicle, the trajectory and motion planning of the ego-vehicle will be defined in real time based on a sampling approach, the model predictive control (MPC) curves and the vehicle's model (T4.1). Further to the above, the ego-vehicle's behavioural decision making will be tested by using long/short-term MOT/MOP in a cascaded integration approach in which the prediction estimation (other vehicles, VRUs, etc.) feeds the ego-vehicle's behavioural decision-making and vice-versa. In addition, high-level behavioural decision making, based on Fuzzy Inference Systems, will be taken into account by considering disturbances and unexpected behaviours including the optimal action to perform (T4.2). Finally, the vehicle's control algorithms will be enhanced with a fail operational mode to track cases of positioning failure (T4.3). The different modules of this experiment will be tested in HIT-FR's and CRF's demo vehicles and in Carla simulator.

Detailed Graphical Description	 *Figure 5: EXP4 example*
Initial Assumptions	Perception Platform (PP) able to reconstruct the experiment. V2X can be optional. Data shall be reliable and integral.
Partners' contribution	CRF has a vehicle for testing. PP and localization will be provided by HIT-FR. TECN will provide ML algorithms for trajectory planning. WMG will provide self-assessment of perception-based localization.
Partners' synergies	HIT-FR provides PP to TECN for the development of algorithms, and to WMG for self-assessment algorithms, which will be integrated in the CRF vehicle demo.
Traffic & Environment conditions	Weather conditions = good (no adverse weather). Road conditions = critical (e.g., for missing lanes). Lighting conditions = clear, daytime. Traffic density = low or medium (not high or traffic jam).
Traffic Participants' (TPs) Attributes	Presence of other vehicles. Number of TPs = any, depending on the traffic conditions. Speed of TPs = any, according to extra-urban and motorway speed limits. Direction of TPs = forward, same direction of ego-vehicle (violations are not considered here). Impairment of the TP's perception = optionally V2X (but cannot be mandatory).
Autonomous Vehicle's (AV) Attributes	Driving direction = forward (reverse not allowed) Speed of AV = as before, any (according to extra-urban and motorway speed limits). TBD others
Limitations	Detection of environment should be provided in advance of TBD (*) seconds. Constraints in the motion control part (controlling the steering wheel, not every angle is possible).
Other relevant information	---
Vehicle Info	
Model	Maserati "Quattroporte" (to be confirmed)
Communication	V2V, V2I
Sensors	Depending on the PP (it can be cameras, radars, LiDAR; TBD ultrasonic sensors).

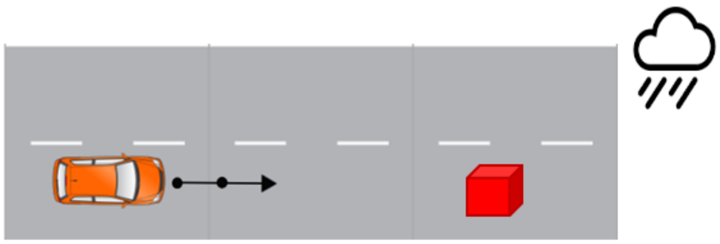
Data	
Availability	TBD
Format	VECTOR tools (so, .MAT or .CSV, but others can be defined).
Openness	Usable for partners of the team; TBD for others
Hints for Evaluation	
KPIs	Some examples: • Time spent in critical regions (defined by TTC). • Number of interventions from human driver / Number of function disengagements. • Number of crashes / near-crashes. To be refined later on.
Preliminary plan (if available)	---

3.5 EXP5: Decision making for motion planning when entering a jammed highway

General Info	
Experiment Title	Decision making for motion planning when entering a jammed highway
Leading Partner	HIT-FR & HIT-UK
Partners Involved	CRF, TECN
Reference Use Case	UC2
Associated Tasks	T3.2, T3.3, T3.4, T4.1, T4.2 & T4.3
AD SuT/ Target Operational Domain and Functional Scenario(s)	
Short Verbal Description	EXP5 is similar to EXP4 with two main differences. The first is that there is not self-assessment (T3.5) of the ego-vehicle. The second difference is that the motion planning involves path and speed planning as well as control of the different highway entering experiments.
Detailed Graphical Description	 *Figure 6: EXP5 example*
Initial Assumptions	No communication errors
Partners' contribution	CRF, and HIT-FR/UK provide vehicle and sensors, HIT-FR and TECN provide perception, localization and path planning software for the use case.
Partners' synergies	---
Traffic & Environment conditions	Traffic jammed lane, with good visibility.
Traffic Participants' (TPs) Attributes	High density of vehicles. Ego vehicle would find it difficult to merge owing to the high density of vehicles.
Autonomous Vehicle's (AV) Attributes	No VRU's, forward direction, ego velocity very low.
Limitations	---
Other relevant information	---
Vehicle Info	
Model	Maserati "Quattroporte" (Modelled in Carla simulator)
Communication	V2V, V2I (potentially difficult on CRF's demo vehicle)

Sensors	Depending on the PP (it can be cameras, radars, LIDAR; TBD ultrasonic sensors).
Data	
Availability	TBD
Format	VECTOR tools (so, .MAT or .CSV, but others can be defined).
Openness	Usable for partners of the team; TBD for others
Hints for Evaluation	
KPIs	Some examples: • Time spent in critical regions (defined by TTC). • Number of interventions from human driver / Number of function disengagement. • Number of crashes / near-crashes.
Preliminary plan (if available)	---

3.6 EXP6: Small object detection at a far range in adverse weather conditions

General Info	
Experiment Title	Small object detection at a far range in adverse weather conditions
Leading Partner	APTIV
Partners Involved	-
Reference Use Case	UC2 & UC3
Associated Tasks	T3.2
AD SuT/ Target Operational Domain and Functional Scenario(s)	
Short Verbal Description	Ego-vehicle approaches a static object (e.g., debris) present on the ego-lane with a high speed. The visibility is deteriorated due to heavy rain/fog/snow during night/day. The vehicle should perform a full stop to avoid a collision or drive over the object safely.
Detailed Graphical Description	EXP6 concerns the sensing of small objects and semantic representation of the environment (object relative position, object lane assignment, object size, object velocity, object over-drivability and estimation of time to collision). The demo vehicle provided by APTIV will be equipped with a low-cost sensor set with perception and localization algorithms running on a development computer. An evaluation of the sensors' performance will be conducted, in order to detect small object and estimate drivability on various weather conditions. In addition, the perception algorithms will be integrated in a SIL environment and subsequently, the performance requirements, by fault-injection, and the observations at vehicle behavior with a simple behavior model, which breaks to avoid collision, will be generated.  *Figure 7: EXP6 example*
Initial Assumptions	CAV is engaged on automated mode and the driver is not monitoring the road (hands-off). There are no faults that occur in the system (sensing, actuation, compute etc.) during the experiment only performance insufficiencies due to bad weather conditions.
Partners' Contribution	APTIV has a test vehicle with a sensor suite comprising of Radars, camera and a LiDAR based ground-truthing system. ML based perception algorithms (sourced external to the project) will be integrated and tested, both in simulations and on the test vehicle. APTIV will also perform a safety analysis (HARA or other methods) to derive the safety goals for this experiment. The safety goals along with the functional requirements for the system will be used to derive requirements for the perception module to ensure a safe behavior.

Partners' Interaction	---
Traffic & Environment	Two lane straight road with the adjacent lane occupied. No other road users are present in the ego lane except for the object of interest. Visibility is impaired due to rain/fog/snow.
Traffic Participants' (TPs) Attributes	---
Autonomous Vehicle's (AV) Attributes	Speeds between 30km/h to 130 km/h
Limitations	---
Other relevant information	APTIV plans to use CarMaker as simulation engine (but could also use CARLA)
Vehicle Info	
Model	PSA Peugeot 3008
Communication	No V2X
Sensors	4x Corner radars, 1x Front radar, 1x Rear radars, 1x Velodyne Alpha, 1x Front HD camera, Prime LiDAR, Applanix PS LV5 (IMU/GPS)
Data	
Availability	To be discussed
Format	APTIV proprietary initially. To be discussed if other formats are required
Openness	To be discussed
Hints for Evaluation	
KPIs	At vehicle level: • Maximum deceleration required to come to stop. • Distance to obstacle after stop. At perception level (open loop real drives): • Distance to obstacle at the time of high-confidence detection and classification. • Distance to obstacle at the time of low-confidence detection and classification. • Accuracy of position and dimensions of detected object. • Accuracy of estimated TTC. • Number of false positives/negative detections and classifications.
Preliminary plan (if available)	APTIV initially plans to do open loop (perception only) for real drive test and close loop (perception + behavior) for simulations.

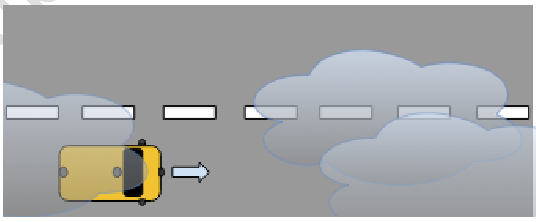
3.7 EXP7: Localization/perception self-assessment for advanced ACC and other vehicles' behaviour prediction under adverse weather or adverse road conditions

General Info	
Experiment Title	Localization/perception self-assessment for advanced ACC and other vehicles' behavior prediction under adverse weather or adverse road conditions
Leading Partner	WMG
Partners Involved	ICCS
Reference Use Case	UC2 & UC3
Associated Tasks	T3.2, T3.5, T4.2
AD SuT/ Target Operational Domain and Functional Scenario(s)	
Short Verbal Description	This experiment focuses on the development of an integrity monitoring mechanism for estimating the distance to the leading vehicle in urban and highway environments under adverse operational domain conditions. The mechanism should reliably indicate the point in time when the relative localization of the ego-vehicle with respect to the leading vehicle must not be trusted and/or the object detection and tracking becomes unreliable. Another objective (not related with the self-assessment objective) is to study the effects of adverse weather conditions on a perception module performing other vehicles' behavior prediction.
Detailed Graphical Description	Onboard perception sensors such as Camera(s), LiDAR and RADAR(s) may be subject to various forms of impairments and faults yielding localization errors. For instance, under adverse weather and lighting conditions the performance of onboard cameras or LiDAR for relative localization to the leading vehicle can degrade. Similarly, adverse weather conditions can affect the quality of camera-based or LiDAR-based object detection and sequentially the prediction of other road users' maneuvers. Therefore, a self-assessment mechanism indicating when to trust the perception of the ego-vehicle is required too. In EXP7, the weather conditions will either be classified or will be known beforehand. Sub-experiments carried out under EXP7 will demonstrate: • The self-assessment of the perception module (e.g., camera-based or lidar-based detection of other vehicles) under adverse weather conditions. Experiments will be carried out both in urban roads and motorway environments. • The integrity monitoring mechanism of the distance estimation to the leading vehicle (using cameras or LiDAR) due to adverse weather or adverse road conditions. The front radar can be used to estimate the ground truth distance to the leading vehicle along a motorway. No Autonomous Driving Function (ADF) will be engaged in motorway driving. • Integrity monitoring of GNSS-based localization in urban roads. Extensive data collection would be required to collect the ground truth.

	• The output of T3.5 is that the ego-vehicle's confidence level for the perception and/or localization is x% and y%, respectively. • The effects of object-level uncertainties caused by bad weather in the task of other vehicles' maneuver prediction/classification (T4.2 by ICCS).  *Figure 8: EXP7 example*
Initial Assumptions	The developed integrity monitoring system will be first tested in a simulation environment, e.g., MATLAB and/or CARLA prior to field trials, data collection and experimentation. Furthermore, assumptions related to sensor range coverage and detection quality with respect to the environment, e.g., density of vehicles, will be determined later. Similarly, the developed self-assessment mechanisms will be first tested using public datasets before data collection. Finally, the prediction of other vehicles' maneuvers study will be evaluated in CARLA by substituting the perception layer with CARLA ground truth, since the focus is on evaluating the other road vehicles' maneuver prediction algorithm robustness.
Partners' Contribution	The developed integrity monitoring and self-assessment systems will be designed by WMG and integrated and tested on public roads or WMG proving ground using the WMG research vehicle. The prediction of other road vehicles' maneuver will be realized by ICCS and tested either on real world dataset or integrated in CARLA to be tested virtually in hand-crafted set of scenarios covering various ODDs.
Partners' Interaction	TBD
Traffic & Environment	Data collection and field trials to assess the performance of the developed integrity monitoring and self-assessment mechanisms under variable weather, road traffic, and lighting conditions, as well as different times of the day.
Traffic Participants' (TPs) Attributes	Other motorway or urban road vehicles including for instance their driving direction and speed profile. Predicted maneuvers of other road users: keep the lane, lane-change, return to the left lane, cut-in from the right, cut-in from the left etc.).
Autonomous Vehicle's (AV) Attributes	Motorway/Urban chauffeur with focus on adaptive cruise control (ACC) (and eventually ALKS). Other attributes include the driving direction and the speed profile of the ego vehicle.
Limitations	There is no intention to engage the drive-by-wire control in motorway driving but the performance of the integrity monitoring system and perception self-assessment mechanisms through live

	on-road data will be evaluated. The drive-by-wire system might be activated for urban driving. In both cases, the WMG research vehicle will be used for data collection. The collected data will be used for offline performance evaluation of the developed integrity monitoring and self-assessment mechanisms. Additionally, virtual scenarios will be generated for testing maneuver prediction of other road vehicles' algorithm.
Other relevant information	---
Vehicle Info	
Model	Ford Mondeo Hybrid; Open Innovation Vehicle Platform.
Communication	Cellular data and V2X /ITS-G5/DSRC, which is available but not required).
Sensors	Cameras, radars, LIDAR, dGPS (may not engage all of them at the end).
Data	
Availability	Object detections of motorway traffic objects surrounding the ego vehicle using its onboard sensors.
Format	Raw data in ROS .bag format.
Openness	Processed data can be shared within the consortium, i.e., data which doesn't require anonymisation such as bounding boxes and csv files.
Hints for Evaluation	
KPIs	Definitions: Position error (PE) is the difference between the estimated position (output of the localization system) and the actual position at each time. Integrity risk (IR) is the probability that the localization system will provide a position error larger than the alert limit (AL) without an alert being triggered. The AL is a system design parameter indicating the maximum allowable PE after which the localization system becomes unavailable, i.e., an alert is triggered. In practice, an upper bound on the position error is calculated, known as protection level (PL), and is compared to the AL. If PL>AL an alert is triggered. The KPIs of integrity monitoring for localization is the number of times that PL>AL while PE<AL, i.e., PE<AL<PL (system unavailable) and the number of times that PE>AL while PL<AL, i.e., PL<AL<PE (hazardous operation). Similar KPIs can be defined for the self-assessment of perception.
Preliminary plan (if available)	---

3.8 EXP8: Driving minor road under adverse weather conditions including perception self-assessment

General Info	
Experiment Title	Driving minor road under adverse weather conditions including perception self-assessment
Leading Partner	S4
Partners Involved	---
Reference Use Case	UC3
Associated Tasks	T3.2, T3.5, T4.2 & T4.3
AD SuT/ Target Operational Domain and Functional Scenario(s)	
Short Verbal Description	Similar to EXP7 but in slow speed roads instead of motorways. Driving in minor roads (<40kmh) under adverse weather conditions. ADS adapts to weather conditions. (Simulation or controlled conditions can be used to produce the conditions)
Detailed Graphical Description	The low atmospheric visibility in adverse weather conditions like fog, snow, and rain reduces the maximum viewing distance of LiDAR sensors. This in turn decreases the object detection and localization performance and cause safety hazards. Weather conditions have effect on sensing and therefore on perception and localization of automated driving system. Use case provides possibility to evaluate the on-board visibility-based localization performance estimate. Safe vehicle control is necessary in case the weather conditions worsen and fail-safe behavior in case of exiting the ODD completely due to extreme weather.  *Figure 9: EXP8 example*
Initial Assumptions	The developed integrity monitoring system will be first tested in a simulation environment, e.g., MATLAB and/or Carla prior to field trials, data collection and experimentation. Furthermore, assumptions related to sensor range coverage and detection quality with respect to the environment, e.g., density of vehicles, will be determined later.
Partners' contribution	Perception and self-assessment system from tasks T3.2 and T3.5. can be evaluated. On-board decision-making systems from T4.2. and T4.3 can be evaluated.
Partners' synergies	---
Traffic & Environment conditions	Data collection and field trials allow to assess the performance of the developed perception and self-assessment systems and on-board decision-making systems under variable weather conditions.

Traffic Participants' (TPs) Attributes	---
Autonomous Vehicle's (AV) Attributes	Low speed automated driving system
Limitations	32 kmh
Other relevant information	---
Vehicle Info	
Model	S4 ADS equipped Toyota Proace Verso EV
Communication	Cellular data 4G
Sensors	Cameras, Radars, LIDAR, RTK GPS
Data	
Availability	Object detections of motorway traffic objects surrounding the ego vehicle using its onboard sensors.
Format	Raw data in ROS .bag format
Openness	Processed data can be shared within the consortium, i.e., data which doesn't require anonymisation such as bounding boxes and CSV files.
Hints for Evaluation	
KPIs	• Measure of weather effect to localization accuracy • Localization performance in different weather conditions • Sensor visibility estimate correctness • Sensor blockage detection correctness • PE and IR as in EXP7.
Preliminary plan (if available)	---

3.9 Summary of Experiments

A summary of each partners' contribution in the different experiments is shown in Table 1. In addition, in Table 2, the operational domains for each experiment are illustrated.

Experiment	Partners' Contribution
EXP1	**TUD:** Full AD stack supporting urban driving focusing on VRUs interaction
EXP2	**TECN**: Vehicle, Motion control, V2V communication **ICCS**: Simulation collaborative driving for CAMs and CPMs
EXP3	**UULM**: Self-assessment of perception, V2X, vehicle infrastructure pilot site or respective data
EXP4	**CRF**: DM, Vehicle, Motion control **HIT**: Perception platform and localisation **TECN**: RT-motion control **WMG**: Perception self-assessment
EXP5	**CRF**: DM, Vehicle, Motion control **HIT**: Perception platform and localisation **TECN**: RT-motion control

EXP6	**APTIV**: Sensing of small objects and semantic representation of the environment (object relative position, object lane assignment, object size, object velocity, object over-drivability and estimation of time to collision).
EXP7	**WMG**: Integrity monitoring and perception self-assessment **ICCS**: Behavior prediction of other vehicles
EXP8	**S4**: Visibility assessment of the lidar (T3.2), Sensor data quality assessment (T3.5), Path planning around static object on the path (T4.1), Decision making for remote operator assistance (T4.2), MRM decision making (T4.3).

Table 1: Contribution of each partner in the different experiments

Experiment	Operational Domains
EXP1	Urban 2-directional road, VRU presence, parked vehicle presence, good and adverse weather.
EXP2	Urban roundabout, low speed, V2V connectivity deployed, good weather.
EXP3	Urban intersection, V2X connectivity deployed, good weather.
EXP4	Peri-urban/ motorway roads with roadworks, unmarked lanes including narrow roads, V2X connectivity deployed (optional), good weather.
EXP5	Motorway/peri-urban on-ramp section (merging onto main road from on-ramp lane), High density of vehicles on the main motorway (traffic jam), good weather.
EXP6	Motorway (two lane straight road with the adjacent lane occupied, presence of debris/unknown object on the ego-lane (no other road users are present in the ego lane), adverse weather incl. rain/fog/snow.
EXP7	Peri-urban/urban/motorway roads, adverse weather, adverse road conditions.
EXP8	Rural/minor roads, slow speed, adverse weather

Table 2: Contribution of each partner in the different experiments

The contents of this Section are crucial because the experiments are the core for the definition of the project requirements, described in Section 4.

4. Requirement Elicitation Methodology

Requirements (REQs) are an essential part of product design. A requirement describes any physical or functional performance of a product or a service. In the EVENTS project, the collected requirements are based on the use cases and experiments, as these were defined in the Section 2 and Section 3 respectively.

Despite the fact that the compiling phase of requirements is often underestimated in a project, the requirement elicitation is a discovery and invention process, not just a collection process. The most important question therefore when compiling the requirements is: “Is anybody else able to understand my requirements?“.

With this under consideration, in this section, the methodology for eliciting the requirements is presented, which aim to address the system functionality required by the EVENTS components and sub-systems, in order to handle the selected use cases and experiments.

4.1 Guidelines for Requirements Collection and Analysis

The first phase of this activity consists of collecting and analysing the requirements, based on the information provided by the partners. In this first phase, requirements are collected and arranged into a hierarchical structure from the top-level feature goals to the low-level atomic requirements, with the goal to assure requirements traceability and the identification of low-level (atomic) requirements.

In order to assure a high quality of requirements, the collection of requirements will follow the SMART method (Specific, Measurable, Attainable, Realizable and Traceable), which gives the criteria to guide the setting of goals, like for example in project management. The meaning of these five criteria is explained in Table 3.

Criteria	Meaning
Specific	A requirement must say exactly what is required.
Measurable	It is possible, once the system has been implemented, to verify that the requirement has been met.
Attainable	It is possible physically for the system to exhibit that requirement under the given conditions.
Realizable	It is possible to achieve a requirement given what is known about the constraints under which the system and the project must be developed.
Traceable	Requirements traceability is the ability to trace (forwards and backwards) a requirement from its conception through its specification to its subsequent design, implementation and test.

Table 3: The five (5) SMART criteria for requirements collection

The requirements collected are a combination of low-level requirements and high-level requirements, the distinction of which will be specified during the project development.

With reference to Table 3, the requirements in EVENTS have been collected so that to fulfil the following criteria:

- Abstract ⇒ Each requirement should be implementation-independent.
- Unambiguous ⇒ Each requirement should be stated in such a way so that it can be interpreted in only one way.
- Traceable ⇒ For each requirement, it should be feasible to determine a relationship between specific documented statement(s) of need and the specific statements in the definition of the system given as evidence of the source of a requirement. It should be noted that, in this first release of requirements, the "Dependencies" column has not been filled in by all partners and for all the requirements (indicated as "empty" or "NA"), which means that Traceability is not ensured in every instance.
- Verifiable ⇒ Each requirement should have the means to prove that the system satisfies the requirements. "Verifying" a requirement does not always mean technical "testing". It also may mean reviews and inspections (e.g., documentation quality requirements).
- Unique ⇒ A requirement must be present exactly once. Duplicate requirements have a tendency of becoming inconsistent.

Further requisites are harder to verify but also important:

- A complete requirements specification must precisely define all the real-world situations that will be encountered and the system's responses to them.
- Consistent and correct, meaning that the requirements are free from contradictions.

These indications imply that requirements can be refined (changes can always happen, since the requirements may not be detailed enough). All the requirements have been individually checked for their comprehensibility, removing all the ambiguities and verifying the necessity of each requirement.

4.2 Guidelines for Terminology and Prioritization of Requirements

The methodology used for describing the requirements in EVENTS is based on the scheme shown in Figure 10.

As illustrated in Figure 10, the requirements are connected with one another in a hierarchical manner: a child requirement details the parent requirement, then requirements are organized in a tree-like manner.

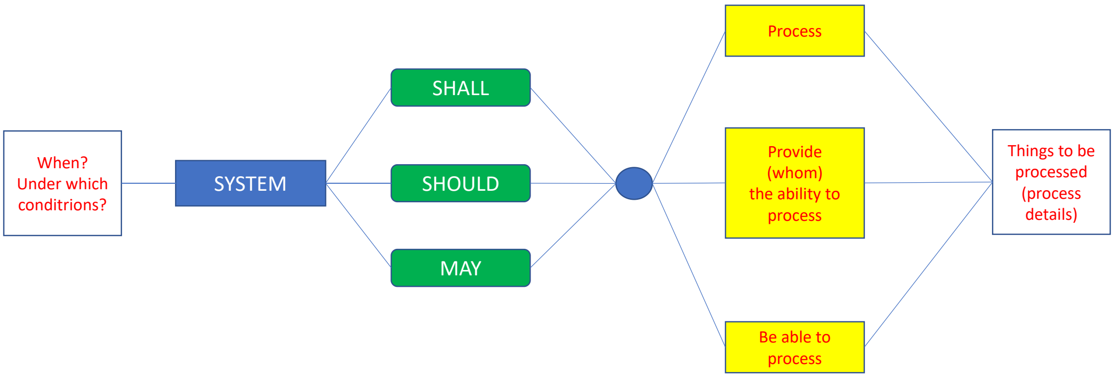


Figure 10: Requirements statement scheme

In the EVENTS project, for the requirements collection, an Excel-based table is used. For each requirement, the required attributes are shown in Table 4.

Column Name	Description	Instructions
ID	Unique Identification code.	---
Type or Category	Classification of Requirements.	With reference to some previous projects[1], the proposed categories are: • General GEN) • Decision Making (DM) • Perception (PER) • Operational (OPE) • Actuation (ACT)
Name	Unique name for the requirement.	It complements the ID
Definition	Concise definition of the requirement (one / two sentence(s) max for each requirement).	The following statements were used: • SHALL is technically binding • SHOULD is an urgent recommendation • MAY specifies optional behavior.
Rationale	A brief explanation why this requirement is important or necessary.	----
Metrics	Provide a target that makes it possible to assess if requirement is satisfied or not.	Requirements and metrics should be always considered together: when we define a requirement, we must always define also its metric(s).
Relevance	Priority assigned to a particular requirement.	In details: • H = High (Essential to have, otherwise no implementation) • M = Medium (Important to have, degraded performances, if not)

[1] Examples are “interACT” (https://www.interact-roadautomation.eu/), “PRYSTINE” (https://prystine.eu/), and so on.

		• L = Low (Nice to have (to add new or additional features to the system).
Owner	Beneficiary partner who created this requirement.	S/he is the author and the responsible.
Status	Degree of requirement fulfilment.	It can be: • Fulfilled • Partially Fulfilled • Not Fulfilled.
Reference Use Case	Refer to the Use Case number that generated this requirement as defined in T2.1 (see also previous Chapters).	Refer to the Use case ID.
Implementation	Where the requirement is Implemented.	For example, in which demonstrator? Real-car or Driving-simulator?
Dependencies	Dependencies on other Requirements.	List other requirement IDs or factors which this requirement will be dependent upon. Leave empty if not needed.
Conflicts	Conflicts with other Requirements.	List all those necessary. Leave empty if not needed.
Review	Review of requirements.	It is a kind of refinement, if needed.
Comments & Notes	Comment and notes on a specific requirement.	As a support, to specify better a single aspect.

Table 4: Information on the columns/attributes for the requirements table

In order to fill in the Excel table, the following guidelines were taken into consideration. In the first phase of collection, requirements have been identified by each partner involved in the activity, using an "identification code (ID)", expressed in the following form:

WPx_[Company]_REQyy_vz.z, (1)

where:

- WPx = number of WP (2-6).
- Company = name of the partner, owner of the requirement.
- REQyy = serial number of the requirement
- vz.z = version of the requirement and the related refinement.

In the second phase, the complete list was refined, similar requirements have been merged and duplicates have been eliminated.

5. List of Requirements

In this section, the complete list of requirements per experiment of the EVENTS project is illustrated. For the purposes of being easily readable and legible, only some of the attributes of the requirements are shown. Namely, these attributes are the Owner of the requirement, ID, Name, Type (i.e., General – GEN, Decision Making – DM, Perception – PER, Operational – OPE, Actuation – ACT) and Description. It should be noted that some of the requirements might appear twice in different experiments by the same owner; they are not duplicates, they apply on both experiments and are listed twice for ease of reference. The complete list of requirements including all the attributes can be found in Annex 3.

5.1 EXP1: Interaction with VRUs under complex urban environment

TUD (Demo Vehicle & Simulation)			
ID	**Type**	**Name**	**Description**
WP5_TUD_REQ001_1	OPE	ODD - Traffic	The system shall function in the urban environment
WP5_TUD_REQ002_1	OPE	ODD - Weather conditions	The system shall function in the presence of light rain and fog
WP5_TUD_REQ003_1	OPE	ODD - Weather conditions	The system shall function in the presence of light snowfall
WP5_TUD_REQ004_1	OPE	ODD - Illumination	The system shall function at day and night
WP5_TUD_REQ005_1	OPE	ODD - Ego Vehicle	The system shall be enabled in a speed range of 5 to 30 km/h
WP3_TUD_REQ006_1	PER	Obstacle localization	The system shall be capable of detecting/localizing obstacles on the road ahead of the vehicle.
WP3_TUD_REQ007_1	PER	Obstacle velocity estimation	The system shall be capable of estimating velocities of moving obstacles on the road ahead of the vehicle
WP3_TUD_REQ008_1	PER	Object classification	The system shall classify obstacles which are pedestrians, riders (e.g. cyclists) and cars as such
WP3_TUD_REQ009_1	PER	Self-localization	The system shall self-localize w.r.t. a global map
WP3_TUD_REQ010_1	OPE	ODD detection	The system shall detect if it is outside its ODD
WP4_TUD_REQ011_1	DM, ACT	Driving behaviour w.r.t. road border	The ego-vehicle shall not drive too closely to the road border

WP4_TUD_REQ012_1	DM, ACT	Driving behaviour w.r.t. obstacles and VRUs	The ego-vehicle shall not drive too closely to obstacles; the minimum distance will depend on whether obstacles are stationary or dynamic, and whether classified as VRU (pedestrians, riders) or not
WP4_TUD_REQ013_1	DM, ACT	Driving behaviour overall	The driving style of the ego-vehicle shall maximize comfort and time efficiency, while safety is strictly maintained

Table 5: TUD's list of requirements on EXP1

5.2 EXP2: Re-establish platoon formation after splitting due to roundabout

TECN (Demo Vehicle & Simulation)			
ID	**Type**	**Name**	**Description**
WP3_TECN_REQ1_v01	PER	Vehicle detection	The system must be able to detect and classify vehicles around itself
WP5_TECN_REQ3_v01	GEN	Road limits	The limits of the road must be clear and provided, either statically or dynamically
WP3_TECN_REQ4_v01	PER	Vehicle detection in advance	Subject vehicle shall be able to detect a stationary/dynamic vehicle in advance
WP3_TECN_REQ5_v01	PER	Pedestrian detection in advance	Subject vehicle shall be able to detect a stationary/dynamic pedestrian in advance
WP3_TECN_REQ6_v01	PER	Localization accuracy	The localization system should provide an accurate positioning for control/decision making
WP4_TECN_REQ7_v01	DM	Localization malfunction	Subject vehicle shall be able to detect a malfunction of the localization system (accidental)
WP4_TECN_REQ8_v01	DM	Localization degraded	Subject vehicle shall be able to detect a reduction of accuracy of the localization system (accidental)
WP4_TECN_REQ9_v01	DM	Vehicle collision avoidance in degraded mode	DM shall be able to execute DDT (Dynamic Driving Task, defined in SAE J3016) in a degraded mode to avoid colliding with other vehicles
WP4_TECN_REQ10_v01	DM	VRU collision avoidance in degraded mode	DM shall be able to execute DDT in a degraded mode to avoid colliding with VRUs
WP4_TECN_REQ11_v01	DM	Fail-degraded operation	The DDT in degraded mode must have the capability of executing a MRM until a safe stopping location is reached

WP4_TECN_REQ12_v01	DM	Platoon stability comfort (1)	The joining process must be smooth, without big speed oscillations
WP4_TECN_REQ13_v01	DM	Platoon stability comfort (2)	The joining process must be smooth, without big speed oscillations
WP4_TECN_REQ14_v01	DM	Safe braking in platooning	Once detected an obstacle (e.g. Pedestrian) the vehicle should be able to stop smoothly
WP4_TECN_REQ15_v01	DM	Fail-safe motion planning	The fail-safe motion planning must provide guidance until a safe state is reached
WP4_TECN_REQ16_v01	DM	Safe braking	Once detected an obstacle (e.g. Pedestrian) the vehicle should be able to stop timely
WP5_TECN_REQ17_v01	DM	Vehicle communications	Vehicle communication must have reasonably low latency between vehicles
WP3_TECN_REQ18_v01	GEN	Digital maps	Digital maps should specify drivable space.

Table 6: TECN's list of requirements on EXP2

ICCS (Simulation)			
ID	**Type**	**Name**	**Description**
WP3_ICCS_REQ01_v01	PER	V2X messages reception	The system must be able to receive V2X messages from multiple observers in the vicinity of the ego-vehicle
WP3_ICCS_REQ02_v01	PER	V2X data processing, fusion and integration	The system must be able to process, fuse and integrate the received V2X information from multiple sources
WP3_ICCS_REQ03_v01	PER	V2X data latency	The system must be able to receive, process and integrate V2X information in a timely manner
WP3_ICCS_REQ04_v01	PER	V2X fused data reliability	The system must be able to trust information fused from V2X from independent sources

Table 7: ICCS's list of requirements on EXP2

5.3 EXP3: Self-assessment and reliability of perception data with complementary V2X data in complex urban environments

UULM (Demo Vehicle & Simulation)			
ID	**Type**	**Name**	**Description**
WP3_UULM_REQ01_v01	GEN	Weather Conditions	The self-assessment system shall work under certain good weather conditions
WP3_UULM_REQ02_v01	GEN	Weather Conditions	The infrastructure V2X system shall work under certain good weather conditions

WP3_UULM_REQ 03_v01	GEN	Lighting Conditions	The self-assessment system shall work under good lighting conditions (daylight)
WP3_UULM_REQ 04_v01	GEN	Lighting Conditions	The infrastructure V2X system shall work under good lighting conditions (daylight)
WP3_UULM_REQ 05_v01	GEN	Road conditions	The self-assessment system shall work under good road conditions
WP3_UULM_REQ 06_v01	PER	Protocol communication	V2X information shall be transmitted via CAMs & CPMs with proprietary extensions
WP3_UULM_REQ 07_v01	GEN	Infrastructure pilot site	Infrastructure Pilot Site shall generate CPMs of the surveilled road area if all conditions are satisfied
WP3_UULM_REQ 08_v01	GEN	Automated Vehicle	Connected automated vehicle shall be able to drive automatically (with safety driver) if all conditions are satisfied
WP3_UULM_REQ 09_v01	PER	Detecting objects with infrastructure pilot site	Infrastructure Pilot Site must detect relevant objects in the corresponding area
WP3_UULM_REQ 10_v01	PER	Tracking objects	The connected automated vehicle shall provide an object tracking and track the relevant objects in its relevant proximity
WP3_UULM_REQ 11_v01	PER	Sensors Detections	The connected automated vehicle shall provide different sensors and sensor types delivering detections to the tracking module
WP3_UULM_REQ 12_v01	GEN	Connected Automated Vehicle	The connected automated vehicle shall be able to receive and process CPMs with proprietary extensions
WP3_UULM_REQ 13_v01	PER	Self-assessment of perception system	The self-assessment of the perception system shall generate reliability scores if all conditions are satisfied

Table 8: UULM's list of requirements on EXP3

5.4 EXP4: Decision making for motion planning when faced with roadworks, unmarked lanes and narrow roads with assistance from perception self-assessment

CRF (Demo Vehicle & Simulation)			
ID	**Type**	**Name**	**Description**
WP5_CRF_REQ01_v01	GEN	Pre-Conditions to activate the function	The system shall be activated if there are no failures, if there is a driver request, if scenarios are visible (activation inside the ODD)

WP5_CRF_REQ02_v01	GEN	Conditions, when function is deactivated	The system shall be deactivated if there are failures, if there is a driver request and if scenarios are not detected (de-activation outside the ODD)
WP3_CRF_REQ03_v01	OPE	Speed Range	The system shall work in the operative speed range (50 - 140 km/h for the CRF demo car)
WP3_CRF_REQ04_v01	OPE	Weather Conditions	The system shall work in specific weather conditions
WP3_CRF_REQ05_v01	OPE	Lighting Conditions	The system shall work in specific lighting conditions
WP5_CRF_REQ07_v01	GEN	Vehicle CAN data	Provision of vehicle sensor information on CAN
WP3-4-5_CRF_REQ08_v01	OPE	System reaction time	The system shall react in real time to the encountered situation
WP3-4-5_CRF_REQ09_v01	GEN	Protocol communication	The components / sub-systems should exchange info via CAN bus. Alternatively, via ETHERNET
WP5_CRF_REQ10_v01	OPE	System capability and characteristics	The system shall track the speed set by the user
WP5_CRF_REQ11_v01	OPE		When the function is enabled, the system shall stop the vehicle in case of traffic jam or obstacles ahead.
WP5_CRF_REQ12_v01	OPE		When the function is enabled, the system shall be able to restart following the user set speed if the obstacle disappears.
WP5_CRF_REQ13_v01	OPE		The system shall adjust and optimize the vehicle speed in case of other vehicles entering from a highway on-ramp
WP3_CRF_REQ16_v01	OPE	Deceleration behaviour	The system shall track/follow the setpoint speed with an acceleration in the range [-3.5 - 2] m/s^2
WP3_CRF_REQ17_v01	PER	Front obstacles selection	The PP shall detect and track most relevant object in front in the vehicle lane
WP3_CRF_REQ18_v01	PER	Rear obstacles selection	The PP shall detect and track most relevant object in vehicle rear lane
WP3_CRF_REQ19_v01	PER	Detection and tracking of surrounding objects	The system shall detect and track most relevant object in vehicle front left lane, front right, rear left, rear right
WP3_CRF_REQ20_v01	PER	Speed Limits	The PP should provide the road speed limits information on CAN
WP3_CRF_REQ21_v01	PER	Road type	The PP shall provide the road type information (on CAN)

WP3_CRF_REQ22_v01	PER	Road line	The PP shall detect the road lines information (on CAN)
WP3_CRF_REQ23_v01	PER	Lane info	The PP shall provide the lane information (on CAN)
WP3_CRF_REQ24_v01	PER	Road works area	The PP shall reconstruct road lines in case of working area or faded/absent line marking
WP4_CRF_REQ25_v01	DM	Vehicle control 1	The DM shall guarantee the lateral control when road curvature is > 1/60m
WP5_CRF_REQ26_v01	OPE	Vehicle control 2	The system shall maintain the centre line when all the condition are satisfied
WP4_CRF_REQ27_v01	DM	Optimal manoeuvre	The DM shall advise if a lane change manoeuvre is convenient
WP5_CRF_REQ28_v01	OPE	Optimal manoeuvre execution 1	The system shall execute a lane change manoeuvre when all the condition are satisfied
WP5_CRF_REQ30_v01	ACT	ODD behaviour 1	The system shall decelerate with a max. long. deceleration of 7m/s2 to avoid a collision with an object if TTC is <= 3s
WP5_CRF_REQ31_v01	ACT	ODD behaviour 2	The system shall decelerate with a maximum absolute deceleration of 3m/s2 when an object is detected in the ego lane and TTC <= 5s & TTC > 3s
WP5_CRF_REQ33_v01	ACT	ODD behaviour over limits	The system shall have a steady braking and stop in the ego lane when there is no response to the take over request.

Table 9: CRF's list of requirements on EXP4

HIT-FR & HIT-UK (Demo Vehicle & Simulation)			
ID	**Type**	**Name**	**Description**
WP3_HIT_REQ1_v01	PER	Object detection and tracking	Detect and Track objects with correct class labels assigned to tracked objects
WP3_HIT_REQ2_v01	PER	Object detection and tracking - Vehicles	Detect and Track road vehicles such as cars, trucks, vans and bicycles.
WP3_HIT_REQ3_v01	PER	Object detection and tracking - Pedestrians	Detect and Track pedestrians
WP3_HIT_REQ4_v01	PER	Object detection and tracking - Road Works	Track road work cones + signs.
WP3_HIT_REQ5_v01	PER	Drivable Road Detection	Provide 2D/3D information related to drivable road. Determine regions in 2D/3D space that correspond to drivable road.

WP3_HIT_REQ6_v01	PER	Detect Lane Marking Information	Road lines detecting from 2D data
WP3_HIT_REQ7_v01	PER	Vehicle Localisation - GNSS	Accurately localise vehicle position using GNSS measurements
WP3_HIT_REQ8_v01	PER	Vehicle Localisation - LiDAR	Accurately localise vehicle position using LiDAR data and in case GNSS fails.
WP3_HIT_REQ9_v01	PER	Object trajectory prediction	Predict tracked object trajectories, of vehicles (cars, trucks, vans, etc) and pedestrians.
WP3_HIT_REQ10_v01	OPE	Drivable Road Extraction (HD-MAP)	Provide 2D/3D information related to drivable road. Determine regions in 2D/3D space that correspond to drivable road.
WP3_HIT_REQ11_v01	OPE	Extract Lane Marking Information (HD-MAP)	Road lines detecting from 2D data

Table 10: HIT-FR's & HIT-UK's list of requirements on EXP4

TECN (Demo Vehicle & Simulation)			
ID	**Type**	**Name**	**Description**
WP3_TECN_REQ1_v01	PER	Vehicle detection	The system must be able to detect and classify vehicles around itself
WP3_TECN_REQ2_v01	PER	Traffic Agents detection	The system must be able to detect and classify traffic agents around itself
WP5_TECN_REQ3_v01	GEN	Road limits	The limits of the road must be clear and provided, either statically or dynamically
WP3_TECN_REQ4_v01	PER	Vehicle detection in advance	Subject vehicle shall be able to detect a stationary/dynamic vehicle in advance
WP3_TECN_REQ5_v01	PER	Pedestrian detection in advance	Subject vehicle shall be able to detect a stationary/dynamic pedestrian in advance
WP3_TECN_REQ6_v01	PER	Localization accuracy	The localization system should provide an accurate positioning for control/decision making.
WP4_TECN_REQ7_v01	DM	Localization malfunction	Subject vehicle shall be able to detect a malfunction of the localization system (accidental)
WP4_TECN_REQ8_v01	DM	Localization degraded	Subject vehicle shall be able to detect a reduction of accuracy of the localization system (accidental)
WP4_TECN_REQ9_v01	DM	Vehicle collision avoidance in degraded mode	DM shall be able to execute DDT (Dynamic Driving Task, defined in SAE J3016) in a degraded mode to avoid colliding with other vehicles

WP4_TECN_REQ10_v01	DM	VRU collision avoidance in degraded mode	DM shall be able to execute DDT in a degraded mode to avoid colliding with VRUs
WP4_TECN_REQ11_v01	DM	Fail-degraded operation	The DDT in degraded mode must have the capability of executing a MRM until a safe stopping location is reached
WP4_TECN_REQ15_v01	DM	Fail-safe motion planning	The fail-safe motion planning must provide guidance until a safe state is reached
WP4_TECN_REQ16_v01	DM	Safe braking	Once detected an obstacle (e.g. Pedestrian) the vehicle should be able to stop timely
WP3_TECN_REQ18_v01	GEN	Digital maps	Digital maps should specify drivable space

Table 11: TECN's list of requirements on EXP4

WMG (Demo Vehicle & Simulation)			
ID	**Type**	**Name**	**Description**
WP3_WMG_REQ01_v01	OPE	Speed range	The self-assessment of perception including speed limit signs shall operate at speeds 10 - 40 km/h
WP3_WMG_REQ02_v01	OPE	Weather and lighting conditions	The self assessment of perception including speed limit signs shall operate at good weather and lighting conditions.
WP3_WMG_REQ03_v01	PER	Perception self-assessment for speed limit signs detection	The system shall issue a warning when the detection of speed limit signs fail.

Table 12: WMG's list of requirements on EXP4

5.5 EXP5: Decision making for motion planning when entering a jammed highway

CRF (Demo Vehicle & Simulation)			
ID	**Type**	**Name**	**Description**
WP5_CRF_REQ01_v01	GEN	Pre-Conditions to activate the function	The system shall be activated if there are no failures, if there is a driver request, if scenarios are visible (activation inside the ODD).
WP5_CRF_REQ02_v01	GEN	Conditions, when function is deactivated	The system shall be deactivated if there are failures, if there is a driver request and if scenarios are not detected (de-activation outside the ODD).

WP3_CRF_REQ03_v01	OPE	Speed Range	The system shall work in the operative speed range (50 - 140 km/h for the CRF demo car)
WP3_CRF_REQ04_v01	OPE	Weather Conditions	The system shall work in specific weather conditions
WP3_CRF_REQ05_v01	OPE	Lighting Conditions	The system shall work in specific lighting conditions
WP5_CRF_REQ07_v01	GEN	Vehicle CAN data	Provision of vehicle sensor information on CAN
WP3_CRF_REQ08_v01	OPE	System reaction time	The system shall react in real time to the encountered situation
WP3_CRF_REQ09_v01	GEN	Protocol communication	The components / sub-systems should exchange info via CAN bus. Alternatively, via ETHERNET
WP5_CRF_REQ10_v01	OPE	System capability and characteristics	The system shall track the speed set by the user
WP5_CRF_REQ11_v01	OPE	System capability and characteristics	When the function is enabled, the system shall stop the vehicle in case of traffic jam or obstacles ahead.
WP5_CRF_REQ12_v01	OPE	System capability and characteristics	When the function is enabled, the system shall be able to restart following the user set speed if the obstacle disappears
WP5_CRF_REQ13_v01	OPE	System capability and characteristics	The system shall adjust and optimize the vehicle speed in case of other vehicles entering from a highway on-ramp
WP3_CRF_REQ14_v01	PER	Ahead obstacles detection (on ramps)	The PP shall detect the presence of other vehicle on the highway on-ramps at least 170m ahead
WP3_CRF_REQ15_v01	PER	Tracking objects (on ramps)	The PP shall detect and track most relevant object in highway on-ramp
WP3_CRF_REQ16_v01	OPE	Deceleration behaviour	The system shall track/follow the setpoint speed with an acceleration in the range [-3.5 - 2] m/s^2
WP3_CRF_REQ17_v01	PER	Front obstacles selection	The PP shall detect and track most relevant object in front in the vehicle lane
WP3_CRF_REQ18_v01	PER	Rear obstacles selection	The PP shall detect and track most relevant object in vehicle rear lane
WP3_CRF_REQ19_v01	PER	Detection and tracking of sorrounding objects	The system shall detect and track most relevant object in vehicle front left lane, front right, rear left, rear right
WP3_CRF_REQ20_v01	PER	Speed Limits	The PP should provide the road speed limits information on CAN
WP3_CRF_REQ21_v01	PER	Road type	The PP shall provide the road type information (on CAN)
WP3_CRF_REQ22_v01	PER	Road line	The PP shall detect the road lines information (on CAN)

WP3_CRF_REQ23_v01	PER	Lane info	The PP shall provide the lane information (on CAN)
WP4_CRF_REQ25_v01	DM	Vehicle control 1	The DM shall guarantee the lateral control when road curvature is > 1/60m
WP5_CRF_REQ26_v01	OPE	Vehicle control 2	The system shall maintain the centre line when all the condition are satisfied
WP5_CRF_REQ28_v01	OPE	Optimal manoeuvre execution 1	The system shall execute a lane change manoeuvre when all the condition are satisfied
WP5_CRF_REQ29_v01	OPE	Optimal manoeuvre execution 2	The system shall evaluate the convenience of a lane change manoeuvre in case of vehicle on highway on -ramp
WP5_CRF_REQ30_v01	ACT	ODD behaviour 1	The system shall decelerate with a max. long. deceleration of 7m/s2 to avoid a collision with an object if TTC is <= 3s
WP5_CRF_REQ31_v01	ACT	ODD behaviour 2	The system shall decelerate with a maximum absolute deceleration of 3m/s2 when an object is detected in the ego lane and TTC <= 5s & TTC > 3s
WP5_CRF_REQ33_v01	ACT	ODD behaviour over limits	The system shall have a steady braking and stop in the ego lane when there is no response to the take over request.

Table 13: CRF's list of requirements on EXP5

HIT-FR & HIT-UK (Demo Vehicle & Simulation)			
ID	**Type**	**Name**	**Description**
WP3_HIT_REQ1_v01	PER	Object detection and tracking	Detect and Track objects with correct class labels assigned to tracked objects
WP3_HIT_REQ2_v01	PER	Object detection and tracking - Vehicles	Detect and Track road vehicles such as cars, trucks, vans and bicycles.
WP3_HIT_REQ3_v01	PER	Object detection and tracking - Pedestrians	Detect and Track pedestrians
WP3_HIT_REQ5_v01	PER	Drivable Road Detection	Provide 2D/3D information related to drivable road. Determine regions in 2D/3D space that correspond to drivable road.
WP3_HIT_REQ6_v01	PER	Detect Lane Marking Information	Road lines detecting from 2D data

WP3_HIT_REQ7_v01	PER	Vehicle Localisation - GNSS	Accurately localise vehicle position using GNSS measurements
WP3_HIT_REQ9_v01	PER	Object trajectory prediction	Predict tracked object trajectories, of vehicles (cars, trucks, vans, etc) and pedestrians.
WP3_HIT_REQ10_v01	OPE	Drivable Road Extraction (HD-MAP)	Provide 2D/3D information related to drivable road. Determine regions in 2D/3D space that correspond to drivable road.
WP3_HIT_REQ11_v01	OPE	Extract Lane Marking Information (HD-MAP)	Road lines detecting from 2D data

Table 14: HIT-FR's & HIT-UK's list of requirements on EXP5

TECN (Demo Vehicle & Simulation)			
ID	**Type**	**Name**	**Description**
WP3_TECN_REQ1_v01	PER	Vehicle detection	The system must be able to detect and classify vehicles around itself
WP5_TECN_REQ3_v01	GEN	Road limits	The limits of the road must be clear and provided, either statically or dynamically
WP3_TECN_REQ4_v01	PER	Vehicle detection in advance	Subject vehicle shall be able to detect a stationary/dynamic vehicle in advance
WP3_TECN_REQ5_v01	PER	Pedestrian detection in advance	Subject vehicle shall be able to detect a stationary/dynamic pedestrian in advance
WP3_TECN_REQ6_v01	PER	Localization accuracy	The localization system should provide an accurate positioning for control/decision making.
WP4_TECN_REQ16_v01	DM	Safe braking	Once detected an obstacle (e.g. Pedestrian) the vehicle should be able to stop timely
WP3_TECN_REQ18_v01	GEN	Digital maps	Digital maps should specify drivable space

Table 15: TECN's list of requirements on EXP5

5.6 EXP6: Small object detection at a far range in adverse weather conditions

APTIV (Demo Vehicle & Simulation)			
ID	**Type**	**Name**	**Description**
WP5_CRF_REQ32_v01	ACT	ODD behaviour 3	The system shall adapt its speed to drive safely (taking also comfort of passengers into account)
WP5_APTIV_REQ001_1	OPE	ODD - Driveable area	The system shall function in highways

WP5_APTIV_REQ002_1	OPE	ODD - Temporary objects	The system shall react to small objects in the ego lane to avoid a collision, reduce severity of collision or drive over them safely when adjacent lanes are not available for driving
WP5_APTIV_REQ003_1	OPE	ODD - Traffic	The system shall take into account vehicles in its rear while decelerating
WP5_APTIV_REQ004_1	OPE	ODD - Weather conditions	The system shall function in the presence of rain and fog
WP5_APTIV_REQ005_1	OPE	ODD - Weather conditions	The system shall function in the presence of snow
WP5_APTIV_REQ006_1	OPE	ODD - Illumination	The system shall function at day and night
WP5_APTIV_REQ007_1	OPE	ODD - Ego Vehicle	The system shall be enabled in a speed range of 30 to 130 km/h
WP3_APTIV_REQ008_1	PER	Small object detection	The system shall be capable of detecting small objects ahead of the vehicle with a minimum dimension of 10cm (h) x 10cm (w) in the ego lane at a minimum range required for a safe reaction (depending on the speed)
WP3_APTIV_REQ009_1	PER	Object classification	The system shall classify the detected object as overdriveable or non-overdrivable
WP3_APTIV_REQ010_1	PER	Object classification	The system shall consider an object as overdriveable if it can be driven over without: 1) destabilizing the vehicle 2) causing any form of damage to the vehicle or 3) causing any form of injury to the driver or passengers
WP3_APTIV_REQ011_1	OPE	ODD detection	The system shall detect if it is outside its ODD
WP4_APTIV_REQ012_1	DM	ODD detection	The system shall be outside ODD if an object is detected but not classified when collision is imminent: Time to collision (TTC) < 3,1 sec
WP4_APTIV_REQ013_1	DM	Outside ODD behaviour	The system shall issue a take over request if it detects outside ODD condition
WP4_APTIV_REQ014_1	DM, ACT	Outside ODD behaviour	The system shall have a steady braking and stop in the ego lane when there is no response to the take over request

WP4_APTIV_REQ015_1	DM, ACT	Initial behaviour	The system shall decelerate with a maximum absolute deceleration of 3m/s2 when an object is detected in the ego lane and TTC <= 6,1 sec and TTC > 3,1 sec
WP4_APTIV_REQ016_1	DM, ACT	Behaviour for Overdriveable object	The system shall adapt its speed to safely drive over an overdriveable object such that the motion profile of the vehicle stays within comfortable limits for the passengers
WP4_APTIV_REQ017_1	DM, ACT	Behaviour for non-overdriveable object	The system shall decelerate with a maximum absolute deceleration of 7m/s2 to avoid a collision with a non-overdriveable object when TTC is <= 3,1sec

Table 16: APTIV's list of requirements on EXP6

5.7 EXP7: Localization/perception self-assessment and other vehicles' behaviour prediction under adverse weather or adverse road conditions

WMG (Demo Vehicle & Simulation)			
ID	**Type**	**Name**	**Description**
WP3_WMG_REQ04_v01	OPE	Speed range	The integrity monitoring mechanism of the distance estimation to the front vehicle shall operate at speeds 60 - 100 km/h along a motorway
WP3_WMG_REQ05_v01	OPE	Weather conditions	The integrity monitoring mechanism of the distance estimation to the front vehicle shall operate under adverse weather or lighting conditions along a motorway
WP3_WMG_REQ06_v01	PER	Integrity monitoring of the distance estimation to the leading vehicle in motorway chauffeur	The system shall issue a warning when the distance estimation to the leading vehicle in motorway chauffeur fails
WP3_WMG_REQ07_v01	OPE	Speed range	The integrity monitoring mechanism for GNSS-based localisation for urban chauffeur shall operate at speeds up to 40 km/h

WP3_WMG_REQ08_v01	PER	Integrity monitoring of GNSS-based localisation in urban chauffeur	The system shall issue a warning when the GNSS-based localisation fails

Table 17: WMG's list of requirements on EXP7

ICCS (Demo Vehicle & Simulation)			
ID	**Type**	**Name**	**Description**
WP4_ICCS_REQ05_v01	PER	Behavior prediction of other vehicles accuracy	The system must be able to predict the behavior of other vehicles by classifying manoeuvres into predefined classes (e.g. lane change to the right, lane change to the left, cut-in from the left), with certain minimum accuracy
WP4_ICCS_REQ06_v01	PER	Behavior prediction of other vehicles reliability	The system must be able to predict the behavior of other vehicles, by classifying manoeuvres into predefined classes (e.g. lane change to the right, lane change to the left, cut-in from the left), with a certain probabilistic certainty
WP4_ICCS_REQ07_v01	PER	Behaviour prediction of other vehicles robust under object-level uncertainty due to bad weather conditions	The system must be able to maintain prediction accuracy and reliability under challenging weather conditions
WP4_ICCS_REQ08_v01	GEN	Behavior prediction of other vehicles: input scenarios	The simulation environment must provide scenario data involving tracked objects trajectories as inputs for the SuT
WP4_ICCS_REQ09_v01	OPE	Behavior prediction of other vehicles: challenging OD	The simulation environment must provide scenario data involving challenging weather conditions like rain or fog

Table 18: ICCS's list of requirements on EXP7

5.8 EXP8: Driving minor road under adverse weather conditions incl. perception self-assessment

S4 (Demo Vehicle & Simulation)			
ID	**Type**	**Name**	**Description**
WP5_S4_REQ001_V1	OPE	ODD - zone	The system shall operate on minor roads
WP5_S4_REQ002_V1	OPE	ODD - subject vehicle	The system shall operate at speeds 0…32km /h

WP5_S4_REQ003_V1	OPE	ODD - weather conditions	The system shall operate in light rain
WP5_S4_REQ004_V1	OPE	ODD - weather conditions	The system shall operate in light snowing
WP5_S4_REQ005_V1	OPE	ODD - road surface conditions	The system shall operate in presence of snow or ice on the road surface
WP3_S4_REQ006_V1	PER	Sensor Visibility estimation	The system shall provide estimate of LIDAR sensor effective visibility
WP3_S4_REQ007_V1	PER	Sensor Visibility adaptation	The system shall adapt its behavior based on changes in sensor visibility
WP3_S4_REQ008_V1	PER	Sensor Obstruction estimation	The system shall provide estimate of amount of sensor obstruction
WP3_S4_REQ009_V1	PER	Sensor Obstruction adaptation	The system shall adapt its behavior based on changes in sensor obstruction
WP3_S4_REQ010_V1	PER	Localization Sensing Monitoring	Localization Sensing Monitor module shall provide estimate of reliability of localization sensor data, based on measured visibility threshold parameter, Lidar effective visibility estimate and sensor obstruction
WP4_S4_REQ011_V1	DM	Path plan around block	System shall plan a safe path around static obstacle
WP4_S4_REQ012_V1	OPE	Path plan verification	dynamically planned path around obstacle should be verifiable by remote operator before execution
WP4_S4_REQ013_V1	DM	Out of ODD	The system shall detect out of ODD and situations that require remote operator assistance and notify the operator
WP4_S4_REQ014_V1	DM	Fail safe operation	The system shall apply minimum risk control strategy in case of system malfunction or unexpected situations that cannot be handled by the system

Table 19: S4's list of requirements on EXP8

6. Requirements' Analysis

In this section, an analysis of the collected requirements is provided, including graphs that give an overall picture of the requirements.

6.1 Collected Requirements: Results

A total of 135 requirements were collected from all 9 partners. In Figure 11, the total number of requirements per partners is shown, in which CRF has the larger number of requirements, justified by being part of two, one of which end-to-end, experiments, followed by TECN, which participates in three experiments. In Figure 12, the total number of requirements per demonstrator is presented. The name of a partner (e.g., APTIV) indicates that the experiment will be implemented in the corresponding partner's demo vehicle (e.g., Demo Vehicle of "APTIV" partner), while, the tag "CARLA" indicates that the experiments will be implemented in the CARLA simulator environment. Again, the larger number of requirements are part of the experiments implemented on CRF's demo vehicle, followed by CARLA, which is going to be used in multiple experiments.

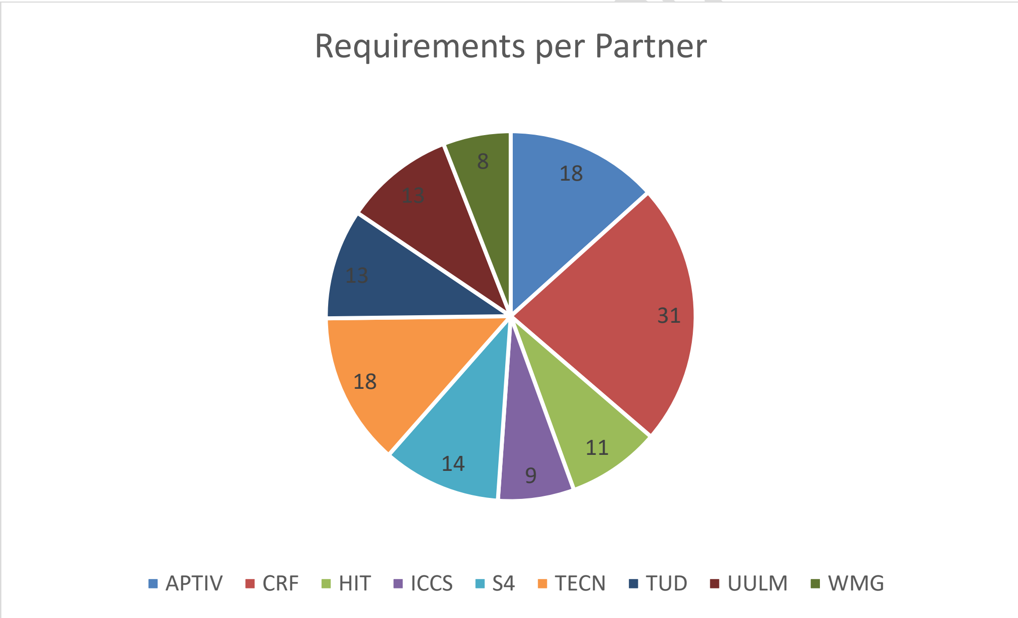


Figure 11: Number of requirements per partner

In Figure 13, the total number of requirements per type/category is shown, with the results (in percentage) being the following:

- General – GEN: 10,6%
- Decision Making – DM: 18,3%
- Perception – PER: 36,6%

- Operational – OPE: 26,8%
- Actuation – ACT: 7,7%

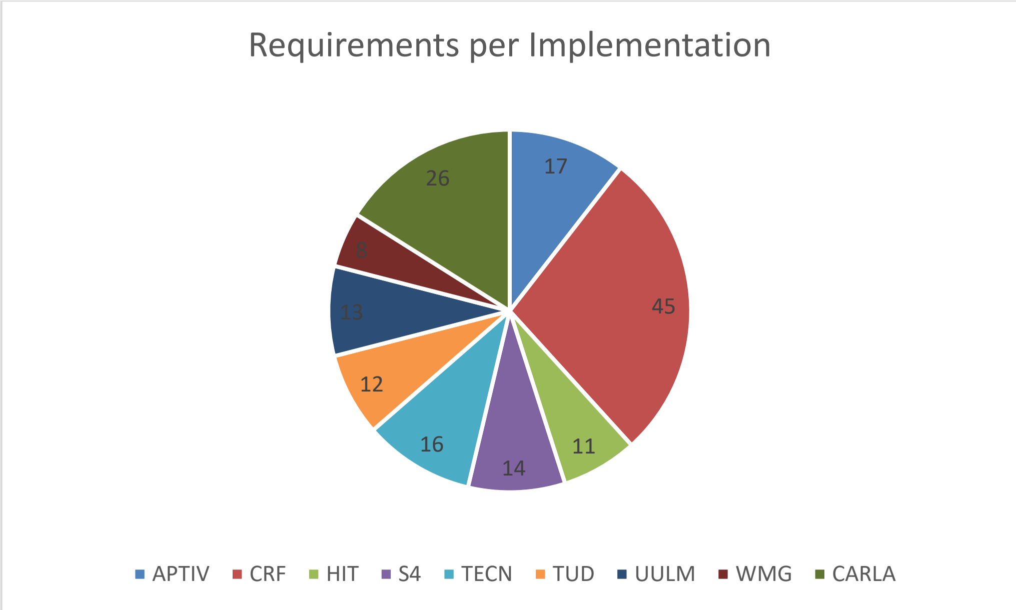


Figure 12: Number of requirements per implementation/demonstration

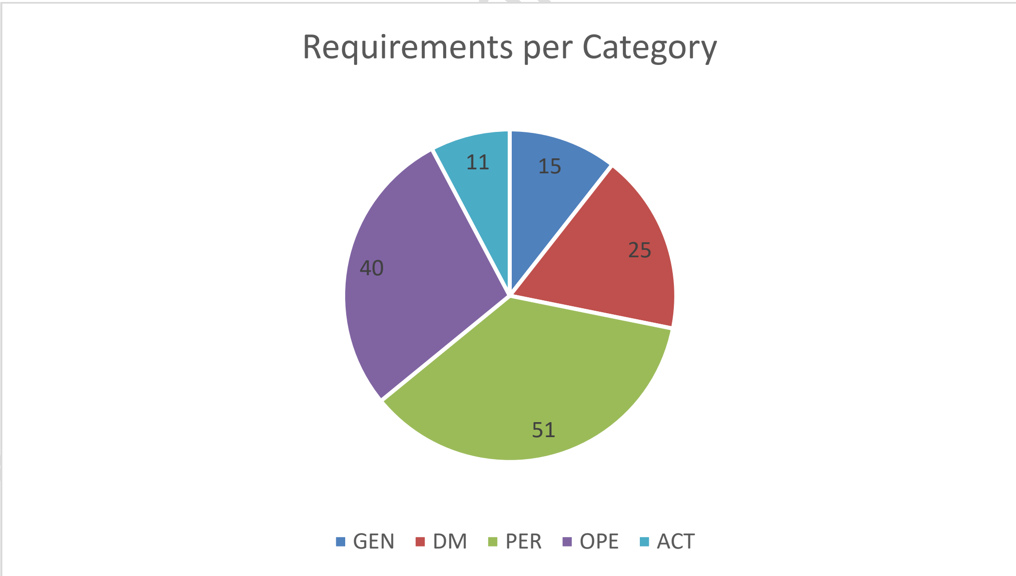


Figure 13: Requirements per type/category

The vast majority of requirements refers to *Perception*, *Operational* and *Decision Making*, which is expected considering the nature and the objectives of the EVENTS project that focuses on the perception and decision-making in complex situations, implemented on demonstrators in selected scenarios.

Figure 14 depicts the total number of requirements per experiment. Experiments 4 (EXP4) and 5 (EXP5) have the larger number of requirements justified by the high number of participating partners, four and three respectively, as well as by the fact that EXP4 is an end-to-end experiment.

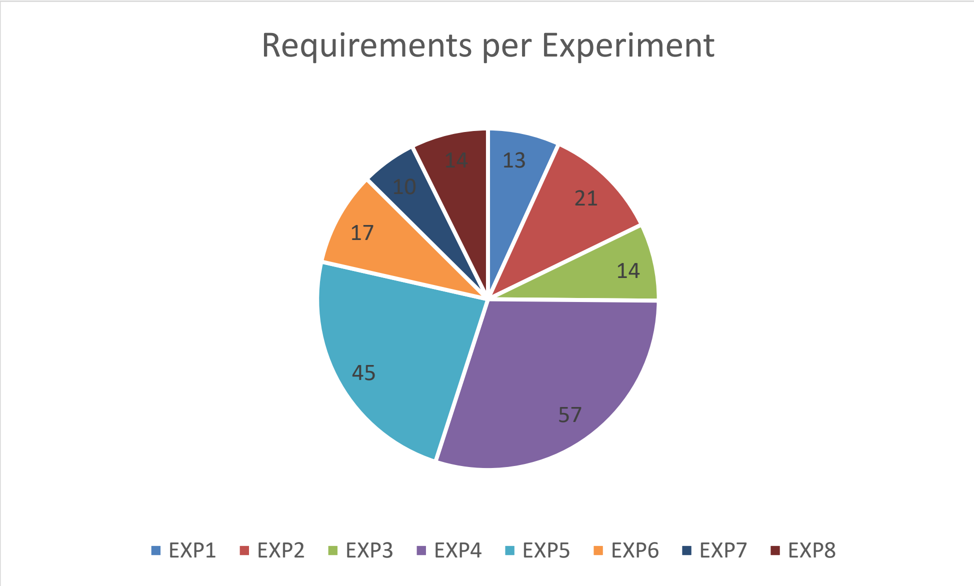


Figure 14: Requirements per experiment (EXP)

6.2 Summary of Requirements

In summary, a total number of 135 requirements have been collected, categorized in General, Decision-Making, Perception, Operational and Actuation. The full list of requirements can be found in the Annex 3.

During the project development cycle, the requirements will be translated into objective Key Performance Indicators (KPIs). In turn, the KPIs will be used to assess and evaluate whether the performance of the system as a whole as well as the performance of the system's individual components are in accordance with the defined requirements. The KPIs will provide the basis for the definition of the evaluation plans and the actual evaluations undertaken in the different WPs and – more importantly – in WP6.

Finally, it should be noted that a list of requirements is a "living list", in the sense that requirements can be added, refined, or even removed, during the development process throughout the project. Still, this uncertainty is, to an extent, captured through the prioritization of the requirements in High (H), Medium (M) and Low (L).

7. Conclusions

The main goal of this document is to define the eight experiments (EXPs) that will be carried out throughout the EVENTS project, based on three pre-defined use cases (UCs), and the associated user and system requirements (REQs). The UCs have been previously defined in the Grant Agreement (GA) and focus on complex scenarios (urban, non-structured environment, adverse weather conditions, and so on) and vulnerable road users (VRUs) scenarios, especially where possible contradictions appear between the decision-making and regulations. This selection has been guided by the previous experience of the partners in EU projects in the same field of autonomous driving (AD), especially where (extensive) pilots have been carried out (e.g., “L3-Pilot” and “EuroFot”). In turn, the eight EXPs are defined either strictly under one UC (e.g., EXP1 is under UC1) or as a combination of more than one UCs (e.g., EXP7 is a combination of UC2 & UC3). The EXPs are defined in such a way as to harness, on the one hand, the expertise of the project’s partners, as well as, on the other hand, cover a wide range of operational design domains (ODDs) and scenarios, while at the same time be consistent with the UCs, as those were initially defined in the GA and later fine-tuned in this document.

Based on that, the REQs have been determined and specified, considering the diversity of the UCs in their respective operational domains (see Section 3). A total of 135 functional requirements have been collected, categorised in General, Decision-Making, Perception, Operational and Actuation. The vast majority of the requirements refers to Perception, Operational and Decision-Making.

The UCs, the EXPs and the related REQs presented in this document will form the basis for the definition of the system’s functional architecture, which is the next task in the project (WP2/T2.3) and subsequently, the topic of the next deliverable (D2.2). In particular, the five categories of requirements (general, decision-making, perception, operational and actuation) will be assigned into the functional blocks of the proposed system architecture and further decomposed into their individual components. In task T2.3, the necessary sensor suites, capable of dealing with the selected use cases, will be proposed and optimized in terms of performance and cost.

References

[1] International Organization for Standardization. (2022). Road vehicles — Safety of the intended functionality (ISO Standard No. 21448:2022)

[2] International Organization for Standardization. (2022). Road vehicles — Test scenarios for automated driving systems (ISO Standard No. 34501:2022)

[3] Go, K. & Carroll, J.M. (2004): The blind men and the elephant: Views of scenario-based system design, Interactions, vol. 11, no. 6, pp. 44–53.

[4] Ulbrich, S., Menzel, T., Reschka, A., Schuldt, F. & Maurer, M. (2015): Defining and Substantiating the Terms Scene, Situation and Scenario for Automated Driving. IEEE International Annual Conference on Intelligent Transportation Systems (ITSC), Las Palmas, Spain, pp. 982-988.

Annex 1. Detailed WP2 Workflow

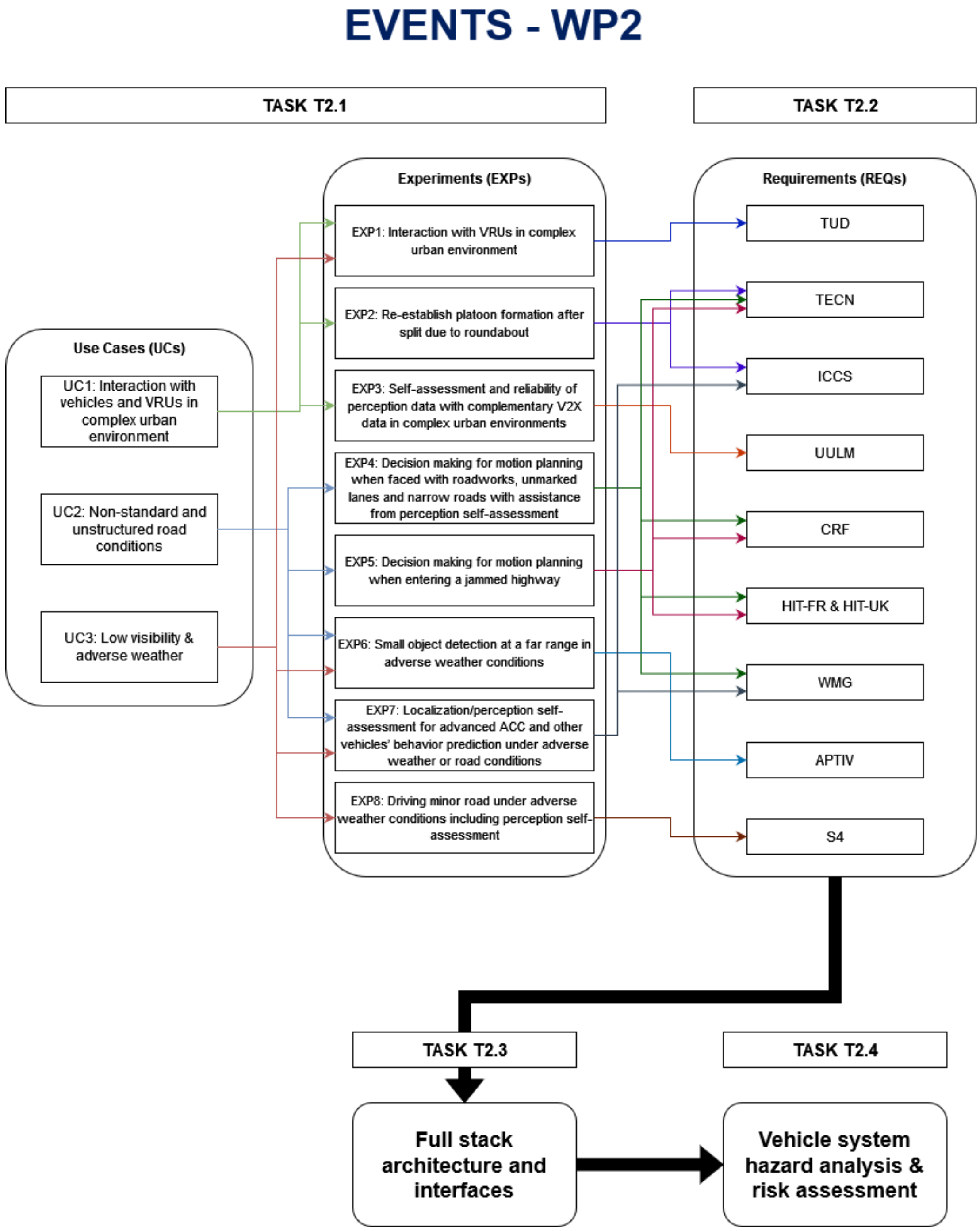


Figure 15: Detailed EVENTS WP2 structure

Annex 2. Use Cases and Experiments Template

In this section, the template for the collection of the experiments is presented.

General Info	
UC Title	
Leading Partner	
Partners Involved	
Reference Use Case	
Scenario	
Short Verbal Description	
Detailed Graphical Description	
Initial Assumptions	
Actors' Contribution	
Actors' Interaction	
Traffic & Environment	
Traffic Participants' (TPs) Attributes	
Autonomous Vehicle's (AV) Attributes	
Limitations	
Other relevant information	
Vehicle Info	
Model	
Communication	
Sensors	
Data	
Availability	
Format	
Openness	
Evaluation	
KPIs	
Comments	

Table 20: EXCEL template for the collection of experiments

Annex 3. Detailed List of Requirements

In this annex, the template of the EXCEL table for the requirements collection as well as the complete list of all the requirements are presented.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
ID	Type/Category	Name	Description	Rationale	Metrics	Relevance	Status	Owner	Reference UC	Implementation	Dependencies	Conflicts	Review	Comments / Notes

Table 21: EXCEL template for requirements collection.

The requirement collection consisted of a total of 15 attributes/columns, which have been explained in more detail in Section 4.2. In the following pages, all the collected requirements are listed, including all their attributes.

It should be noted that all values in the column "Metrics" are preliminary and might change upon fine-tuning the setup of each experiment.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	ID	**Cat.**	**Name**	**Description**	**Rationale**	**Metrics**	**Relevance**	**Status**	**Owner**	**Experiments**	**Implementation**	**Dependencies**	**Conflicts**	**Review**	**Comments / Notes**
1	WP5_CRF_REQ01_v01	GEN	Pre-Conditions to activate the function	The system shall be activated if there are no failures, if there is a driver request, if scenarios are visible (activation inside the ODD).	Identification of condition to activate the function	Check of failures, check driver answer and check outputs from PP. [QUALIT.]	H	NA	CRF	EXP4 EXP5	CRF demo vehicle	NA	Any	NA	
2	WP5_CRF_REQ02_v01	GEN	Conditions, when function is deactivated	The system shall be deactivated if there are failures, if there is a driver request and if scenarios are not detected (de-activation outside the ODD).	Identification of condition to deactivate the function	Check of failures, check driver answer and check outputs from PP. [QUALIT.]	H	NA	CRF	EXP4 EXP5	CRF demo vehicle	NA	NA	NA	
3	WP3_CRF_REQ03_v01	OPE	Speed Range	The system shall work in the operative speed range (50 - 140 km/h for the CRF demo car)	Necessary to define a range of velocity where the system is active	50 - 140 km/h for CRF demo car (motorways and extra-urban). When active, the system can work also in the range 0 - 50 km/h.	H	NA	CRF	EXP4 EXP5	CRF demo vehicle	NA	NA	NA	T3.5
4	WP3_CRF_REQ04_v01	OPE	Weather Conditions	The system shall work in specific weather conditions	Necessary to define the weather conditions, where the system can work: sunny, cloudy, light rain; no heavy rain, fog and snow.	Check on trial, if the system works in the requested conditions. [QUALIT.]	H	NA	CRF	EXP4 EXP5	CRF demo vehicle	NA	NA	NA	T3.5
5	WP3_CRF_REQ05_v01	OPE	Lighting Conditions	The system shall work in specific lighting conditions	Necessary to define the lighting conditions where the system can work: day time (and not nightime or sunset/sunrise.	Check on trial if the system works in the requested conditions. [QUALIT.]	H	NA	CRF	EXP4 EXP5	CRF demo vehicle	NA	NA	NA	T3.5
6	WP5_CRF_REQ07_v01	GEN	Vehicle CAN data	Provision of vehicle sensor information on CAN	Necessary inputs for PP (camera, LiDAR, etc.) and planning.	Availability of: steering wheel angle, wheel speed, yaw rate, windscreen wiper and gear accelerations (x, y) [QUALIT]	H	NA	CRF	EXP4 EXP5	CRF demo vehicle	NA	NA	NA	
7	WP3_CRF_REQ08_v01	OPE	System reaction time	The system shall react in real time to the encountered situation	To guarantee the safety of the system and of the vehicle.	Proposed max. value: 100ms [QUANTIT]	H	NA	CRF	EXP4 EXP5	CRF demo vehicle	NA	NA	NA	This means that the maximum delay of each sub-system (PP, DM, etc.) can be 100ms. Task T3.4 & T3.5
8	WP3_CRF_REQ09_v01	GEN	Protocol communication	The components / sub-systems should exchange info via CAN bus. Alternatively, via ETHERNET	To make the internal communication easier and in "real-time".	Check on trial, that all necessary messages are present. [QUALIT.]	H	NA	CRF	EXP4 EXP5	CRF demo vehicle	NA	NA	NA	T3.4 & T3.5
9	WP5_CRF_REQ10_v	OPE	System capability and	The system shall track the speed set by the user	The system has to present certain	When the function is enabled, the control	H	NA	CRF	EXP4 EXP5	CRF demo vehicle	NA	NA	NA	Referred to the function

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	ID	Cat.	Name	Description	Rationale	Metrics	Relevance	Status	Owner	Experiments	Implementation	Dependencies	Conflicts	Review	Comments / Notes
10	WP5_CRF_REQ11_v01	OPE	characteristics	When the function is enabled, the system shall stop the vehicle in case of traffic jam or obstacles ahead.	features, such as: follow the speed set by the driver (in a given range), deal with complex situations, and so on.	must track the set-speed with a SS error of *** When active, the system shall be able to track the speed to 0 kph. Check on trial that the command is executed. [QUALIT.]	H	NA	CRF	EXP4 EXP5	CRF demo vehicle	NA	NA	NA	
11	WP5_CRF_REQ12_v01	OPE		When the function is enabled, the system shall be able to restart following the user set speed if the obstacle disappears.			H	NA	CRF	EXP4 EXP5	CRF demo vehicle	NA	NA	NA	
12	WP5_CRF_REQ13_v01	OPE		The system shall adjust and optimize the vehicle speed in case of other vehicles entering from a highway on ramp			H	NA	CRF	EXP4 EXP5	CRF demo vehicle	NA	NA	NA	
13	WP3_CRF_REQ14_v01	PER	Ahead obstacles detection (on ramps)	The PP shall detect the presence of other vehicle on the highway on-ramps at least 170m ahead	To define the maximum detection range	Measurement of detection range [QUANTIT.]	H	NA	CRF	EXP5	CRF demo vehicle	NA	NA	NA	Considering the ego vehicle travelling at 130 km/h and the obstacle at 40 km/h.
14	WP3_CRF_REQ15_v01	PER	Tracking objects (on ramps)	The PP shall detect and track most relevant object in highway on-ramp	To track objects on ramps entering the motorway	Check on trial that the entering object is present and tracked. [QUALIT.]	H	NA	CRF	EXP5	CRF demo vehicle	NA	NA	NA	Availability of: relative speed, distance and position
15	WP3_CRF_REQ16_v01	OPE	Deceleration behaviour	The system shall track/follow the setpoint speed with an acceleration in the range [-3.5 - 2] m/s^2	To define acceptable acceleration behaviour (in terms of performances and comfort)	Measurement of acceleration value. [QUANTIT.]	H	NA	CRF	EXP4 EXP5	CRF demo vehicle	NA	NA	NA	
16	WP3_CRF_REQ17_v01	PER	Front obstacles selection	The PP shall detect and track most relevant object in front in the vehicle lane	To select the most relevant (critical) object in front of the ego-vehicle	Check on trial that the object ahead on the same lane is present and tracked. [QUANTIT.]	H	NA	CRF	EXP4 EXP5	CRF demo vehicle	NA	NA	NA	Availability of: relative speed, distance and position
17	WP3_CRF_REQ18_v01	PER	Rear obstacles selection	The PP shall detect and track most relevant object in vehicle rear lane	To select the most relevant (critical) object from the rear of the ego-vehicle	Check on trial that the rear object(s) is/are present and tracked. [QUANTIT.]	H	NA	CRF	EXP4 EXP5	CRF demo vehicle	NA	NA	NA	Availability of: relative speed, distance and position
18	WP3_CRF_REQ19_v01	PER	Detection and tracking of sorrounding objects	The system shall detect and track most relevant object in vehicle front left lane, front right, rear left, rear right	To detect and track the objects sorrounding the ego-vehicle	Check on trial that relevant objects around the AD vehicle are considered. [QUANTIT.]	H	NA	CRF	EXP4 EXP5	CRF demo vehicle	NA	NA	NA	Availability of: relative speed, distance and position
19	WP3_CRF_REQ20_v01	PER	Speed Limits	The PP should provide the road speed limits information on CAN	To know and regulate vehicle speed limits	Check on trial. [QUANTIT.]	M	NA	CRF	EXP4 EXP5	CRF demo vehicle	NA	NA	NA	TBD if available.
20	WP3_CRF_REQ21_v01	PER	Road type	The PP shall provide the road type information (on CAN)	To know the type of road	Check on trial that type of road is present. [QUANTIT.]	H	NA	CRF	EXP4 EXP5	CRF demo vehicle	NA	NA	NA	

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	ID	**Cat.**	**Name**	**Description**	**Rationale**	**Metrics**	**Relevance**	**Status**	**Owner**	**Experiments**	**Implementation**	**Dependencies**	**Conflicts**	**Review**	**Comments / Notes**
21	WP3_CRF_REQ22_v01	PER	Road line	The PP shall detect the road lines information (on CAN)	To know how the road is in the future, with its main characteristics, such as curvature	Check on trial that such a info is present. [QUANTIT.]	H	NA	CRF	EXP4 EXP5	CRF demo vehicle	NA	NA	NA	Availability of: curvature, curvature dervative, angle, lateral offset from lane center, exist prob, Left and right lanes
22	WP3_CRF_REQ23_v01	PER	Lane info	The PP shall provide the lane information (on CAN)	To know the structure of the lanes and their number	Check on trial that such a info is present. [QUANTIT.]	H	NA	CRF	EXP4 EXP5	CRF demo vehicle	NA	NA	NA	Availability of: number of lanes, current lane number
23	WP3_CRF_REQ24_v01	PER	Road works area	The PP shall reconstruct road lines in case of working area or faded/absent line marking	To know in advance (and in time) the road works presence	Check on trial that road-works are present and correctly localized and if reconstructed lanes are within the error margin. [QUANTIT.]	H	NA	CRF	EXP4	CRF demo vehicle	NA	NA	NA	
24	WP4_CRF_REQ25_v01	DM	Vehicle control 1	The DM shall guaratee the lateral control when road curvature is > 1/60m	For controllability at low velocities and high curvatures	Check on trial, measuring the value. [QUANTIT.]	H	NA	CRF	EXP4 EXP5	CRF demo vehicle	NA	NA	NA	
25	WP5_CRF_REQ26_v01	OPE	Vehicle control 2	The system shall mantain the center line when all the condition are satisfied	For lateral controllability	Lateral error (TBD threshold) [QUANTIT.]	H	NA	CRF	EXP4 EXP5	CRF demo vehicle	NA	NA	NA	When the function is enabled, the control must track the lane center with a lateral maximum error of TBD m
26	WP4_CRF_REQ27_v01	DM	Optimal maneuver	The DM shall advise if a lane change maneuver is convenient	For optimal decision about the best maneuver to act	Optimization parameters (TBD) are satisfied [QUANTIT.]	H	NA	CRF	EXP4	CRF demo vehicle	NA	NA	NA	
27	WP5_CRF_REQ28_v01	OPE	Optimal maneuver execution 1	The system shall execute a lane change maneuver when all the condition are satisfied	Actuation of the best selected maneuver	Check on trial that the maneuver is executed. Measurements of comfort and safety will be considered (*). [QUALIT.]	H	NA	CRF	EXP4 EXP5	CRF demo vehicle	WP3_CRF_REQ22_v01 WP3_CRF_REQ32_v01 WP3_CRF_REQ24_v01	NA	NA	Especially for scenarios with road-works. (*) This includes lateral and longitudinal acceleration of the maneuver, error of the final lateral position, minimum distance from the obstacke ahead in the new lane (if present), etc.
28	WP5_CRF_REQ29_v01	OPE	Optimal maneuver execution 2	The system shall evaluate the convenience of a lane change maneuver in case of vehicle on highway on -ramp	Actuation of the best selected maneuver	Check on trial. Measurements of comfort and safety will be considered (*). [QUALIT.]	H	NA	CRF	EXP5	CRF demo vehicle	WP3_CRF_REQ22_v01 WP3_CRF_REQ32_v01 WP3_CRF_REQ24_v01	NA	NA	(*) This includes lateral and longitudinal acceleration of the maneuver, error of the final lateral position, minimum distance from the obstacke ahead in the new lane (if present), etc.
29	WP5_CRF_REQ30_v01	ACT	ODD behaviour 1	The system shall decelerate with a max. long. deceleration of 7m/s2 to avoid a collision with an object if TTC is <= 3s	Braking limits for collision avoidance/mitigation	1. Maximum deceleration required to come to a full stop. 2. Distance to obstacle after stop 3.	L	NA	CRF	EXP4 EXP5	CRF demo vehicle		NA	NA	Thresholds shall be confirmed.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	ID	**Cat.**	**Name**	**Description**	**Rationale**	**Metrics**	**Relevance**	**Status**	**Owner**	**Experiments**	**Implementation**	**Dependencies**	**Conflicts**	**Review**	**Comments / Notes**
30	WP5_CRF_REQ31_v01	ACT	ODD behaviour 2	The system shall decelerate with a maximum absolute deceleration of 3m/s2 when an object is detected in the ego lane and TTC <= 5s & TTC > 3s	To avoid high levels of unintended braking	NA	H		CRF	EXP4 EXP5	CRF demo vehicle		NA	NA	Thresholds shall be confirmed.
31	WP5_CRF_REQ32_v01	ACT	ODD behaviour 3	The system shall adapt its speed to drive safely (taking also comfort of passengers into account)	Behaviour when object is overdriveable	Motion profile of the object while driving over the object	H		APTIV	EXP3 EXP4	CRF demo vehicle		NA	NA	
32	WP5_CRF_REQ33_v01	ACT	ODD behaviour over limits	The system shall have a steady braking and stop in the ego lane when there is no response to the take over request.	System behaviour outside ODD and no response to take over request	NA	L		CRF	EXP4 EXP5	CRF demo vehicle		NA	NA	
33	WP3-5_UULM_REQ01_v01	GEN	Weather Conditions	The self-assessment system shall work under certain good weather conditions	Necessary to define the weather conditions, where the self-assessment of the perception system can work: good weather conditions (sunny, cloudy)	Check on trial. [QUALIT.]	H	NA	UULM	EXP3	UULM demo vehilce	NA	NA	NA	
34	WP3-4_UULM_REQ02_v01	GEN	Weather Conditions	The infrastructure V2X system shall work under certain good weather conditions	Necessary to define the weather conditions, where the infrastructure perception system can work: good weather conditions (sunny, cloudy)	Check on trial. [QUALIT.]	H	NA	UULM	EXP3	UULM pilot site	NA	NA	NA	
35	WP3-5_UULM_REQ03_v01	GEN	Lighting Conditions	The self-assessment system shall work under good lighting conditions (daylight)	Necessary to define the lighting conditions, where the self-assessment of the perception system can work: good lighting conditions (sunny, daylight)	Check on trial. [QUALIT.]	H	NA	UULM	EXP3	UULM demo vehilce	NA	NA	NA	
36	WP3-4_UULM_REQ04_v01	GEN	Lighting Conditions	The infrastructure V2X system shall work under good lighting conditions (daylight)	Necessary to define the lighting conditions, where the infrastructure perception system can work: good lighting conditions (sunny, daylight)	Check on trial. [QUALIT.]	H	NA	UULM	EXP3	UULM pilot site	NA	NA	NA	

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	ID	**Cat.**	**Name**	**Description**	**Rationale**	**Metrics**	**Relevance**	**Status**	**Owner**	**Experiments**	**Implementation**	**Dependencies**	**Conflicts**	**Review**	**Comments / Notes**
37	WP3_UULM_REQ05_v01	GEN	Road conditions	The self-assessment system shall work under good road conditions	Necessary to define the road conditions, where the self-assessment of the perception system can work: good road conditions (clear, simple, no road works)	Check on trial. [QUALIT.]	H	NA	UULM	EXP3	UULM demo vehilce	NA	NA	NA	
38	WP3-4_UULM_REQ06_v01	PER	Protocol communication	V2X information shall be transmitted via CAMs & CPMs with proprietary extensions	pilot site and connected automated vehicles with compatible data interface available	Check on trial. [QUALIT.]	H	NA	UULM	EXP3	UULM pilot site	NA	NA	NA	
39	WP3-4_UULM_REQ07_v01	GEN	Infrastructure pilot site	Infrastructure Pilot Site shall generate CPMs of the surveilled road area if all conditions are satisfied	Necessary for V2X augmented perception	Check on trial. [QUALIT.]	H	NA	UULM	EXP3	UULM pilot site	NA	NA	NA	
40	WP3_UULM_REQ08_v01	GEN	Automated Vehicle	Connected automated vehicle shall be able to drive automatically (with safety driver) if all conditions are satisfied	Necessary for implementing the experiment	Check on trial. [QUALIT.]	H	NA	UULM	EXP3	UULM demo vehilce	NA	NA	NA	
41	WP3-4_UULM_REQ09_v01	PER	Detecting objects with infrastructure pilot site	Infrastrature Pilot Site must detect relevant objects in the corresponding area	Necessary for augment the onboard perception of the ego-vehicle and as input for the tracking algorithm	Check on trial. [QUALIT.]	H	NA	UULM	EXP3	UULM pilot site	NA	NA	NA	
42	WP3-5_UULM_REQ10_v01	PER	Tracking objects	The connected automated vehicle shall provide an object tracking and track the relevant objects in its relevant proximity	Necessary for the self-asssessment of the perception system is a running object tracking	Check on trial. [QUALIT.]	H	NA	UULM	EXP3	UULM demo vehilce	NA	NA	NA	
43	WP3-5_UULM_REQ11_v01	PER	Sensors Detections	The connected automated vehicle shall provide different sensors and sensor types delivering detections to the tracking module	Necessary for the self-asssessment perception system that it is able to detect single failures	Check on trial. [QUALIT.]	H	NA	UULM	EXP3	UULM demo vehilce	NA	NA	NA	
44	WP3_UULM_REQ12_v01	GEN	Connected Automated Vehicle	The connected automated vehicle shall be able to receive and process CPMs with proprietary extensions	Necessary for augmented perception by V2X data	Check on trial. [QUALIT.]	H	NA	UULM	EXP3	UULM demo vehilce	NA	NA	NA	
45	WP3-5_UULM_REQ13_v01	PER	Self-assessment of perception system	The self-assessment of the perception system shall generate reliability scores if all conditions are satisfied	Perception self-asssessment is necessary for experiment	Self-assessment scores are calculated	H	NA	UULM	EXP3	UULM demo vehilce	NA	NA	NA	

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	ID	Cat.	Name	Description	Rationale	Metrics	Relevance	Status	Owner	Experiments	Implementation	Dependencies	Conflicts	Review	Comments / Notes
46	WP3_TECN_REQ1_v01	PER	Vehicle detection	The system must be able to detect and classify vehicles around itself	DM cannot ensure safety with unreliable surrounding information	Reliability of 85% or higher [QUANTIT.]	H	Not Fulfilled	TECN	EXP2 EXP4 EXP5	TECN Twizy	NA	NA	NA	
47	WP3_TECN_REQ2_v01	PER	Traffic Agents detection	The system must be able to detect and classify traffic agents around itself	DM cannot ensure safety with unreliable surrounding information	Reliability of 85% or higher [QUANTIT.]	H	Not Fulfilled	TECN	EXP4	CARLA / CRF Demo Veh.	NA	NA	NA	
48	WP5_TECN_REQ3_v01	GEN	Road limits	The limits of the road must be clear and provided, either statically or dynamically	DM needs that information so the vehicle does not go offroad	NA	H	Not Fulfilled	TECN	EXP2 EXP4 EXP5	CRF demo vehicle	NA	NA	NA	
49	WP3_TECN_REQ4_v01	PER	Vehicle detection in advance	Subject vehicle shall be able to detect a stationary/dynamic vehicle in advance	To know in advance the surrounding agents	Detection at least in the equivalent distance of 5 seconds. Check on trial. [QUALIT.]	M	Not Fulfilled	TECN	EXP2 EXP4 EXP5	TECN Twizy	T4.3	NA	NA	
50	WP3_TECN_REQ5_v01	PER	Pedestrian detection in advance	Subject vehicle shall be able to detect a stationary/dynamic pedestrian in advance	To know in advance the surrounding agents	Detection at least in the equivalent distance of 5 seconds.Check on trial. [QUALIT.]	M	Not Fulfilled	TECN	EXP2 EXP4 EXP5	TECN Twizy	T4.3	NA	NA	
51	WP3_TECN_REQ6_v01	PER	Localization accuracy	The localization system should provide an accurate positioning for control/decision making.	To properly obtain the vehicle localization	Position error should be less than 10cm [QUANTIT.]	M	Not Fulfilled	TECN	EXP2 EXP4 EXP5	TECN Twizy / Carla	T4.3	NA	NA	
52	WP4_TECN_REQ7_v01	DM	Localization malfunction	Subject vehicle shall be able to detect a malfunction of the localization system (accidental)	To know the system health in order to trigger safe operational control	Check on trial. [QUALIT.]	M	Not Fulfilled	TECN	EXP2 EXP4	TECN Twizy / Carla	T4.3	NA	NA	
53	WP4_TECN_REQ8_v01	DM	Localization degraded	Subject vehicle shall be able to detect a reduction of accuracy of the localization system (accidental)	To know the system health in order to trigger safe operational control	Positioning error of more than 20cm or more. Check on trial. [QUALIT.]	M	Not Fulfilled	TECN	EXP2 EXP4	TECN Twizy / Carla	T4.3	NA	NA	
54	WP4_TECN_REQ9_v01	DM	Vehicle collision avoidance in degraded mode	DM shall be able to execute DDT (Dynamic Driving Task, defined in SAE J3016) in a degraded mode to avoid colliding with other vehicles	To ensure safety	Check on trial. [QUALIT.]	M	Not Fulfilled	TECN	EXP2 EXP4	TECN Twizy / Carla	T4.3	NA	NA	
55	WP4_TECN_REQ10_v01	DM	VRU collision avoidance in degraded mode	DM shall be able to execute DDT in a degraded mode to avoid colliding with VRUs	To ensure safety	Check on trial. [QUALIT.]	M	Not Fulfilled	TECN	EXP2 EXP4	TECN Twizy / Carla	T4.3	NA	NA	
56	WP4_TECN_REQ11_v01	DM	Fail-degraded operation	The DDT in degraded mode must have the capability of executing a MRM until a safe stopping location is reached	To ensure safety	Check on trial. [QUALIT.]	M	Not Fulfilled	TECN	EXP2 EXP4	TECN Twizy / Carla	T4.3	NA	NA	

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	ID	**Cat.**	**Name**	**Description**	**Rationale**	**Metrics**	**Relevance**	**Status**	**Owner**	**Experiments**	**Implementation**	**Dependencies**	**Conflicts**	**Review**	**Comments / Notes**
57	WP4_TECN_REQ12_v01	DM	Platoon stability comfort (1)	The joining process must be smooth, without big speed oscilations	Instabilty problems in dense traffic situations can lead to accidents	Speed peak<110%reference [QUANTIT.]	H	Not Fulfilled	TECN	EXP2	TECN Twizy / Carla				To measure correctly this requirement the Joining maneuvre must be performed with a constant speed
58	WP4_TECN_REQ13_v01	DM	Platoon stability comfort (2)	The joining process must be smooth, without big speed oscilations	Instabilty problems in dense traffic situations can lead to accidents	Stability time < 1s at 50km/h [QUANTIT.]	H	Not Fulfilled	TECN	EXP2	TECN Twizy / Carla				To measure correctly this requirement the Joining maneuvre must be performed with a constant speed
59	WP4_TECN_REQ14_v01	DM	Safe braking in platooning	Once detected an obstacle (e.g. Pedestrian) the vehicle should be able to stop smoothly	Braking should be safe for both, the obstacle and the driver	Stop at least a distance of 0.5m. With a max deceleration of 0.6g [QUANTIT.]	H	Not Fulfilled	TECN	EXP2	TECN Twizy / Carla	Good perception performance			In this use case the pedestrian should be waiting to cross the street so it can be detected by the perception system soon enough
60	WP4_TECN_REQ15_v01	DM	Fail-safe motion planning	The fail-safe motion planning must provide guidance until a safe state is reached	The vehicle cannot be stopped inmediately in case of localization failure. Instead, it must remain operating in degraded mode until a safe state is reached	Check on trial. [QUALIT.]	H	Not Fulfilled	TECN	EXP2 EXP4	TECN Twizy / Carla				
61	WP4_TECN_REQ16_v01	DM	Safe braking	Once detected an obstacle (e.g. Pedestrian) the vehicle should be able to stop timely	Braking should be safe for both, the obstacle and the driver	Stop at least a distance of 0.5m. With a max deceleration of 0.8 g [QUANTIT.]	H	Not Fulfilled	TECN	EXP2 EXP4 EXP5	TECN Twizy / Carla				
62	WP5_TECN_REQ17_v01	DM	Vehicle communications	Vehicle communication must have reasonably low latency between vehicles	Vehicle communications is essential for platoon coordination	Latency below 100ms. [QUANTIT.]	H	Not Fulfilled	TECN	EXP2	TECN Twizy / Carla				
63	WP3_TECN_REQ18_v01	GEN	Digital maps	Digital maps should specify drivable space.	Provide road limits, parking spots, drivable space, road direction, etc	Check on trial. [QUALIT.]	H	Not Fulfilled	TECN	EXP2 EXP4 EXP5	TECN Twizy / Carla				
64	WP5_APTIV_REQ001_1	OPE	ODD - Driveable area	The system shall function in highways	Driving area and traffic situation for the system	NA	H		APTIV	EXP6	APTIV demo vehicle	NA			

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65	WP5_APTIV_REQ002_1	OPE	ODD - Temporary objects	The system shall react to small objects in the ego lane to avoid a collision, reduce severity of collision or drive over them safely when adjacent lanes are not available for driving	Avoid collision with debris or other small objects in the ego lane	NA	H		APTIV	EXP6	APTIV demo vehicle	APTIV_REQ008_1, APTIV_REQ009_1, APTIV_REQ010_1, APTIV_REQ014_1, APTIV_REQ015_1, APTIV_REQ016_1, APTIV_REQ017_1			
66	WP5_APTIV_REQ003_1	OPE	ODD - Traffic	The system shall take into account vehicles in its rear while decelerating	Avoid rear collision	NA	M		APTIV	EXP6	APTIV demo vehicle	APTIV_REQ015_1			
67	WP5_APTIV_REQ004_1	OPE	ODD - Weather conditions	The system shall function in the presence of rain and fog	Specifying weather conditions	APTIV_REQ008_1,APTIV_REQ009_1 shall be satisfied	H		APTIV	EXP6	APTIV demo vehicle	NA			
68	WP5_APTIV_REQ005_1	OPE	ODD - Weather conditions	The system shall function in the presence of snow	Specifying weather conditions	APTIV_REQ008_1,APTIV_REQ009_1 shall be satisfied	M		APTIV	EXP6	APTIV demo vehicle	NA			
69	WP5_APTIV_REQ006_1	OPE	ODD - Illumination	The system shall function at day and night	Specifying lighting conditions	APTIV_REQ008_1,APTIV_REQ009_1 shall be satisfied	M		APTIV	EXP6	APTIV demo vehicle	NA			
70	WP5_APTIV_REQ007_1	OPE	ODD - Ego Vehicle	The system shall be enabled in a speed range of 30 to 130 km/h	Specifying ego vehicle speed	APTIV_REQ008_1,APTIV_REQ009_1 shall be satisfied	M		APTIV	EXP6	APTIV demo vehicle	NA			
71	WP3_APTIV_REQ008_1	PER	Small object detection	The system shall be capable of detecting small objects ahead of the vehicle with a minimum dimension of 10cm (h) x 10cm (w) in the ego lane at a minimum range required for a safe reaction (depending on the speed)	Specifying the minimum size of object that requires a reaction from the system	1. Number of false positives or negatives 2. TTC to object at the time of low and high-confidence detections 3. Accuracy of position and dimensions 4. Processing delay for detecting the object	H		APTIV	EXP6	APTIV demo vehicle	APTIV_REQ002_1			
72	WP3_APTIV_REQ009_1	PER	Object classification	The system shall classify the detected object as overdriveable or non-overdrivable	Necessary input for decision making on braking behaviour	1. Number of false classifications 2. TTC to object at the time of classification 3. Processing delay for classification	H		APTIV	EXP6	APTIV demo vehicle	APTIV_REQ002_1, APTIV_REQ008_1			

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73	WP3_APTIV_REQ010_1	PER	Object classification	The system shall consider an object as overdriveable if it can be driven over without: 1) destabilizing the vehicle 2) causing any form of damage to the vehicle or 3) causing any form of injury to the driver or passengers	Definition of an overdriveable object	NA	H		APTIV	EXP6	APTIV demo vehicle	APTIV_REQ002_1			
74	WP3_APTIV_REQ011_1	OPE	ODD detection	The system shall detect if it is outside its ODD	Required for safe behaviour outside of ODD	Percentage of mis-classifications, Time taken to detect outside ODD conditions	M		APTIV	EXP6	APTIV demo vehicle	APTIV_REQ001_1, APTIV_REQ002_1, APTIV_REQ003_1, APTIV_REQ004_1, APTIV_REQ005_1, APTIV_REQ006_1, APTIV_REQ007_1			
75	WP4_APTIV_REQ012_1	DM	ODD detection	The system shall be outside ODD if an object is detected but not classified when collision is imminent: Time to collision (TTC) < 3,1 sec	Necessary input for enabling/disabling the system	NA	M		APTIV	EXP6	APTIV demo vehicle	APTIV_REQ008_1, APTIV_REQ009_1, APTIV_REQ011_1			
76	WP4_APTIV_REQ013_1	DM	Outside ODD behaviour	The system shall issue a take over request if it detects outside ODD condition	The system considers driver as a fallback	NA	M		APTIV	EXP6	APTIV demo vehicle	APTIV_REQ011_1, APTIV_REQ012_1			
77	WP4_APTIV_REQ014_1	DM, ACT	Outside ODD behaviour	The system shall have a steady braking and stop in the ego lane when there is no response to the take over request	System behaviour outside ODD and no response to take over request	NA	L		APTIV	EXP6	APTIV demo vehicle	APTIV_REQ002_1, APTIV_REQ013_1			
78	WP4_APTIV_REQ015_1	DM, ACT	Initial behaviour	The system shall decelerate with a maximum absolute deceleration of 3m/s2 when an object is detected in the ego lane and TTC <= 6,1 sec and TTC > 3,1 sec	To avoid high levels of unintended braking	NA	H		APTIV	EXP6	APTIV demo vehicle	APTIV_REQ002_1, APTIV_REQ008_1, APTIV_REQ009_1			
79	WP4_APTIV_REQ016_1	DM, ACT	Behaviour for Overdriveable object	The system shall adapt its speed to safely drive over an overdriveable object such that the motion profile of the vehicle stays within comfortable limits for the passengers	Behaviour when object is overdriveable	Motion profile of the object while driving over the object	H		APTIV	EXP6	APTIV demo vehicle	APTIV_REQ002_1, APTIV_REQ008_1, APTIV_REQ009_1			

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80	WP4_APTIV_REQ017_1	DM, ACT	Behaviour for non-overdriveable object	The system shall decelerate with a maximum absolute deceleration of 7m/s2 to avoid a collision with a non-overdriveable object when TTC is <= 3,1sec	Braking limits for collision avoidance/mitigation	1. Maximum deceleration required to come to a full stop. 2. Distance to obstacle after stop 3. Relative velocity with the object in case of collision	H		APTIV	EXP6	APTIV demo vehicle	APTIV_REQ002_1, APTIV_REQ008_1, APTIV_REQ009_1			
81	WP5_S4_REQ001_V1	OPE	ODD - zone	The system shall operate on minor roads	Operational setting of system	N/A	H		S4	EXP8	S4 Demo vehicle	NA	NA	NA	
82	WP5_S4_REQ002_V1	OPE	ODD - subject vehicle	The system shall operate at speeds 0...32km /h	Operational setting of system	N/A	H		S4	EXP8	S4 Demo vehicle	NA	NA	NA	
83	WP5_S4_REQ003_V1	OPE	ODD - weather conditions	The system shall operate in light rain	Weather capabilities	Other requirements can be satisfied this condition present	M		S4	EXP8	S4 Demo vehicle	NA	NA	NA	
84	WP5_S4_REQ004_V1	OPE	ODD - weather conditions	The system shall operate in light snowing	Weather capabilities	Other requirements can be satisfied this condition present	M		S4	EXP8	S4 Demo vehicle	NA	NA	NA	
85	WP5_S4_REQ005_V1	OPE	ODD - road surface conditions	The system shall operate in presense of snow or ice on the road surface	Weather capabilities	Other requirements can be satisfied this condition present	M		S4	EXP8	S4 Demo vehicle	NA	NA	NA	
86	WP3_S4_REQ006_V1	PER	Sensor Visibility estimation	The system shall provide estimate of LIDAR sensor effective visibility	Iinformation about visibility is needed to adap the system behavior (such as speed) to a safe level	Visibility estimate in meters. Verified against ground truth value.	H		S4	EXP8	S4 Demo vehicle	NA	NA	NA	T3.2
87	WP3_S4_REQ007_V1	PER	Sensor Visibility adaptation	The system shall adapt its behavior based on changes in sensor visibility	If visibility decreases system must reduce speed in order to be able to react in time.	The adaptation enables system to detect and react to objects in time. Test scenario verification.	H		S4	EXP8	S4 Demo vehicle	NA	NA	NA	T3.2
88	WP3_S4_REQ008_V1	PER	Sensor Obstruction estimation	The system shall provide estimate of amount of sensor obstruction	Undetected and mitigated partial sensor obstruction by snow or dirt can create blind spots for perception and reduce safety. It may also have effect to Lidar localization in low feature environment.	the percentage of data points affected by obstructions. Angles affected over decided treshold such as 50% obstruction (from top view of the vehicle) e.g. 34..37deg. Compared to ground truth values.	H		S4	EXP8	S4 Demo vehicle	NA	NA	NA	T3.5
89	WP3_S4_REQ009_V1	PER	Sensor Obstruction adaptation	The system shall adapt its behavior based on changes in sensor obstruction		The system reaches safe state if obstruction causes risk for operation.	H		S4	EXP8	S4 Demo vehicle	NA	NA	NA	T3.5

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90	WP3_S4_ REQ010_ V1	PER	Localization Sensing Monitoring	Localization Sensing Monitor module shall provide estimate of reliability of localization sensor data, based on measured visibility treshold parameter, Lidar effective visibility estimate and sensor obstruction	Monitor purpose is communicate positioning degradation level so that control modules may adapt vehicle behavior to operate safely.	Confidence measure of the LIDAR-based localization reliability in real-time. This measure is compared against ground truth data or other reliable localization methods.	M		S4	EXP8	S4 Demo vehicle	NA	NA	NA	
91	WP4_S4_ REQ011_ V1	DM	Plan plan around block	System shall plan a safe path around static obstacle	ADS should not stop operation because its preplanned path is blocked by e.g. parked vehicle or road work.	Planned paths are within the allowed driving area and have no collision to static objects	H		S4	EXP8	S4 Demo vehicle	NA	NA	NA	T4.1
92	WP4_S4_ REQ012_ V1	OPE	Path plan verification	dynamically planned path around obstacle should be verifiable by remote operator before execution	All trajectories should be verified before execution.	Visual representation of the planned trajectory represents correctly the path	M		S4	EXP8	S4 Demo vehicle	NA	NA	NA	T4.1
93	WP4_S4_ REQ013_ V1	DM	Out of ODD	The system shall detect out of ODD and situations that require remote operator assistance and notify the operator.	Unexpected situations or non-standard road conditions that may require human intervention and make appropriate decisions to ensure the safety of the vehicle and other road users.	Percentage of erroneous classifications. Delay to detect outside ODD conditions	H		S4	EXP8	S4 Demo vehicle	NA	NA	NA	T4.2
94	WP4_S4_ REQ014_ V1	DM	Fail safe operation	The system shall apply minimum risk control strategy in case of system malfunction or unexpected situations that cannot be handled by the system.	Safety requirements	Delay from detection to start minimum risk maneuver. Time to reach minimum risk state.	H		S4	EXP8	S4 Demo vehicle	NA	NA	NA	T4.3
95	WP3_HIT _REQ1_v0 1	PER	Object detection and tracking	Detect and Track objects with correct class labels assigned to tracked objects	Accurate class label and ID assigned to tracked object important for safe planning	Detect object up to 50m, processing time <50ms, accuracy 0.95	H	NA	HIT	EXP4 EXP5	HIT/CRF/TECH Vehicle	NA	NA	NA	
96	WP3_HIT _REQ2_v0 1	PER	Object detection and tracking - Vehicles	Detect and Track road vehicles such as cars, trucks, vans and bicycles.	The 3D position of vehicles should be displayed to enable safe path planning	Track objects up to 50m, processing time <30ms, accurate vehicle state estimation	H	NA	HIT	EXP4 EXP5	HIT/CRF/TECH Vehicle	NA	NA	NA	

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97	WP3_HIT_REQ3_v01	PER	Object detection and tracking - Pedestrians	Detect and Track pedestrians	Accurate class label and ID assigned to tracked object important for safe planning	Detect pedestrians up to 50m, processing time <50ms, accuracy 0.95	H	NA	HIT	EXP4 EXP5	HIT/CRF/TECH Vehicle	NA	NA	NA	
98	WP3_HIT_REQ4_v01	PER	Object detection and tracking - Road Works	Track road work cones + signs.	The 3D position of cones should be displayed to enable safe path planning	Track objects up to 50m, processing time <30ms, accurate vehicle state estimation	M	NA	HIT	EXP4	HIT/CRF/TECH Vehicle	NA	NA	NA	
99	WP3_HIT_REQ5_v01	PER	Drivable Road Detection	Provide 2D/3D information related to drivable road. Determine regions in 2D/3D space that correspond to drivable road.	Detecting drivable surface enables vehicle to safely plan path	pixel accuracy measure for both 2D and 3D	H	NA	HIT	EXP4 EXP5	HIT/CRF/TECH Vehicle	NA	NA	NA	
100	WP3_HIT_REQ6_v01	PER	Detect Lane Marking Information	Road lines detecting from 2D data	Important for safe planning and maintaining vehicle lane wise control	2D pixel accuracy measure	H	NA	HIT	EXP4 EXP5	HIT/CRF/TECH Vehicle	NA	NA	NA	
101	WP3_HIT_REQ7_v01	PER	Vehicle Localisation - GNSS	Accurately localise vehicle position using GNSS measurements	Accurate localisation important for HD Map information extraction	root mean square error (RMSE)< 0.5m	H	NA	HIT	EXP4 EXP5	HIT/CRF/TECH Vehicle	NA	NA	NA	
102	WP3_HIT_REQ8_v01	PER	Vehicle Localisation - LiDAR	Accurately localise vehicle position using LiDAR data and in case GNSS fails.	Accurate localisation important for HD Map information extraction. GNSS may fail in GNSS denied regions. To this end, it is important to have back up localisation system.	root mean square error (RMSE) < 0.5m	H	NA	HIT	EXP4	HIT/CRF/TECH Vehicle	NA	NA	NA	
103	WP3_HIT_REQ9_v01	PER	Object trajectory prediction	Predict tracked object tracjectories, of vehicles (cars, trucks, vans, etc) and pedestrians.	Important for enabling AV to anticiapte and adjust motion plan to other road users.	Accurate non-ego trajectory prediction up to 2-3seconds from current time, for all traffic participants less 50m from ego.	H	NA	HIT	EXP4 EXP5	HIT/CRF/TECH Vehicle	NA	NA	NA	
104	WP3_HIT_REQ10_v01	OPE???	Drivable Road Extraction (HD-MAP)	Provide 2D/3D information related to drivable road. Determine regions in 2D/3D space that correspond to drivable road.	Using Pose and HD-MAP to extract drivable surface enables vehicle to safely plan path	Performance dependant on global pose accuracy	H	NA	HIT	EXP4 EXP5	HIT/CRF/TECH Vehicle	NA	NA	NA	

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105	WP3_HIT_REQ11_v01	OPE???	Extract Lane Marking Information (HD-MAP)	Road lines detecting from 2D data	Using Pose and HD-MAP for extracting rad lines. Important for safe planning and maintaining vehicle lane wise control	Performance dependant on global pose accuracy	H	NA	HIT	EXP4 EXP5	HIT/CRF/TECH Vehicle	NA	NA	NA	
106	WP3_WMG_REQ01_v01	OPE	Speed range	The self-assessment of perception including speed limit signs shall operate at speeds 10 - 40 km/h	A series of speed limit signs with decreasing speed values indicate that the EGO vehicle approaches roadworks.	N/A	H		WMG	EXP4	WMG Demo vehicle	N/A	N/A	N/A	T3.5
107	WP3_WMG_REQ02_v01	OPE	Weather and lighting conditions	The self assessment of perception including speed limit signs shall operate at good weather and lighting conditions.	See above	N/A	H		WMG	EXP4	WMG Demo vehicle	N/A	N/A	N/A	T3.5
108	WP3_WMG_REQ03_v01	PER	Perception self-assessment for speed limit signs detection	The system shall issue a warning when the detection of speed limit signs fail.	Speed limit signs might not be always detected due to their small size even under good weather and lighting conditions. Therefore a self-assessment mechanism of the perception is required to mitigate the risk of missed detections.	Given that the detection of traffic signs fails, the system must issue a warning within a distance of 30 m from the traffic sign and with probability larger than x%.	H		WMG	EXP4	WMG Demo vehicle	N/A	N/A	N/A	T3.5
109	WP3_WMG_REQ04_v01	OPE	Speed range	The integrity monitoring mechanism of the distance estimation to the front vehicle shall operate at speeds 60 - 100 km/h along a motorway.	Under adverse weather or lighting conditions, the camera- or lidar-based relative localisation to the front vehicle along a motorway can degrade.	N/A	H		WMG	EXP7	WMG Demo vehicle	N/A	N/A	N/A	T3.5
110	WP3_WMG_REQ05_v01	OPE	Weather conditions	The integrity monitoring mechanism of the distance estimation to the front vehicle shall operate under adverse weather or lighting conditions along a motorway.	See above	N/A	H		WMG	EXP7	WMG Demo vehicle	N/A	N/A	N/A	T3.5

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111	WP3_WMG_REQ06_v01	PER	Integrity monitoring of the distance estimation to the leading vehicle in motorway chauffeur	The system shall issue a warning when the distance estimation to the leading vehicle in motorway chauffeur fails.	See above	Given that the error in distance estimation to the front vhicle in motorway chauffeur exceeds x% of the actual distance, the system shall issue a warning with probability larger than y%.	H		WMG	EXP7	WMG Demo vehicle	N/A	N/A	N/A	T3.5
112	WP3_WMG_REQ07_v01	OPE	Speed range	The integrity monitoring mechanism for GNSS-based localisation for urban chauffeur shall operate at speeds up to 40 km/h	In urban chauffeur GNSS-based localisation can fail, e.g., due to multipath propagation, hence, an integrity monitoring mechanism is needed to mitigate the risks	N/A	H		WMG	EXP7	WMG Demo vehicle	N/A	N/A	N/A	T3.5
113	WP3_WMG_REQ08_v01	PER	Integrity monitoring of GNSS-based localisation in urban chauffeur	The system shall issue a warning when the GNSS-based localisation fails.	See above	Given that the GNSS-based localisation error in urban chauffeur exceeds x meters, the system shall issue a warning with probabliity larger than y%	H		WMG	EXP7	WMG Demo vehicle	N/A	N/A	N/A	T3.5
114	WP3_ICCS_REQ01_v01	PER	V2X messages reception from multiple observers in the vicinity of the ego-vehicle	The system must be able to receive V2X messages	The vehicle's decision making cannot ensure safety without receiving V2X information	Reception of V2X messages [QUALIT.]	H	NA	ICCS	EXP2	Carla simulator	NA	NA	NA	Focus is on other vehciles' status and object-level percpetion data (similar to informaiton contained in ETSI CAM/CPM). Carla does not support simulated V2X messaging per se. Proper assumptions and implementation should ensure the soundness of the simulation. Task T3.4
115	WP3_ICCS_REQ02_v01	PER	V2X data from multiple sources processing, fusion and integration	The system must be able to process and integrate the received V2X information	The vehicle's decision making cannot ensure safety without the processing and integration of V2X information	Processing/integration of V2X information [QUALIT.]	H	NA	ICCS	EXP2	External module integrated with CARLA or Carla simulator	WP3_ICCS_REQ01_v01	NA	NA	Focus is on other vehciles' status and object-level percpetion data (similar to informaiton contained in ETSI CAM/CPM). Carla does not support simulated V2X messaging per se. Proper assumptions and implementation should ensure the soundness of the simulation. The proposed module can be implemented outside CARLA and bridged with CARLA via ROS bridge or other solution. Task T3.4.

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	ID	Cat.	Name	Description	Rationale	Metrics	Relevance	Status	Owner	Experiments	Implementation	Dependencies	Conflicts	Review	Comments / Notes
116	WP3_ICCS_REQ03_v01	PER	V2X data latency	The system must be able to receive, process and integrate V2X information in a timely manner	The vehicle's decision making cannot ensure safety without low latency.	Receive, process and integrate V2X information in cycles equal or less than 100ms [QUANTIT.]	H	NA	ICCS	EXP2	Carla simulator	WP3_ICCS_REQ01_v01 & WP3_ICCS_REQ02_v01	NA	NA	Carla does not support simulated V2X messaging per se. Proper assumptions and implementation should ensure the soundness of the simulation. Task T3.5
117	WP3_ICCS_REQ04_v01	PER	V2X fused data reliability	The system must be able to trust information fused from V2X from independendt sources	The vehicle's decision making cannot ensure safety with unreliable information	Reliability of 85% or higher [QUANTIT.]	H	NA	ICCS	EXP2	External module integrated with CARLA or Carla simulator	WP3_ICCS_REQ01_v01 & WP3_ICCS_REQ02_v01	NA	NA	Carla does not support simulated V2X messaging per se. Proper assumptions and implementation should ensure the soundness of the simulation. Task T3.5
118	WP4_ICCS_REQ05_v01	PER	Behavior prediction of other vehicles accuracy	The system must be able to predict the behavior of other vehicles by classifying maneuvers into prefefined classes (e.g. lane change to the right, lane change to the left, cut-in from the left), with certain minimum accuracy	DM cannot ensure safety with low accuracy	Accuracy of 95% or higher [QUANTIT.]	H	NA	ICCS	EXP7	Carla simulator	NA	NA	NA	An investigation regarding the feasibility of accurate deterministic trajectory predictions is ongoing. Task T4.2
119	WP4_ICCS_REQ06_v01	PER	Behavior prediction of other vehicles reliability	The system must be able to predict the behavior of other vehicles, by classifying maneuvers into prefefined classes (e.g. lane change to the right, lane change to the left, cut-in from the left), with a certain probabilistic certainty.	DM cannot ensure safety based on predictions with low probabilistic certainty.	Probabilistic certainty of 80% or higher [QUANTIT.]	H	NA	ICCS	EXP7	Carla simulator	NA	NA	NA	A probabilistic prediction should be considered reliable only if the corresponding probability is very high (indicating a probable event) or very low (indicating an improbable event). Task T4.2
120	WP4_ICCS_REQ07_v01	PER	Behaviour prediction of other vehicles robust under object-level uncertainty due to bad weather conditions	The system must be able to maintain prediction accuracy and reliability under challenging weather conditions	DM needs to remain robust under challenging weather conditions that udnermine object-level perception	Drop of accuracy and reliability under challenging weather conditions not higher than 5%	H	NA	ICCS	EXP7	External module integrated with CARLA or Carla simulator	WP4_ICCS_REQ09_v01	NA	NA	Since the perception layer is abstracted the input for the experiment, i.e. tracked objects' trajectories, should be artificially tweaked in order to mimic bad weather effects.
121	WP4_ICCS_REQ08_v01	GEN	Behavior prediction of other vehicles: input scenarios	The simulation environment must provide scenario data involving tracked objects trajectories as inputs for the SuT	For this module to be tested independently, perception layer outputs should be abstracted.	NA	H	NA	ICCS	EXP7	External module integrated with CARLA or Carla simulator	NA	NA	NA	TBD Other vehicles' behaviour data generated in simulation
122	WP4_ICCS_REQ09_v01	OPE	Behavior prediction of other vehicles: challenging OD	The simulation environment must provide scenario data involving challenging weather conditions like rain or fog	Robustness of the algorithm under adverse weather is a basic objective of the module in this experiment	NA	H	NA	ICCS	EXP7	External module integrated with CARLA or Carla simulator	NA	NA	NA	CARLA provides specific configurations for bad weather.

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	ID	**Cat.**	**Name**	**Description**	**Rationale**	**Metrics**	**Relevance**	**Status**	**Owner**	**Experiments**	**Implementation**	**Dependencies**	**Conflicts**	**Review**	**Comments / Notes**
123	WP5_TUD_REQ001_1	OPE	ODD - Traffic	The system shall function in the urban environment	Driving area and traffic situation for the system		H	0	TUD	EXP1	TUD demo vehicle				
124	WP5_TUD_REQ002_1	OPE	ODD - Weather conditions	The system shall function in the presence of light rain and fog	Specifying weather conditions		M	0	TUD	EXP1	TUD demo vehicle				
125	WP5_TUD_REQ003_1	OPE	ODD - Weather conditions	The system shall function in the presence of light snowfall	Specifying weather conditions		M	0	TUD	EXP1	TUD demo vehicle				
126	WP5_TUD_REQ004_1	OPE	ODD - Illumination	The system shall function at day and night	Specifying lighting conditions		H	0	TUD	EXP1	TUD demo vehicle				
127	WP5_TUD_REQ005_1	OPE	ODD - Ego Vehicle	The system shall be enabled in a speed range of 5 to 30 km/h	Specifying ego vehicle speed		H	0	TUD	EXP1	TUD demo vehicle				
128	WP3_TUD_REQ006_1	PER	Obstacle localization	The system shall be capable of detecting / localizing obstacles on the road ahead of the vehicle.	Necessary input for decision making for obtaining driveable area and for avoiding collisions.	Obstacles are defined as objects that have a width >= 20 cm and a height >= 20 cm above the road surface. Lateral localization tolerance < 4°or 0.3m, whichever larger (corresponds to ± 1.4 m at 20 m, center). Longitudinal tolerance < 4% of distance or 0.3m, whichever larger (corresponds to ± 0.8 m at 20 m, center). With these tolerances, at least 90%, 95%, 99% and 99,9% of the obstacles are to be correctly detected within 20-40m, 10-20m, 5-10m and 1-5m distance ranges, respectively, within the driving corridor, within	H	0	TUD	EXP1	TUD demo vehicle				

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	ID	Cat.	Name	Description	Rationale	Metrics	Relevance	Status	Owner	Experiments	Implementation	Dependencies	Conflicts	Review	Comments / Notes
129	WP3_TUD_REQ007_1	PER	Obstacle velocity estimation	The system shall be capable of estimating velocities of moving obstacles on the road ahead of the vehicle.	Necessary input for decision making for obtaining driveable area and for avoiding collisions.	Obstacles are defined as objects that have a width >= 20 cm and a height >= 20 cm above the road surface. Lateral velocity tolerance < 4°/s or 0.4 m/s if latter larger (corresponds to ± 1.4 m/s at 20 m, center). Longitudinal velocity tolerance < 8% or 0.6 m/s if latter larger (corresponds to ± 1.6 m/s at 20 m, center). With these tolerances, at least 90%, 95%, 99% and 99,9% of the obstacles are to be correctly determined within 20-40m, 10-20m, 5-10m and 1-5m distance ranges, respectively, within the driving corridor, within a latency of 300 ms.	M	0	TUD	EXP1	TUD demo vehicle	WP3_TUD_REQ006_1			
130	WP3_TUD_REQ008_1	PER	Object classification	The system shall classify obstacles which are pedestrians, riders (e.g. cyclists) and cars as such.	Definition of an important set of road users with relevance for motion prediction and decision making.	Classification accuracy for the pedestrian+riders class combined and for the car class shall each be >95% (i.e. TP+TN / TP+FP+TN+FN) within a latency of 300 ms.	M	0	TUD	EXP1	TUD demo vehicle	WP3_TUD_REQ006_1, WP3_TUD_REQ007_1,			
131	WP3_TUD_REQ009_1	PER	Self-localization	The system shall self-localize w.r.t. a global map.	Required for safe behaviour within ODD	Lateral self-localization error max. 0.3 m. Longitudinal localization error max 0.5 m. These error bounds are to be achieved in 99% of time.	M		TUD	EXP1					
132	WP3_TUD_REQ010_1	OPE	ODD detection	The system shall detect if it is outside its ODD	Required for safe behaviour outside of ODD	Percentage of mis-classifications, Time taken to detect outside ODD conditions	M	0	TUD	EXP1	TUD demo vehicle				
133	WP4_TUD_REQ011_1	DM, ACT	Driving behaviour w.r.t. road border	The ego-vehicle will not drive too closely to the road border	Required for safe behaviour within ODD	The ego-vehicle will not come closer than 0.3m to the road border in 99.9% of time.	H	0	TUD	EXP1	CARLA simulator, TUD demo vehicle	WP3_TUD_REQ009_1			

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134	WP4_TUD_REQ012_1	DM, ACT	Driving behaviour w.r.t. obstacles and VRUs	The ego-vehicle will not drive too closely to obstacles; the minimum distance will depend on whether obstacles are stationary or dynamic, and whether classified as VRU (pedestrians, riders) or not.	Required for safe behaviour within ODD	The ego-vehicle will not come closer than 0.75 m to stationary obstacles which are not VRUs (pedestrian, riders). The ego-vehicle will not come closer than 1.5 m and 1.0 m to obstacles that are dynamic or which are VRUs, for ego-speeds of 10-30 km/h and 0-10 km/h, respectively.	H	0	TUD	EXP1	CARLA simulator, TUD demo vehicle	WP3_TUD_REQ006_1, WP3_TUD_REQ007_1, WP3_TUD_REQ008_1,			
135	WP4_TUD_REQ013_1	DM, ACT	Driving behaviour overall	The driving style of the ego-vehicle will maximize comfort and time efficiency, while safety is strictly maintained	Required for user acceptance	Limits on maximum acceleration/deceleration and steering rate.	H	0	TUD	EXP1	CARLA simulator, TUD demo vehicle	WP4_TUD_REQ011_1, WP4_TUD_REQ012_1			