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/).

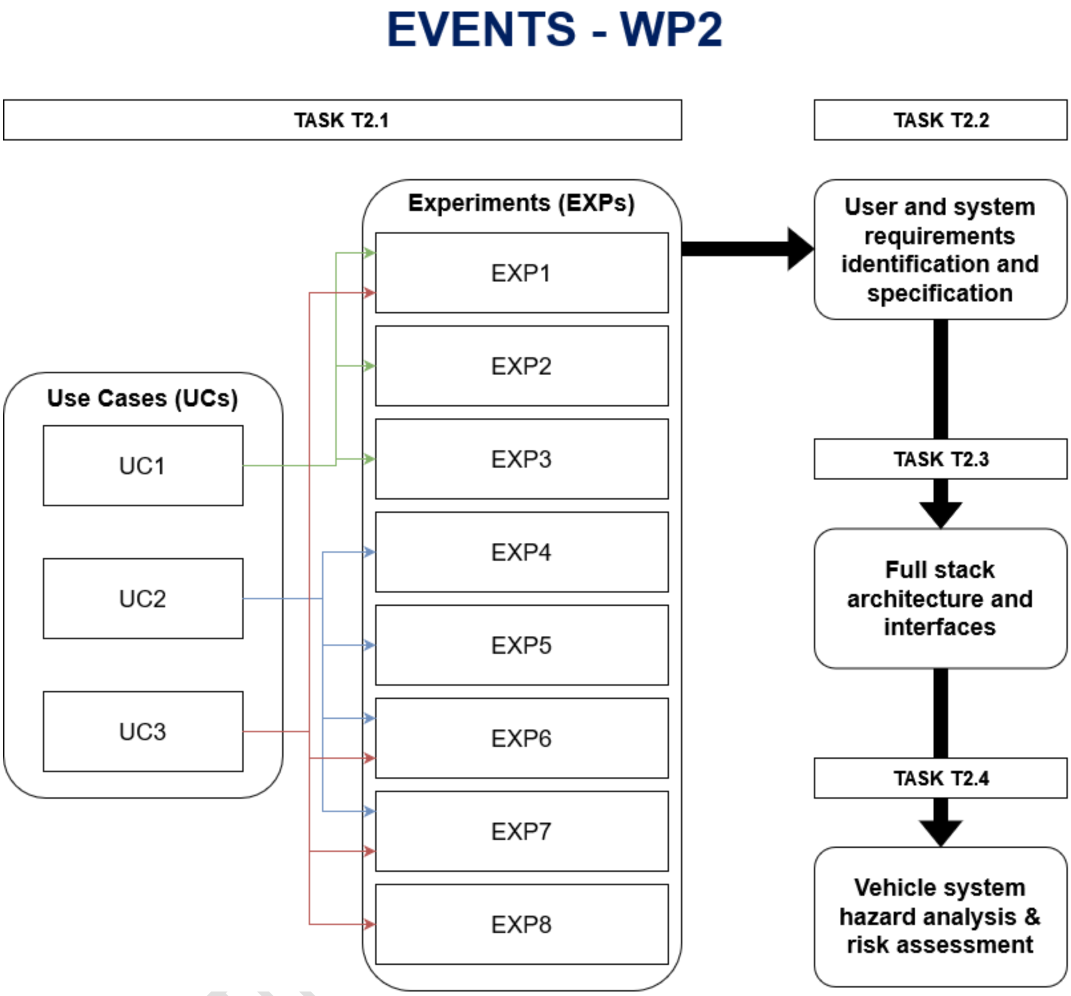


Figure 1: EVENTS WP2 structure

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. PERCIV 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.

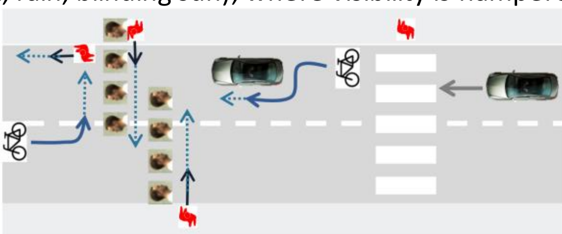
Based on the abovementioned described UCs, in the next Section, we illustrate the experiments carried out in the EVENTS project.

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.

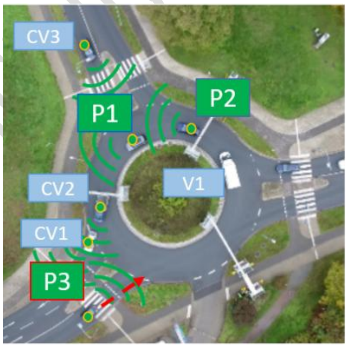
3.1 EXP1: Interaction with VRUs in complex urban environment

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

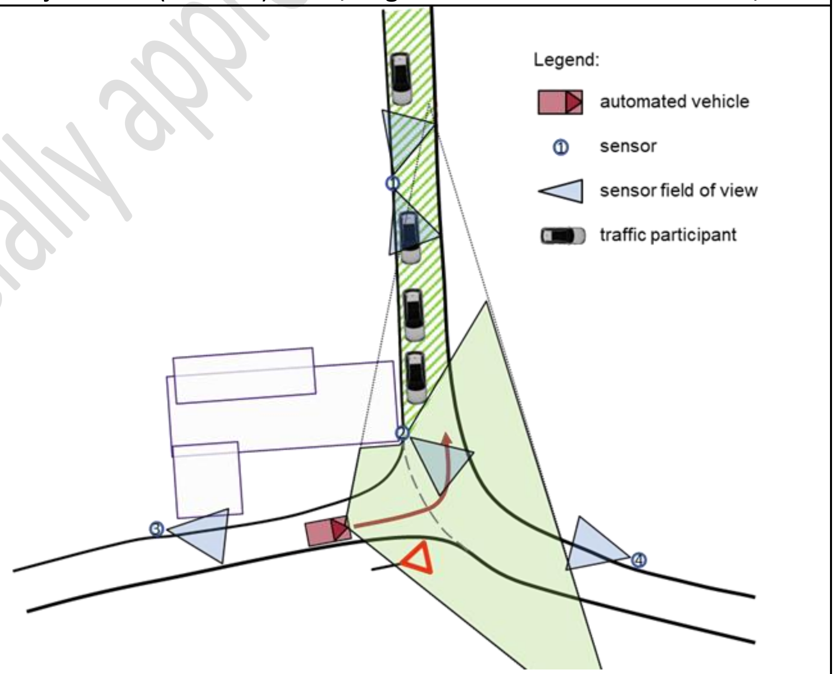
Figure 3: EXP2 example

<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.

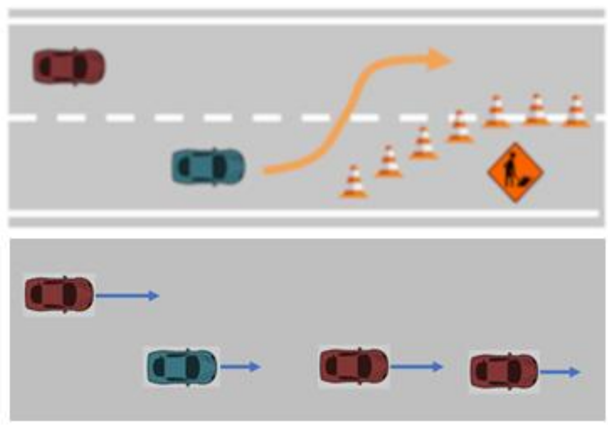
3.3 EXP3: Self-assessment and reliability of perception data with complementary V2X data in complex urban environments

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)	---

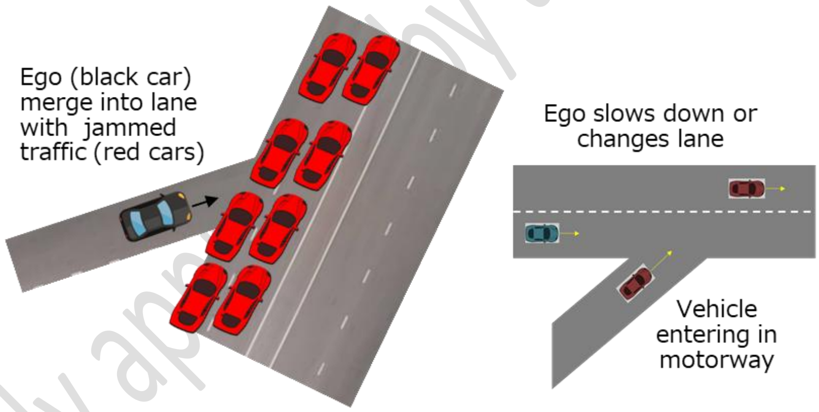
3.4 EXP4: Decision making for motion planning when faced with roadworks, unmarked lanes and narrow roads with assistance from perception self-assessment

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).

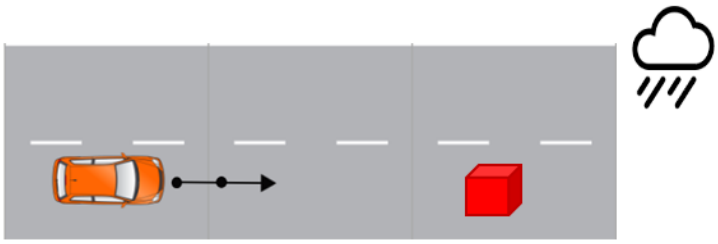
Data	
Availability	TBD
Format	VECTOR tools (so, .MAT or .CSV, but others can be defined).
Openness	Usable for partners of the team; TBD for others
Hints for Evaluation	
KPIs	Some examples: • Time spent in critical regions (defined by TTC). • Number of interventions from human driver / Number of function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

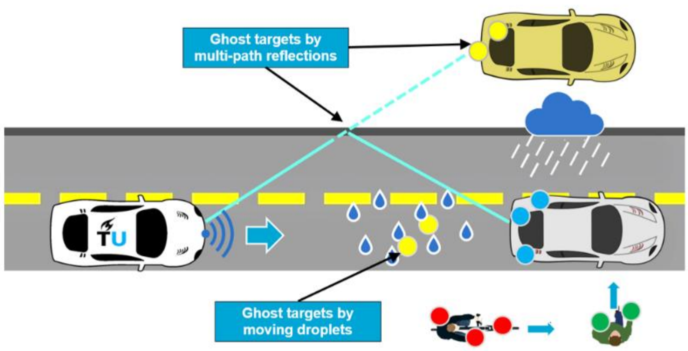
3.7 EXP7: Localization/perception self-assessment for advanced ACC and other vehicles' behaviour prediction under adverse weather or adverse road conditions

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: Emergency evasion manoeuvre under adverse weather conditions including perception self-assessment

General Info	
Experiment Title	Emergency evasion manoeuvre under adverse weather conditions including perception self-assessment
Leading Partner	PERCIV
Partners Involved	TUD
Reference Use Case	UC3
Associated Tasks	T3.2, T3.5, T4.1, T4.2 & T4.3
AD SuT/ Target Operational Domain and Functional Scenario(s)	
Short Verbal Description	End to end (from perception to control) experiment to perform collision avoidance manoeuvre (e.g. with leading vehicle, cyclist, etc.) in poor weather conditions on a potentially slippery road surface. (Simulation or controlled conditions can be used to produce the conditions).
Detailed Graphical Description	Rain can influence the ego-vehicle in multiple ways. First, it makes perception harder as rain droplets and water stirred up by the tires hamper most automotive sensors' performance. Second, a wet, slippery surface could lead to vehicle instability, especially at the edge of its friction limits. 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 control 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 the radar perception's coverage and detection quality with respect to the environment, e.g., accuracy of estimated locations and velocities are initially assumed, and determined statistically 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' interactions	PERCIV will develop the perception algorithms and TUD will integrate them in their vehicle for decision-making and control.

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 (rainy) 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	1. TUD: Toyota Prius 2013 (For control development and demo) 2. PERCIV: VW ID3 2023
Communication	Cellular data 4G
Sensors	Cameras, Radars, LIDAR, RTK GPS
Data	
Availability	Raw data, pre-processed data (segmented point clouds) and highly processed data: object detections of 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 depending on agreements with sensor providers.
Hints for Evaluation	
KPIs	• Localization and object detection performance in different weather conditions • Self-assessment performance in different weather conditions • Control performance in different weather conditions
Preliminary plan (if available)	1.TU Delft and Perciv AI together will artificially create rainy conditions on a test track/dedicated road to replicate the desired scenario in a safe way. 2.Perciv AI will collect multimodal datasets, including next generation 4D radar sensors, cameras, lidars, and GNSS systems using the artificially created and real rainy scenarios to train and tune their perception algorithms. 3.Perciv will use the collected data to develop novel, AI driven radar perception algorithms, which will filter the input in multiple ways (e.g. ghost vs real radar points) and output a list of objects and estimated ego-motion/odometry information based on the weather robust radar sensors, addressed in T3.2 and T3.5. These outputs will be an input to TUD's motion control module developed in T4.3 and T4.5. 4.Integrate a full stack pipeline into a TUD research vehicle, including the perception, the motion control, and their communication.

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	**PERCIV**: Perciv AI and TU Delft together will present a "full stack" solution, i.e. starting from perception and understanding the environment (Perciv AI), to vehicle control (TU Delft) in rainy / wet pavement conditions.

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: The operational domain of each experiment

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, requirements are gathered by each partner and concern each of the individual experiments, as those are defined in Section 3. These requirements are elicited by considering the specific details of each experiment, the role of each partner within said experiments, and the use case(s) (defined in Section 2) under which these experiments have been described.

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.

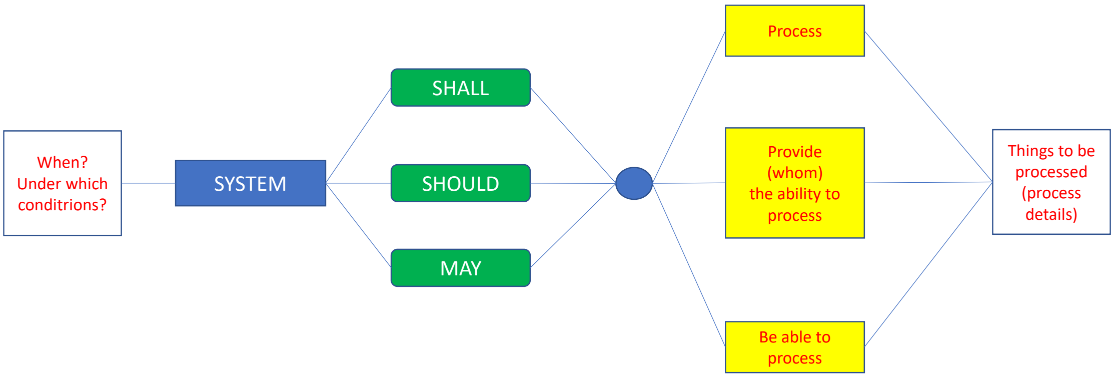


Figure 10: Requirements statement scheme

In the EVENTS project, for the requirements collection, an Excel-based table (shown fully in Annex 3) 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)

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

		• M = Medium (Important to have, degraded performances, if not) • 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 set of the requirements derived per experiment after concatenating requirements from each experiment module developer (see Annex X) is presented. As described in Section 4, system and user requirements have been elicited based on the purpose of each experiment and its high-level description as provided in the Experiments' tables (Section 3).

For the purposes of being easily readable and legible, only a subset of the attributes of the requirements (shown fully in Annex 3) are reported in the following tables. 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.

Technical Note: 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 with all their attributes, including the metrics for each requirement, can be found in Annex 3. It should be noted that several of the stated requirements (approximately 35 requirements) have explicitly defined metrics (KPIs) and for many others, the exact value/parameter to be satisfied will be defined either during the trial or will be given from the SOTIF analysis (task T5.3).

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_REQ 01_v01	GEN	Weather Conditions	The self-assessment system shall work under certain good weather conditions
WP3_UULM_REQ 02_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		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_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: Emergency evasion manoeuvre under adverse weather conditions including perception self-assessment

PERCIV & TUD (Demo Vehicle & Simulation)			
ID	**Type**	**Name**	**Description**
WP5_PERCIV_REQ001_V1	OPE	ODD - zone	The system shall operate on minor roads
WP5_PERCIV_REQ002_V1	OPE	ODD - subject vehicle	The system shall operate at speeds 0…32km /h
WP5_PERCIV_REQ003_V1	OPE	ODD - weather conditions	The system shall operate in light to heavy rain
WP5_PERCIV_REQ004_V1	OPE	ODD - road surface conditions	The system shall operate in presence of water on the road surface
WP3_PERCIV_REQ005_V1	PER	perception self-assessment	The system shall provide estimate of its current perception capabilities, i.e. self-assessment
WP3_Perciv_REQ006_V1	PER	Self-localization	The system shall self-localize w.r.t. a global map
WP3_PERCIV_REQ006_V1	PER	Point cloud Segmentation	The system shall segment the radar point cloud based on noise, movement, and class probabilities
WP3_PERCIV_REQ007_V1	PER	Obstacle localization	The system shall be capable of detecting/localizing obstacles on the road ahead of the vehicle based on radar.
WP4_TUD_REQ014_V1	DM, ACT	Path and follow plan around obstacle	System shall plan and follow a safe path around obstacles

Table 19: PERCIV's and TUD'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 130 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 and TUD, which participate in three and two experiments respectively. 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.

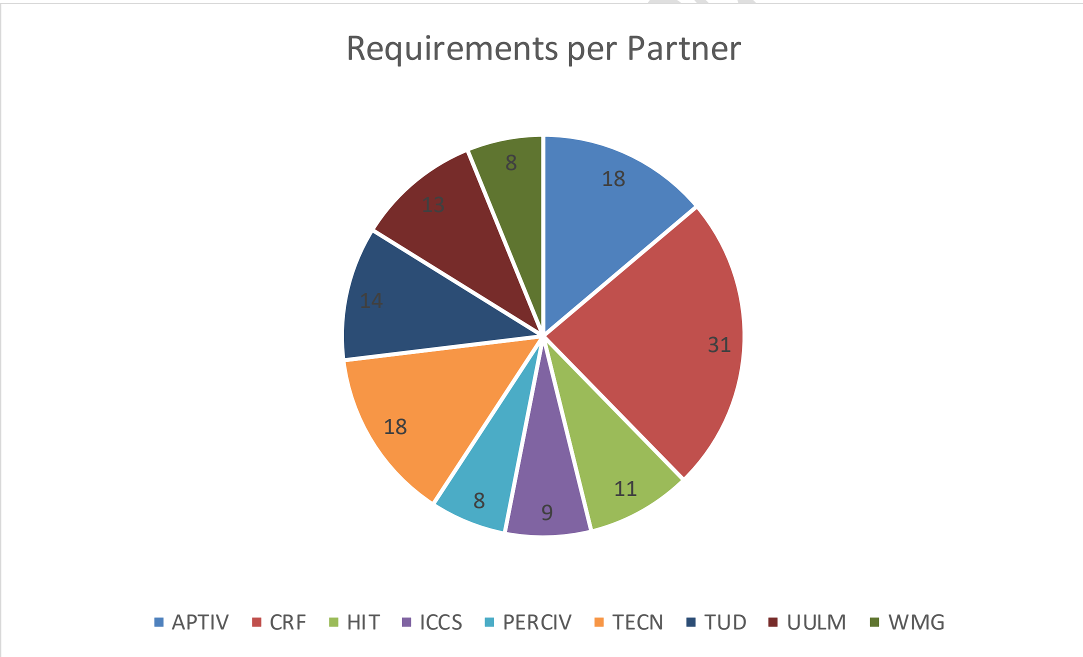


Figure 11: Number of requirements per partner

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

- General – GEN: 10,9%
- Decision Making – DM: 16,7%
- Perception – PER: 36,2%

- Operational – OPE: 27,5%
- Actuation – ACT: 8,7%

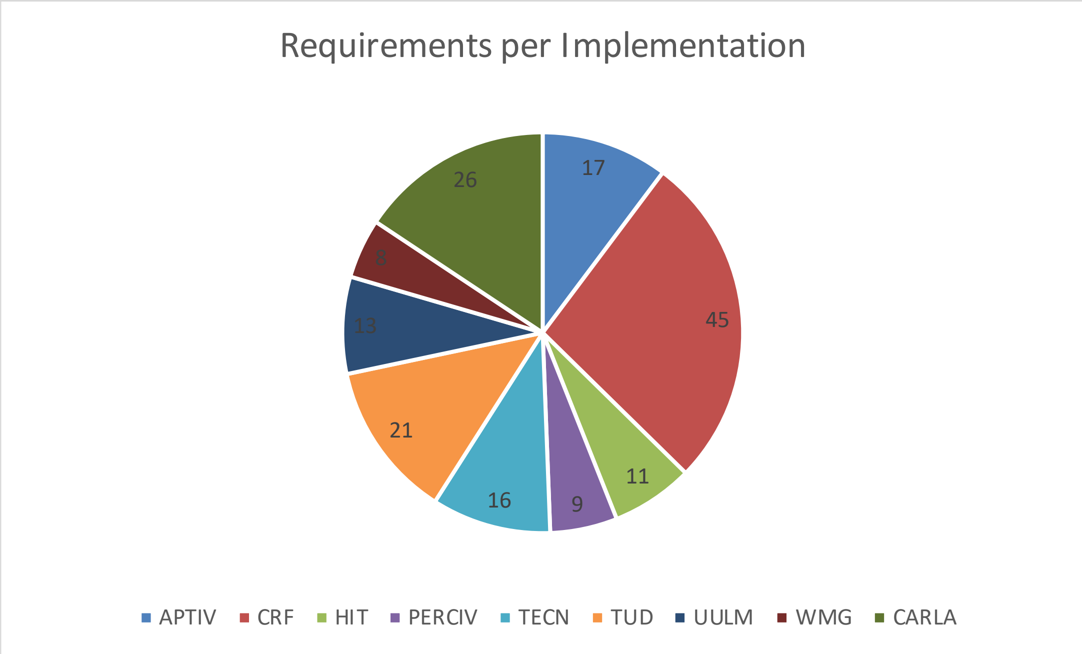


Figure 12: Number of requirements per implementation/demonstration

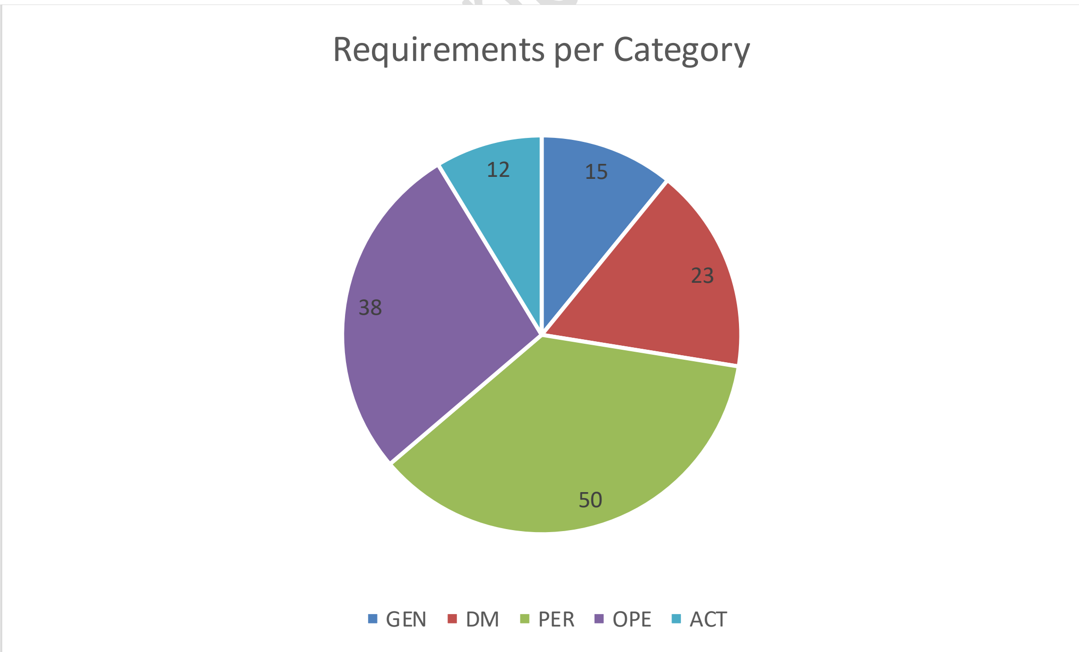


Figure 13: Requirements per type/category

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.

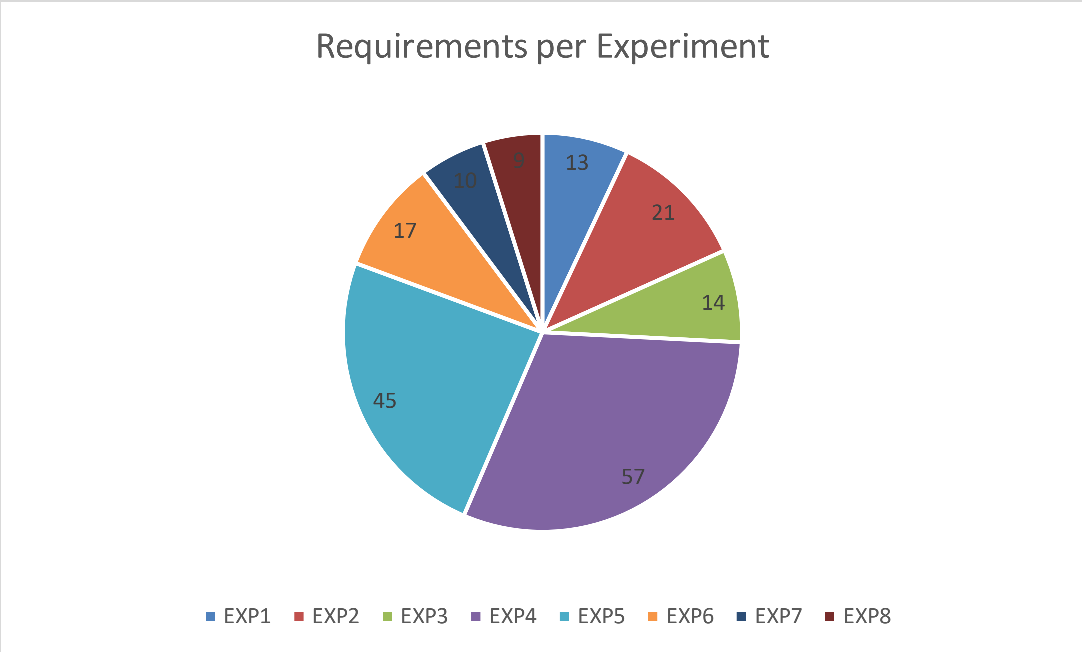


Figure 14: Requirements per experiment (EXP)

6.2 Summary of Requirements

In summary, a total number of 130 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, most of the requirements[2] 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.

[2] Not all of the requirements will have a KPI/baseline, since the purpose of some of them is to check whether a specific experiment stays within the defined ODD. These requirements are binary, i.e., True or False.

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., EXP2 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

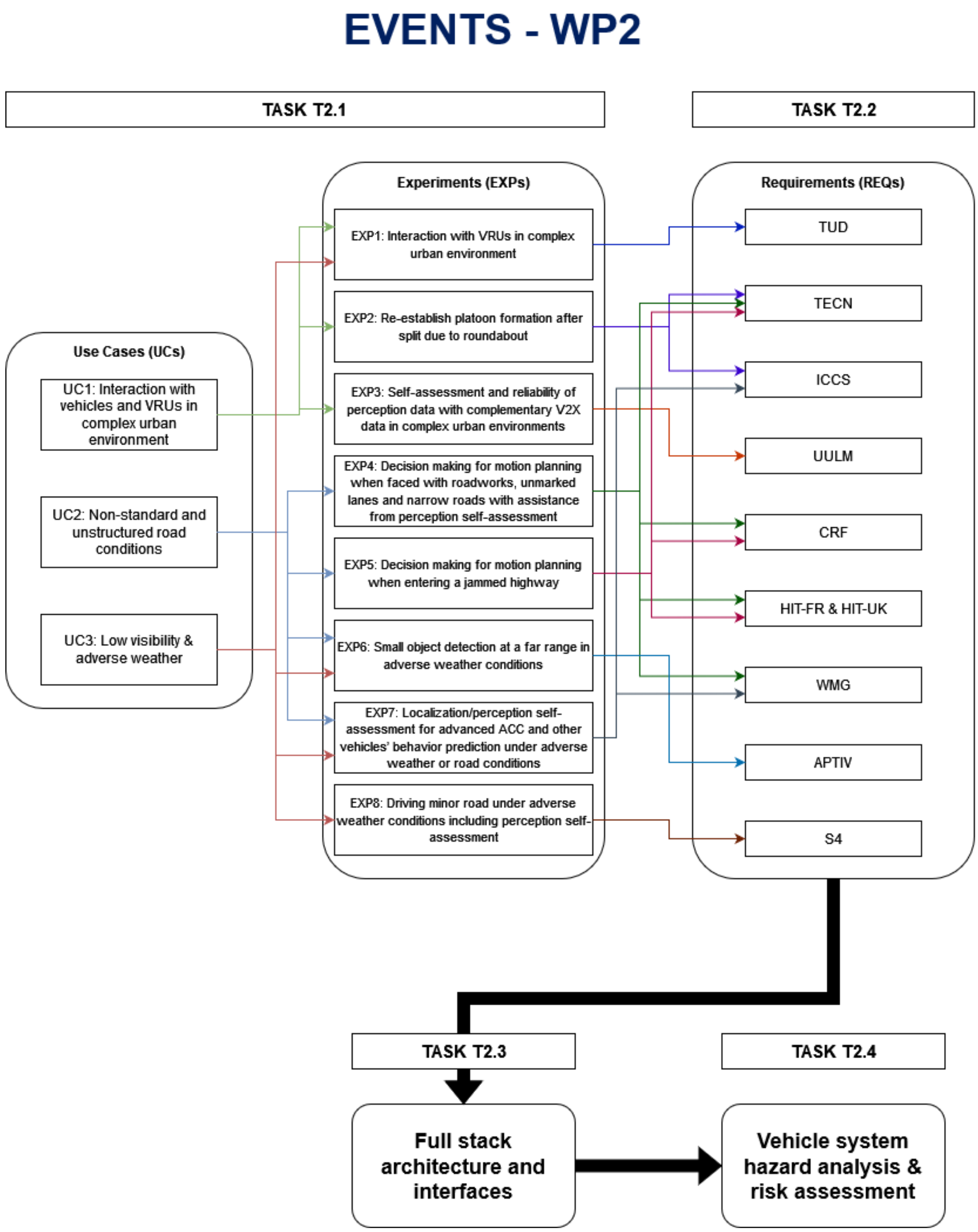


Figure 15: Detailed EVENTS WP2 structure

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.