ENSEMBLE

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ENSEMBLE

ENabling **S**af**E** **M**ulti-**B**rand p**L**atooning for **E**urope

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Revision history

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3.4	25/05/2020	Marika Hoedemaeker (TNO)	• Corrected missing reference on page 38	Final

FIGURES

TABLES

1. EXECUTIVE SUMMARY

1.1. Context and need of a multi brand platooning project

Context

Platooning technology has made significant advances in the last decade, but to achieve the next step towards deployment of truck platooning, an integral multi-brand approach is required. Aiming for Europe-wide deployment of platooning, 'multi-brand' solutions are paramount. It is the ambition of ENSEMBLE to realize pre-standards for interoperability between trucks, platoons and logistics solution providers, to speed up actual market pick-up of (sub)system development and implementation and to enable harmonization of legal frameworks in the member states.

Project scope

The main goal of the ENSEMBLE project is to pave the way for the adoption of multi-brand truck platooning in Europe to improve fuel economy, traffic safety and throughput. This will be demonstrated by driving up to seven differently branded trucks in one (or more) platoon(s) under real world traffic conditions across national borders. The project goals for each year are:

- Year 1: setting the specifications and developing a reference design with acceptance criteria.
- Year 2: implementing this reference design on the OEM's trucks as well as performing impact assessments with several criteria.
- Year 3: focus on testing the multi-brand platoons on test tracks and international public roads.

The technical results will be evaluated against the initial requirements. Also, the impact on fuel consumption, drivers and other road users will be established. In the end, all activities within the project aim to accelerate the deployment of multi-brand truck platooning in Europe.

Abstract of this Deliverable

The purpose of this deliverable is to describe testing procedures and definition in the ENSEMBLE project to validate the implemented function and to ensure interoperability between different brands.

Earlier testing phases such as software testing, integration testing or unitary testing are outside the scope of this document and are expected to be carried by OEMs on their own responsibility.

In this deliverable a methodology to assess complex platooning at IDIADA's test track and on Open Road is defined. In order to develop this methodology first is needed to define KPIs and consolidate the tests that will be carried out in the previous stages of the testing activities such as:

- Test in a controlled environment for the validation and performance evaluation of the platoon capabilities.
- Simulation tests initially validated for the platooning coordination capabilities.
- Demonstration tests on public roads to prove the feasibility of truck platoons in Europe.

In WP5, the different validation activities will be performed in the following tasks and deliverables:

- Task 5.1: brief description the testing activities and the methodology used to validate all project requirements (D5.1).
- Task 5.2: verify and validate the complex platooning implementations (D5.2).
- Task 5.3: validate the operational performance of the overall system on public roads and including license exemptions (D5.3/D5.4).
- Task 5.4: perform the technical evaluation of the platooning system developed in the project (D5.5).
- Task 5.5: perform a final demonstration of the platooning system (D5.6).

In deliverable D5.1 the first states of the test plan and the common methodology plan description are defined. The complete version will be submitted in deliverable D5.7.

2. INTRODUCTION

The overall objective of the task 5.1 Test and demonstration plan is to define a methodology to define a methodology to assess the implemented multi-brand solutions developed in the ENSEMBLE project, and to define complex test cases for multi-brand platoons and to select an appropriate route for open road testing. To achieve this objective, each ENSEMBLE project work package needs to identify requirements and KPI's that are used to define the test plan. The information that each work package has provided is described below:

- WP2 has defined the specifications of the whole multi-brand truck platooning concept to be implemented in 7 trucks from different OEMs and assessed within the testing carried out in WP5. The main activity consists in defining a common specification of the strategic, Tactical and Operational Layer and their interfaces. Also, the defined use cases and project requirements (V2X, Safety, etc) in this work package will be used as inputs to include inside the test plan and test case definition. There is a regular feedback between WP's to update the functional specifications due to newly acquired insights and experiences.

- WP3 is responsible for the development and implementation of the platooning technology in the trucks. One truck per OEM is instrumented with a brand-specific layered platooning automation system, which enables the truck to operate in a multi-brand platoon. The WP3 must provide a list of test cases that each OEM will implement and validate during in-house testing. It will be included inside the test plan and considered for multi-brand verification.

- WP4 is responsible of the impact assessment for multi-brand platooning on road infrastructure, environment, other road users and logistics. The WP4 has created a KPI's list to be verified and measured during open road testing and it will be used as inputs during the open road test definition; traffic flow, impact on fuel consumption and emissions, pavements, bridges and tunnels. This information is added inside the test plan definition.

A specific test matrix and test plan has been defined to align the interest of each WP. The WP needs are identified and explained in this deliverable. The Definition of test cases and the overall KPI's are essential for the development of the test protocol.

The complete list of defined KPIs that is being used for the test matrix description is explained in section 5.3.

A test matrix has been defined from the identified KPIs. The test matrix includes test-cases that will cover all of the project requirements and assess the project objectives. The next steps which are being executed and will be included in the final test plan to be finalised in the next deliverable D5.7, are the following:

- Defining of generic complex test cases definition, agreed with the consortium.
- Test cases allocation definition (Mono/Three/complex brand).
- Open road test definition including WP4 KPIs.
- Open road simulation environment definition.
- Final data management plan.
- Final demonstration detailed definition.

3. TESTING OBJECTIVES

In the testing phase of the project, the test object is handled as a black box. A detailed overview of the architecture of the complete vehicles or other single components and their architecture is not in the testing focus for this work package and is not explicitly handled or tested.

The process flow of the overall method is based on the V-cycle as it can be seen in Figure 1:

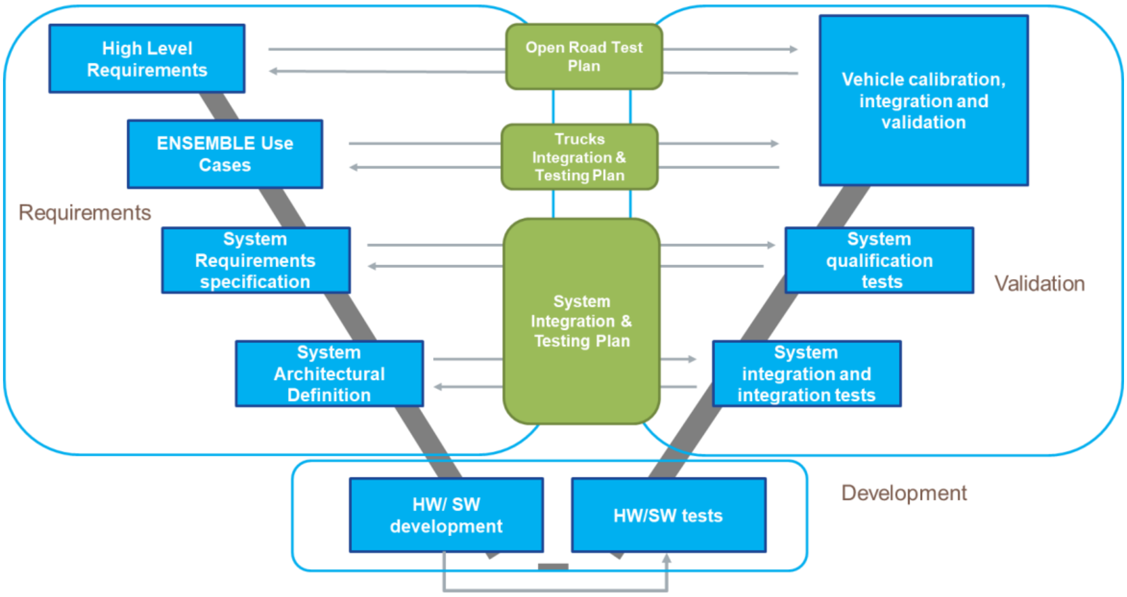

Figure 1: V-cycle testing Levels

The methodology defined for the verification and validation of the platooning function will be divided in three main levels:

- ***System Integration***: In this phase, both the developed platoon coordination and the individual platooning systems shall be verified. This task will be conducted in WP3.
- ***Trucks Integration:*** The vehicles developed will be tested at different levels:
    - In-house mono-brand platoons.
    - Three-brand platoons.
    - Multi-brand platoons.

- ***Open Road:*** In this phase, the global platooning system shall be tested on open roads. Key aspects of this evaluation phase will be multi-brand platooning performance, interaction with other road users and the impact on traffic and infrastructure and real-world emissions.

4. SYSTEM INTEGRATION & TEST PLAN

The main objective of this phase is to perform a verification and validation of the specification defined for the white label truck. ENSEMBLE deliverable D2.4 (Konstantinopoulou et al, 2019). This deliverable provides the definition of the requirements and specifications of the white-label multi-brand truck platooning concept to be implemented, tested and demonstrated with trucks of 7 different European OEMs.

The white-label truck concept takes into consideration Platooning as a support function (in D2.4 described as Platoon level A), which will form the basis of the intended public road demonstration at the end of the project. Deliverable D2.4 concentrates on the operational and tactical layer, but also identifies required interactions with the Strategic and Services Layers.

Figure 2 describes the different modules and layers of the platooning function.

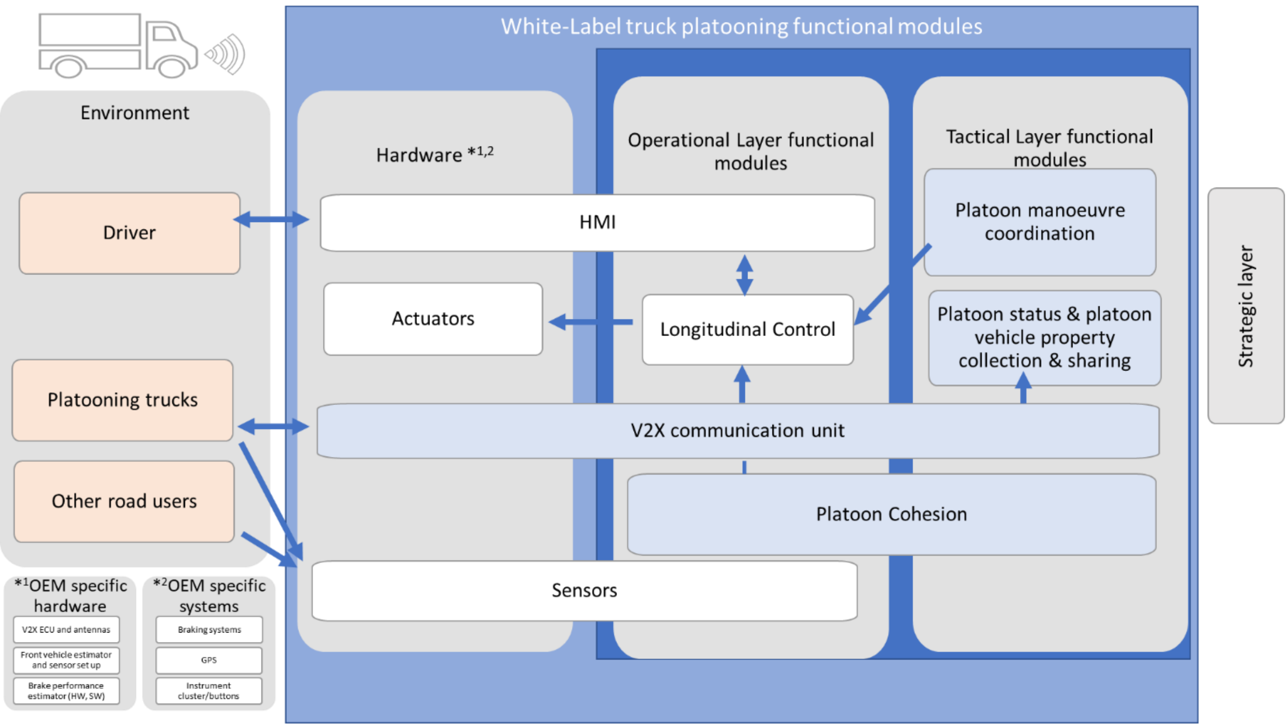

Figure 2: System Overview picture

The light blue boxes indicate the common functionality for which specifications have been made (Tactical and operational layer).

- V2X communication: this is the whole set of hardware and software to establish the communication required for platooning (the specifications are described in D2.8, Atanossow et al, 2019).
- Platooning information sharing: this is a module that collects and contains the relevant information (properties, status) of the platoon and the platooning vehicles that must be commonly shared in the platoon (specified in this deliverable).
- Platoon manoeuvre coordinator: this is a module that coordinates specific maneuver's that need a cooperative approach rather than an individual one (specified in this deliverable).
- Platoon cohesion mechanism: this is a module that contains the common tactical strategies to preserve the cohesion of a platoon, e.g. on hilly road, after a cut-in, etc. Platoon cohesion as a function is addressed both in the tactical layer and the operational layer. The tactical layer provides the required information, the operational layer uses this information to perform the platoon cohesion in longitudinal control. (specified in this deliverable).

For the white blocks in Figure 2 requirements have been formulated for the operational Layer which are OEM specific.

- HMI: this module provides the required logic for the interfacing to the driver. (specified in this deliverable).
- Sensors: this software module provides the host vehicle environmental perception and localization based on vehicle-mounted sensors
- Longitudinal control: this module contains the control algorithms for automatically executing vehicle acceleration and deceleration, e.g. to drive at a certain seed, to maintain a desired inter-vehicle gap or to perform emergency braking. (specified in this deliverable).

Related to the environment, communication modules need to be established with other road users, platooning trucks (V2V), infrastructure (V2I) and the driver (HMI) to provide the necessary information and interact with the platoon.

The parts that are more OEM specific are:

- V2X Antennas
- Front vehicle estimator and sensor set up
- Brake performance estimator (HW and SW)

Finally, these are the systems that probably need no direct change, but only a different (extra) interface:

- Braking system
- GPS
- Instrument cluster / Button

5. TRUCKS INTEGRATION & TEST PLAN

5.1. Test Plan Overview

The test plan of the ENSEMBLE project includes the overall activities of integration and testing at the vehicle level. Once each OEM has completed their testing activities at the system level, the testing at vehicle level will take place. These activities will be carried out in different sub-phases as indicated in Figure 3:

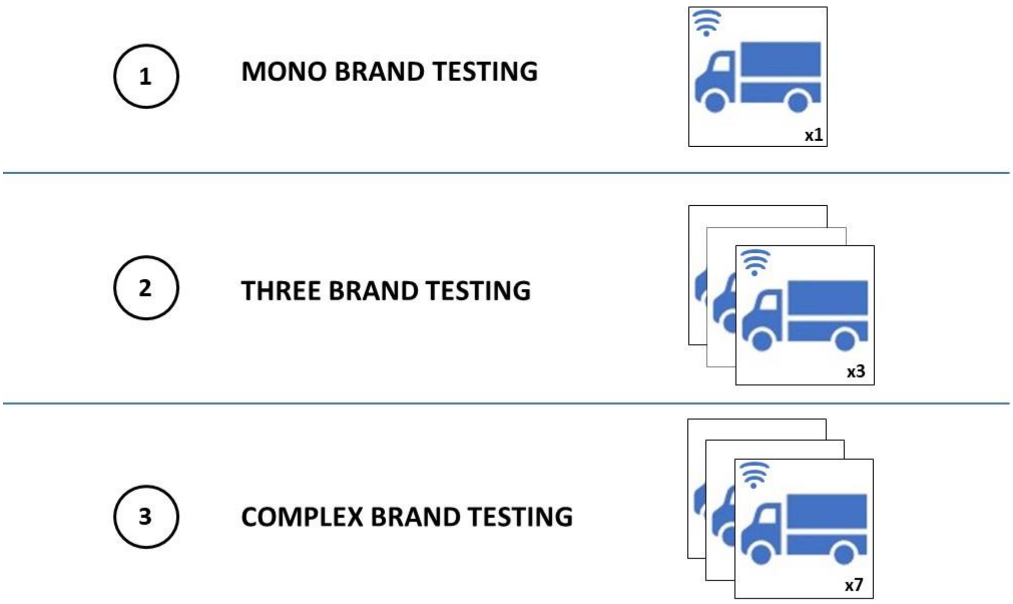

Figure 3: Test overview

Figure 3 shows the different testing phases. The 1st phase is the Mono-Brand testing that will take place at the OEM's laboratories and will be carried out around January - February 2020. The 2nd phase includes the three / four – brand testing and will take place between May – June of 2020. Lastly, the 3rd phase will include the multi-brand testing at IDIADA test tracks, followed by the open road testing in Catalonia (Spain) which will take place between August and September 2020.

5.2. Test objectives

The Platooning assessment methodology that is being developed in the ENSEMBLE project is based on the Key Performance Indicators (KPI's) which will be the baseline for the Test plan development.

There are three main goals at the ENSEMBLE project: improving the fuel economy, traffic safety, and throughput in multi-brand truck platooning.

In Table 1, the use cases defined in deliverable D2.2 (Vissers et al, 2018) are linked to the main objectives of the project. This table shows in which use cases the three main objectives of the project will be assessed.

Use Cases	Road Safety	Energy efficiency	Throughput
Platoon Joining	x		x
Engaging to platoon	x		x
Platooning	x	x	x
Disengage platoon	x		x

Table 1: Correlation with use cases and main objectives of Ensemble

To evaluate basic system functionality, some KPI's will be defined to be able to assess the platooning performance.

5.3. Key Performance Indicators Definition

In this section, for each objective several KPIs will be defined. These KPIs are generic and will be more specific when the test cases for multi-brand platooning are defined. Five KPIs defined for Road safety have been defined:

- **Road Safety:**
    - The Minimum Time gap between trucks
    - TTC and Deceleration Rate to Avoid a Crash (DRAC)
    - The Mean and maximum duration of the transfer of control between driver and vehicle
    - Number of instances where the driver must take manual control
    - Time to take over vehicle control when the system cannot provide support / handle the driving situation.

Linked to road safety is the platooning performance that will be assessed as well during the multi-brand testing and open road testing. Ten KPIs have been defined and are listed below:

- **Platooning Performance:**
    - Speed variation while traveling in steady-state platooning
    - Mean and maximum longitudinal acceleration and deceleration

- Number of emergency decelerations
- Maximum jerk (rate of change in acceleration, longitudinal)
- The mean and variance of the time gap to the vehicle in front
- Number of instances where the driver must take manual control
- Number of events when speed needs to be lowered due to other vehicles cutting-in
- Number of cut-ins while platooning
- Frequency of occurrence of TTC (time to collision) below defined safety margin
- The number of autonomous braking events (when there is a brake flag)

For energy efficiency, 4 KPIs have been defined and are listed below:

- **Energy Efficiency:**
  - Fuel consumption [l/km]
  - Fuel efficiency [l/ton-km]
  - Average speed [km/h]
  - Annual traffic CO2 emissions (tones/year) on a route or in a region

To assess Throughput the following list of KPIs has been defined as follows:

- **Throughput:**
  - Road capacity for a given road section
  - Median speed on a given road section
  - Number of vehicles per hour through a road section
  - Average travel time (minutes) per road/km
  - Total travel time and distance traveled per road section or route
  - Effective capacity

A summary of the defined test cases for the different testing phases can be found in Table 2. This table shows the general view of the testing. This table will be used for developing more complex scenarios for multi-brand testing while considering the work done in the other work packages. Also, it will help to see the use cases that do not have so many tests associated and need to be more represented.

Scenario	Use Case ID as defined in D2.2	Mono-brand	Three-brand	Multi-brand
Engaging to platoon	UC2.1	T1.1	T2.1, T2.2.3	
Platooning	UC3.1	T1.6	T2.17, T2.13, T2.17, T2.18, T2.19, T2.25, T2.26	T3.1.1, T3.1.2, T3.3, T3.4, T3.5, T3.6,

				T3.7, T3.8, T3.9, T3.10, T3.11, T3.3
	UC3.2.1		T2.1.5	
	UC3.2.2		T2.16, T2.10	
	UC3.3	T1.7	T2.14	
	UC3.4.1		T2.7, T2.21, T2.22	
	UC3.4.2	T1.51	T2.8	T3.2
	UC3.4.3	T1.5.2	T2.9.2	T3.2
	UC3.4.4	T.1.2, T.1.3		T2.2, T2.3, T2.11
Disengage platoon	UC3.5.1.1	T1.4.1	T2.6, T2.20	
	UC3.5.1.2	T1.4.2	T2.5	
	UC3.5.1.3	T1.4.3	T2.12, T2.4	
	UC3.5.2		T2.24	

Table 2: Test cases planned for the different testing phases of the project

The results in Table 2 will change during the following months since mono-brand, three-brand and multi-brand test cases being defined at this moment.

5.4. Testing Environments

5.4.1. Test Tracks

The multi-brand testing will be carried out at the IDIADA Proving Ground which is placed at 70 km south-west of Barcelona. Figure 4 shows an aerial view of IDIADA's proving ground.

Figure 4: Aerial view IDIADA's proving ground

The test track selected is the High-Speed Track (see Figure 5), it is an oval track of 7,5 km, with four lanes of 4 meters width, north and south straights of 2 km long and a maximum banking bend of 80% (38,66°) on the west and east curves. The travel direction is always clockwise, and the speed limit is 250 km/h in shared use.

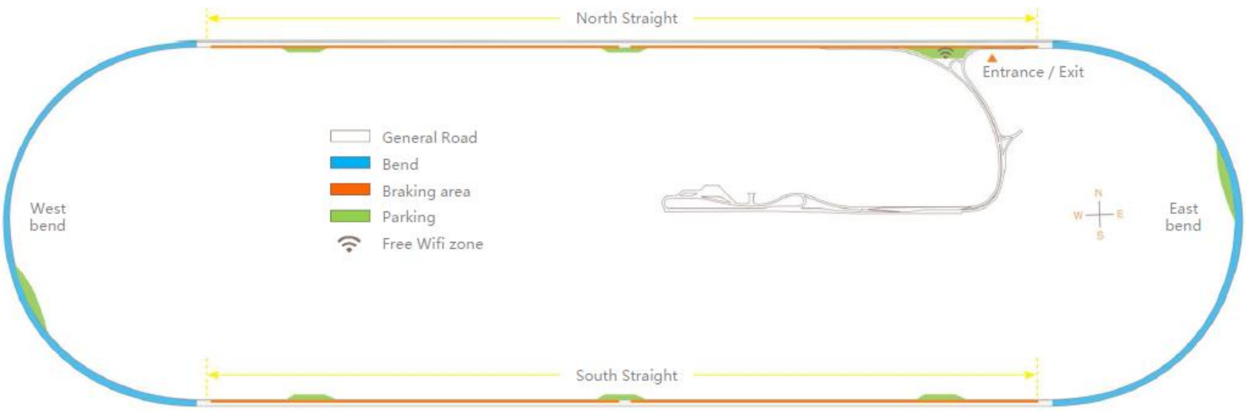

Figure 5: High-speed track map

In order to carry out the testing, it will be necessary to ask for the exclusivity of the test track as a platoon of 7 trucks can compromise the safety of the others in the High-speed track. More details for the testing in IDIADA will be defined in the coming months.

5.4.2. Test track equipment

5.4.2.1. Connectivity Lab

The Connectivity Lab is in IDIADA's proving ground with a set of test tracks equipped with state-of-the-art communication technologies for Cooperative and Connected Vehicles. The deployed network (see Figure 4) compliances with Europe and US international standards. A private mobile network (2G, 3G, 4G, 5G…) with full control of the network parameters including radio access network and back-end systems is available for development, validation, and testing of cooperative and connected vehicle applications.

Figure 6: IDIADA Infrastructure map

5.4.2.2. Data Logging Equipment

In the ENSEMBLE project, IDIADA will adapt a data acquisition system called iDAPT which is a multi-purpose, flexible OBU development tool for connected and autonomous prototyping and development activities. This data acquisition system integrates the NVIDIA Jetson platform, with a selection of modular connectivity and positioning technologies with standard and emerging automotive I/O inside one safe and reliable tool.

This device provides the ability to "retro-fit" connected vehicle capabilities into an existing system for prototyping/development needs. With its modular design, components can be removed/upgraded as required. IDAPT also provides the ability to startup without any user interaction using 3 different mechanisms: wake on CAN, wake on ignition and wake on RTC (configurable specified time).

This tool is ideal for:

- ADAS & CAV Field Operational Test (FOT)
- Connected vehicle projects
- V2X application development
- Cyber-security development
- Camera imaging and object detection
- Automotive IoT prototyping
- Sensor development (LiDAR, RADAR)
- Automated vehicle controls
- Machine learning algorithm development
- Prototype datalogging

In Figure 7 an overview of the setup that will be integrated in each of the trucks is shown.

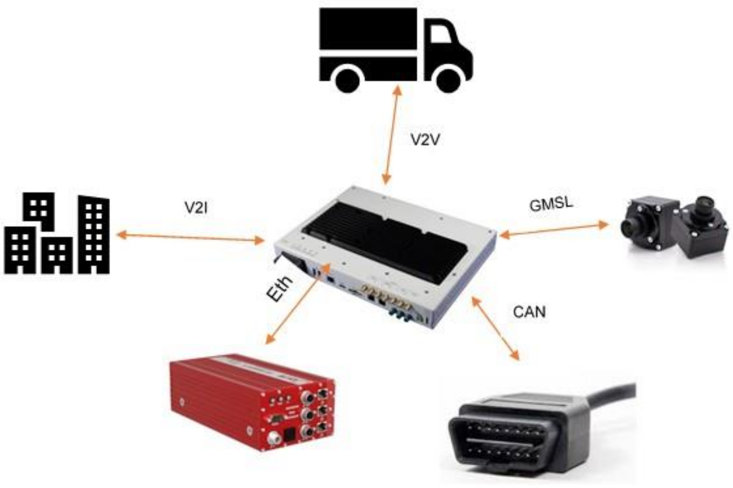

Figure 7: iDAPT setup configuration

Table 3 is a summary of the equipment's that will be used for multi-brand and Open road testing:

Tool	Type	Description
iDAPT	Hardware	This tool will be in charge of recording all the data necessary for the verification of the test cases defined for proving grounds.
Reference GPS	Hardware	This device will be used as the reference positioning system.
Cameras	Hardware	The cameras will be used for recording the driver behaviour and the front view and rear view of the truck.
OBD	Hardware	OBD will be used for recording all the necessary data from the internal sensors of the truck.
SDR	SW/HW	Radio communication system where components that have been traditionally implemented in hardware are instead implemented by means of software on an embedded system.

Table 3: List of equipment

5.4.2.3. Impact of Platooning on Pavement Structure

In order to assess the impact of the platooning on the pavement, in WP4 is considered the instrumentation of a pavement package in order to identify pulses, loads and deformation experienced by the structure when platoon is passing through. The signals are identified and introduced in IFSTTAR simulation tool in order to estimate consequences of platooning effect on pavement structures in the long term.

Even though WP4 leadership is clearly at IFSTTAR's side, the test activity is to be conducted in IDIADA test tracks, pavement instrumentation has been planned in the same test facilities and installation works have been coordinated by IDIADA following IFSTTAR's recommendations.

Selection of sensors location:

In order to select a the most appropriate location for the sensor's installation IDIADA considered IFSTTAR's requirements for data acquisition as well as constrains related to the test activities conducted in the technical center. The location selected for sensors installation was one particular spot of the General Road South straight because it includes the following conditions:

- Perfect conditions for vehicle stabilization before measuring spot – vehicles with 1km in straight conditions at 0% longitudinal slope after a soft curve that allows certain velocity at the beginning of the straight.
- It is next to Dynamic Platform A parking area that offers a space were people collecting data can safely stand during data acquisition process segregated from test traffic.
- Electrical power supply and WIFI is available.

In Figure 8 it can be seen IDIADA track view including schematic graphic references as follows:

Figure 8: Pavement validation track

- **Red spot** marks location selected for sensors installations.
- **Light blue line** marks the area available for vehicle stabilization.
- **Green line** marks the return trajectory in order to complete.
- **Black spot** marks a parking area available in the loop that allows running vehicles to be stop and verify data acquisition results and/or receive.

A plan view of the area selected for sensors installation showing the adjacent Dynamic Platform parking area can be find in Figure 9.

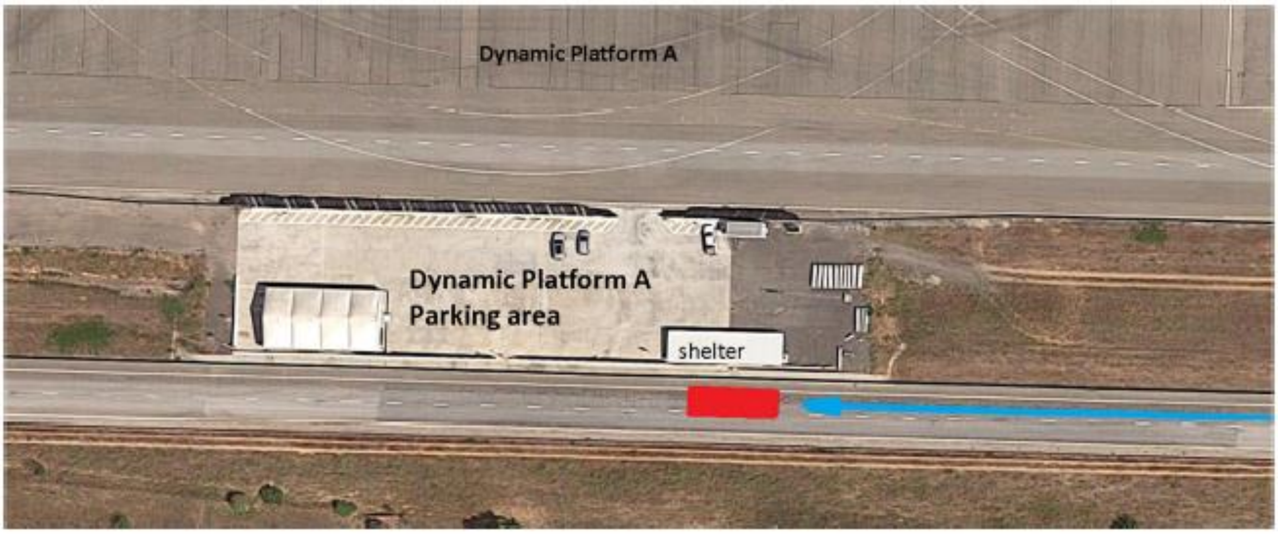

Figure 9: Sensors installation location

A set of different tests will be carried out as it is shown below:

- 2 different temperatures: <20°C (tests in January – March 2019) and T=> 30°C (tests in June – September 2019)
- 3 different speeds (60 km/h, 75 km/h and 90 km/h)
- Each isolated truck and the platoon (with 3 trucks)
- Distances D between the trucks function of the speed (about 0.5 second between each truck)
- All the trucks will be loaded at minimum 40 tons (maximum load 44 tons).
- All the trucks will be weighted before the tests (by Ifsttar).
- The trucks are the same trucks which will used in a platoon (T2S3).

In Figure 10 the test configuration is explained.

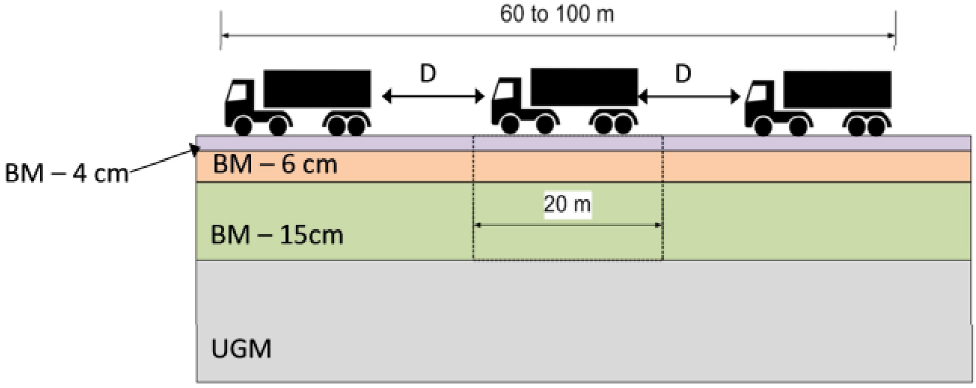

Figure 10: Pavement impact test setup

In table 4, the test cases that will be executed are described in detail.

	T<20°C		T=>30°C	
	Each truck	Platoon with 3 trucks	Each truck	Platoon with 3 trucks
60 km/h	2 passages	D=8m 4 passages	2 passages	D=8m 4 passages
75 km/h	2 passages	D=10.5m 4 passages	2 passages	D=10.5m 4 passages
90 km/h	2 passages	D=12.5m 4 passages	2 passages	D=12.5m 4 passages

Table 4: Test setup characteristics

First set of tests will be carried out in January 2020 in IDIADA test tracks.

5.5. Test Cases

To have a common understanding of the concepts of use case and test case, a definition for each one has been written as follows:

- A **Use-case** represents a (critical) scenario where a solution, usually the system that is being developed, needs to be implemented. The use case describes various conditions where the system shall respond. These conditions can be interactions from the system's user, other traffic participants or road conditions

- A **Test case** is a set of requirements and variables under which the system will be tested and assessed. The results will determine whether a system accomplishes the criteria requirements for acceptance. The process of developing test cases can also help find problems in the requirements or design of an application

The test cases will be tested in different testing phases such as mono-brand, three-brand and multi-brand as is explained in the following sections.

5.5.1. Mono and Three Brand Platooning

The mono and three brand testing will take place in WP3. The **Mono-brand testing** will take place at each OEM's facility. The testing will be carried out with an instrumented truck which has the developed technology implemented and is capable of performing tests on the operational layer, the tactical layer, and on the interface of the Strategic layer. The implementation will consider Platooning Level A as described in D2.2 and D2.4.

The **Three-brand testing,** the trucks will be tested in groups of three in two different test tracks. The groups will be as follows:

- MAN & SCANIA & VOLVO / RENAULT.
- DAF & DAIMLER & IVECO.

The following table shows the overview of the test cases for mono-brand and three-brand that will take place in WP3.

Test Chapter	No.	Test name
steady state testing	0,1	Steady-state platooning test at 2s gap at max. design speed
	0,2	Steady-state platooning test at design gap and at max. design speed
	0,3	Steady-state platooning test at design gap and at max. design speed
	0,4	Steady-state platooning test at design gap and mild acceleration of lead truck on CC/ACC
	0,5	Steady-state platooning at design gap and using CC/ACC deceleration based on HMI speed adjustments
	0,6	Steady-state platooning at design gap and using CC/ACC acceleration of -2 m/s^2
Mono brand testing	1,1	Join test towards design gap and max. design speed

	1,2	Platoon test at design gap and 80 --> 60 km/h
	1,3	Platoon test at design gap and 60 --> 80 km/h
	1,4	Leave test at design gap
	1,5	Tests at design gap and a vehicle cut-in
	1,6	Steady-state platooning test at design gap with simulated communication interrupt
	1,7	Emergency braking with -5 m/s2 and maximum performance
	1,9	Add braking to low speed and standstill
	1.x	More tests to be added depending on functional safety concept
	1.y	Additional test(s) to adjust safe gap to brake capacity changes communicated from LV
Three brand testing (note these are done three times with the different partners as LV, FV and TV)	2.1	Join test at design gap and 80 km/h
	2.2	Platoon test at design gap and 80 --> 60 km/h
	2.3	Platoon test at design gap and 60 --> 80 km/h
	2.4	Leave test at design gap
	2.5	Leave test at design gap
	2.6	Leave test at design gap (note: leave as lead, trailing, following)
	2.7	Tests at 80 km/h and change gap sizes
	2.8	Tests at design gap and a vehicle cut-in
	2.9	Tests at design gap and a vehicle cut-in creating a large distance to the lead vehicle
	2.10	Tests at design gap and driver braking
	2.11	Test at design gap with simulated communication interrupt
	2.12	Emergency braking with -5 m/s2 and maximum performance
	2.13	Test at design gap with LV braking to 30 km/h and FV resuming
	2.14	Test at design gap with LV braking to 30 km/h and FV NOT resuming
	2.x	Additional test(s) that can be used to verify the implementation of split (between 1 and 2, and between 2 and 3)
	2.y	Additional road side interaction tests

Table 5: Mono & Three brand test cases description

There are ongoing discussions about the three-brand test definition and the content of the table may change. The final version will be included in deliverable D5.7.

5.5.2. Multi Brand Platooning

Multi-brand platoons will be tested to verify that the developed solutions meet all the requirements, comply with the specifications, are interoperable and evaluate the full performance of the platoon solution implemented without considering the service layer, responsible for the coordination of platoons.

The platoon will be tested in IDIADA testing facilities under complex scenarios defined in task 5.1 and using information from derivable D.2.2 for the use cases and D.2.4 for functional specifications. A first overview of the complex use cases is explained Table 6.

Use case		
Platoon engagement	Engagement from behind	Different platoon speeds
		Different joiner speeds
Platooning	Steady state	Fuel Consumption
		Time gap stability
		Speed modification readjustment of the platoon
		Indicated lane change to avoid an obstacle/slower vehicle
		Indicated lane change to stay in the planned route (e.g. road fork)
		Deceleration of the whole platoon due to a tight bend
	Follow to Stop Main Flow	Reduce to 30 km/h then accelerate again
	Follow to Stop Alternative Flow	The driver should get control after slowing to 30km/h, if not, tuck will enter leave use case
	Emergency Braking	Due to EB from the lead truck
		Due to EB from the following truck
		An EB starts and the connection is lost
	Platoon gap adaptation	crossing a border, change of regulation in platoon gap

	because of I2V interaction	
	Platoon speed adaptation because of I2V interaction	traffic jam, road work, tight bend
	Cut-in vehicle in for a long period	vehicle intruding the platoon
	Cut-in + cut-out	vehicle crossing the platoon to exit on a highway
	Time gap adaptation because of system status	Safety adaptation of time gap due to GPS/platoon service failure
Disengage	Leaving platoon by trailing truck	Trailing truck increases gap or exits highway
		Leaving truck is faster and overtakes all trucks
	Leaving platoon by leading truck	Leading truck decides to exit the highway
		Leaving truck is slower, is overtaken by the rest of the trucks behind him
	Leaving platoon by follower truck	Leaving truck is faster and overtakes all trucks
		Leaving truck takes the highway exit
		Leaving truck is slower, is overtaken by the rest of the trucks behind him
	Split platoon by follower truck	Split due to different routes, each platoon takes one direction
		Split due to the speed difference induced by the load and power of trucks
		Emergency Split due to truck break down

Table 6: Definition of complex Use Cases for multi-brand platooning

The complex use cases showed in Table 4 will be more detailed in the following months and will be reflected in D5.7. Appendix A, gives the latest version of the complex test cases definition. Until now the test cases have been linked to the use cases and a definition of each test case has been written. Also, some parameters such as speed, track lanes needed for testing, the number of tests to carry out and metrics linked to the KPIs explained in section 5.3 have been defined. The content of Appendix A will change, and the final version will include a detailed definition of the test cases, the test criteria to assess the results and the specific equipment that will be needed for testing the multi-brand platooning.

5.6. Exemption Tests

The National Road Traffic Authority in Spain is called Dirección General de Tráfico (DGT) and co-ordinates the traffic across the country. The DGT is a body depending on the Interior Ministry of the Spanish Government and guarantees road safety. Among its responsibilities, DGT is also in charge of road traffic management and is responsible of the licence exemption process for testing in Spanish Roads (http://www.dgt.es/es/).

Detailed information of the exemption procedures and tests will be provided in Task 6.3.2, Deliverable 6.11.

6. OPEN ROAD TEST PLAN

6.1. Overview

The ENSEMBLE project's main objective is to create a fully functional road train (platooning) that can be adopted to unmodified public highways and interact with surrounding traffic. Therefore, the platooning vehicles not only need to be tested on the test track, but also on the open, public road. The main objective here is to test whether the platoon system behaves safely and as intended.

The effect of platooning on environment, safety and traffic flow will be addressed in WP4. This WP will make use of the measurements done on the test track and on the real road as much as possible.

To test the effects of the platooning on infrastructure, we have installed specific sensors in the IDIADA test track to measure the damage on pavement. The details of this effect and test setup were described inside section 5.4.2.3.

The open road test may include roads with specific characteristics, including:

- Minimum, average and maximum speeds of traffic.
- Number of lanes.
- Types of manoeuvres that a driver will need to undertake.
- Traffics flow.
- Infrastructure needs.
- Fuel & Emission consumptions.

6.2. Test Environments

6.2.1. Test Environments

Catalonia Living Lab is a public-private framework for development and testing of connected and automated vehicle (CAV) technologies. Its primary goal is to cover all CAV related development and testing needs with Catalan (public) infrastructures and industry.

Catalonia Living Lab provides the main test environments required in the development process of connected and automated vehicles: from virtual simulation to laboratories, proving grounds and public roads.

Abertis motorways has equipped a 20km section of public highway with the latest technologies in terms of communication (ITS-G5), sensing, traffic management 2.0 and data analytics. The test site is in the Mediterranean Corridor (TEN-T Network) between Barcelona and the French Border. The specific highway segment is over 20km of four-lane carriageway and includes four intersections and a 180m tunnel. This service provides the opportunity to demonstrate any project related to CAV in a real traffic scenario supported by the latest technologies and the support of an experienced partner.

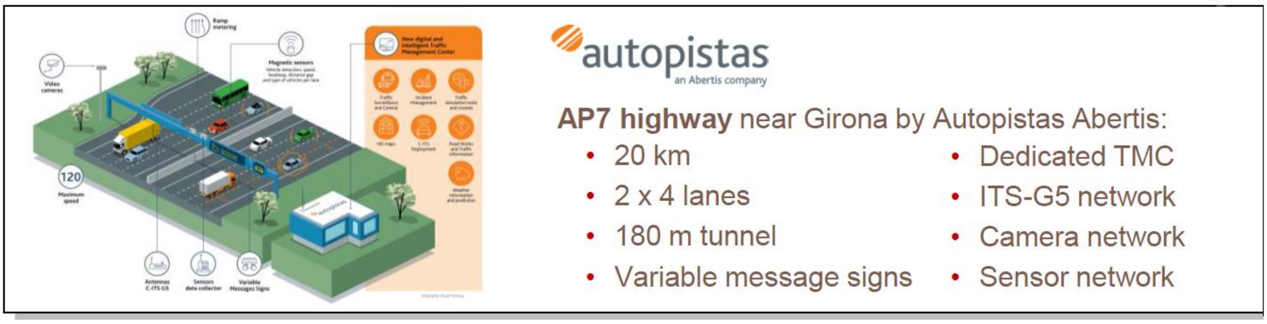

Figure 11: Catalonia Living Lab testbed

6.2.2. Open Road Simulation Environment

Based on the experience accumulated and gathered during the simulation task in WP4 (task 4.5.2), this task aims to support the real-world experiment plan (task 5.1, data acquisition plan). First, data collection recommendations will be delivered to task 5.1. Second, the data collected during the real-world experiment (task 5.4) will be used to verify consistency of simulation assumptions, mainly regarding the parameter's calibration and platoon properties. Finally, the gathered data will be prepared for general use beyond the project by third parties.

Currently, the route section that be included in the simulation tool is being defined, the different parameters looked at are: traffic conditions, mapping of different equipment (cameras & sensors), track conditions, etc. This information will be included in Task 4.5.2 (WP4).

The open route section that will be simulated and validated to corroborate the information, will be the same as described in section 6.2.4.2.

6.2.2.1. Measuring traffic data

Traffic can be characterized at multiple scales: at microscopical scale specific vehicle interactions are aimed to be measured. At macroscopic level aggregated behaviours of a group of drivers are intended to be examined. Example of microscopic characteristics are individual vehicle speed, space headway, acceleration. At a macroscopic level, aggregation of microscopic variables is regularly measured at fixed points in space. Examples of this traffic data are average speed, flow, occupancy. Each technology captures two different type of behaviours that are important to understand variations in traffic flow. This sensor scheme can be observed in Figure 12.

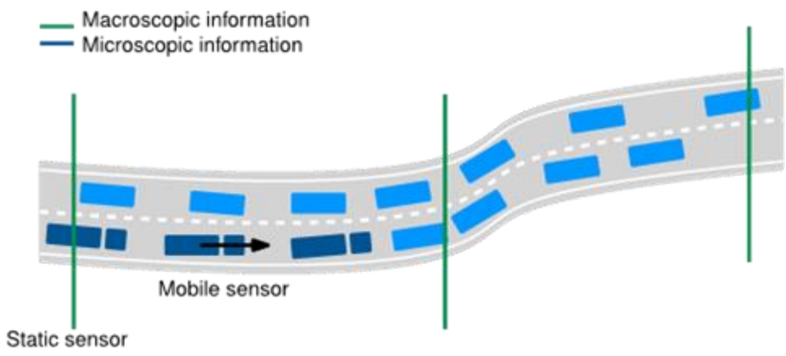

Figure 12: Catalonia Living Lab testbed

Test characteristics:

The proposed tests are split in two parts. Tests on test tracks and tests on public roads. Tests on tracks are focused on characterization of *dynamic performance and operation* of multi-brand truck platooning as well as the *platoon behaviour during manoeuvres.* On the other hand, tests on public roads are intended to measure the *impact on traffic flow & other road users*. In order to precisely capture traffic behaviour, it is important to rely on both sources of information.

The objective of both kind of tests are:

- Measure the individual variability of headway space, speed and acceleration of a formation of trucks in a platoon where the composition is characterized by different brands. This objective should impact tasks T4.4, T4.5, T4.3.2, T5.4. WP3.
- Measure the total time taken to perform specific manoeuvres in traffic. (T4.4, T4.5, T5.4).
- Examine and measure behaviours of traffic conditions surrounding a truck platoon. One example of such condition is: measuring the overtaking flow, or the relative differential speed between the trucks and the other vehicles on the road. (T4.4, T4.5, T4.3.2.)
- Determine the achievable effect of truck platooning under real world conditions on roads in the presence of specific traffic conditions, such as overtaking traffic flow. (T4.4, T4.5, T5.4)

6.2.2.2. Measuring traffic data

Sensors can capture different types of traffic data which in terms of level of aggregation allows a better estimation of the traffic states, as well as levels of detail. Data availability is important to characterize the traffic behaviour in different scales of space and time.

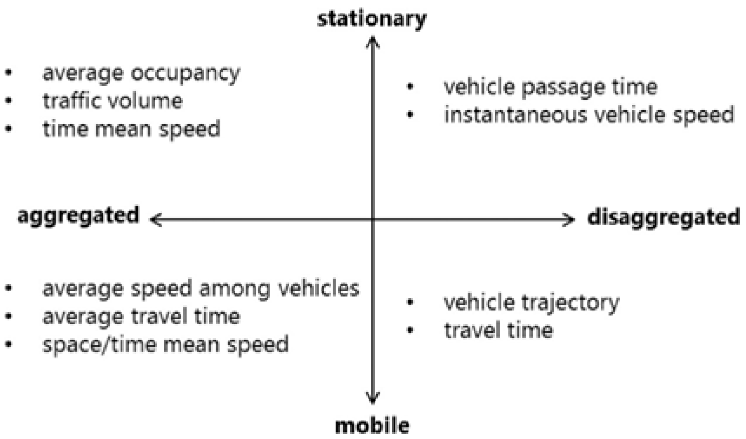

Figure 13: Aggregation data levels and details on the captured information

Mobile data is data associated with specific vehicles that usually provides measurements along a vehicle trajectory. It is a big source of interest for monitoring traffic due to the introduction of sophisticated ADAS functionalities that appear more often in new vehicles such as ACC. Nevertheless, the interaction of these technologies may lead to traffic instabilities. Examples of mobile data for traffic is GPS data, Bluetooth technologies and more recently radar sensors widely used in autonomous vehicles.

6.2.3. Data logging equipment

Emissions and fuel consumption measuring equipment:

One of the objectives of the project is measuring the fuel consumption and emissions. Each truck will be equipped with a dedicated sensors. The measurements will be carried out during IDIADA test tracks and open road test. The equipment is going to be used is the SEMS equipment developed by TNO.

The SEMS equipment contains the following characteristics:

- Fuel consumption measured using the OBD connector integrated in SEMS,
- GPS tool integrated in SEMS,
- External emissions sensors,
- 24V switched measurements using external sensor,
- GRPS to send data to central TNO server,

- SEMS can record additional I/O.

Figure 14 shows the SEMS block diagram and the different connections available.

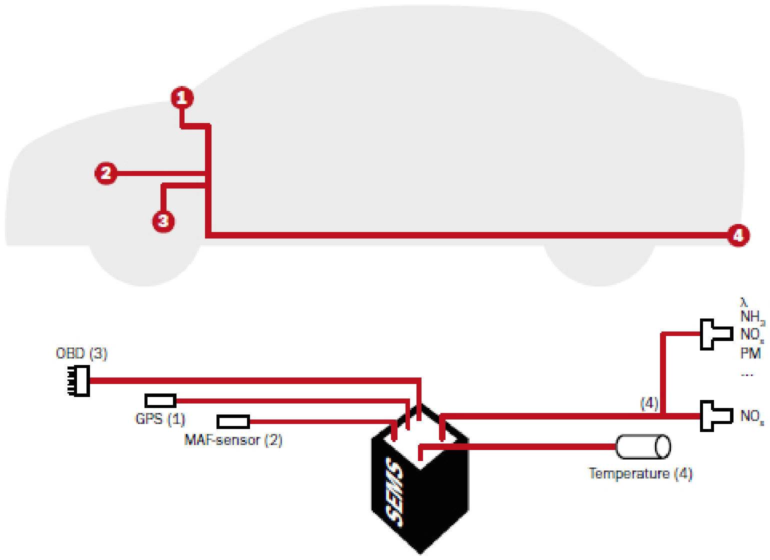

Figure 14: SEMS block diagram

6.2.4. Open Road test definition

In this section we will define the Open route track according to some inputs received by WP4 activities; list of measurables and inputs to validate during this open route test.

6.2.4.1. Fuel consumption & Emission route

To ensure the correct evaluation of the fuel consumption and emissions results, we will use the route that starts and end in the same point inside IDIADA facilities. Figure 15 shows the route IDIADA-Fraga – IDIADA by using Google Earth tools.

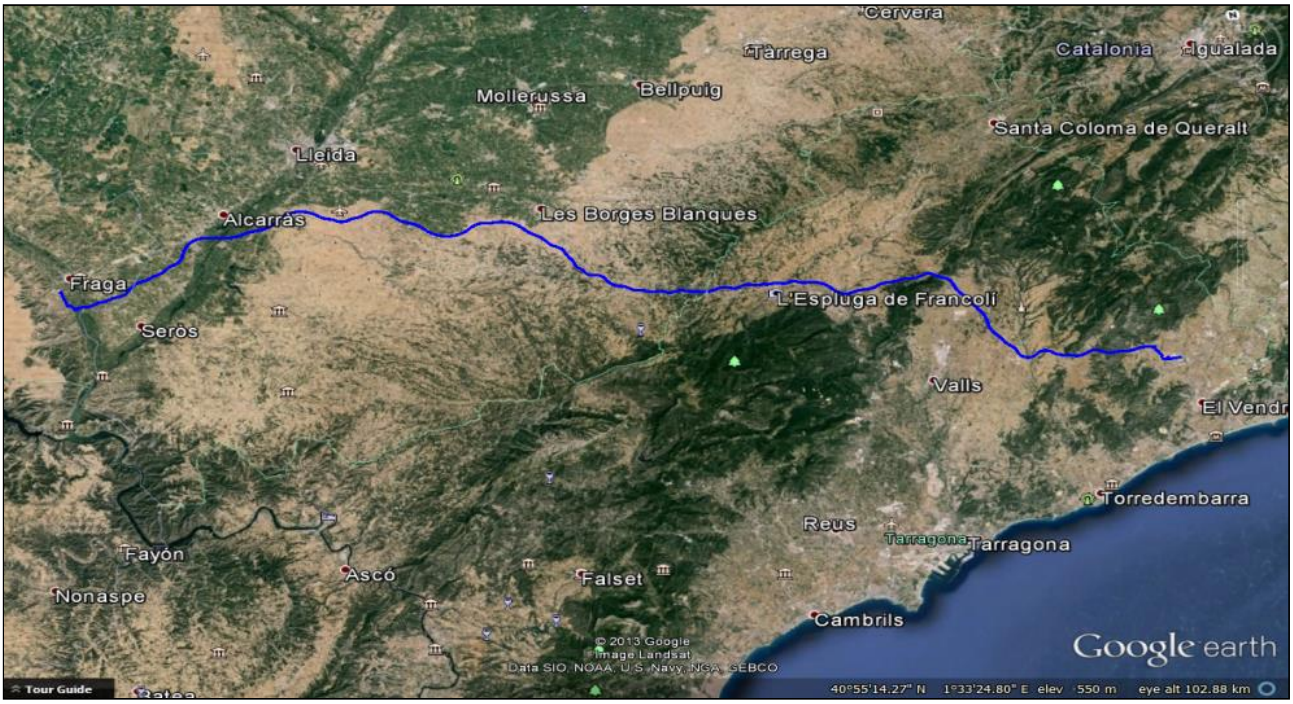

Figure 15: Route IDIADA-Fraga-IDIADA overview

Table 7 the main theoretical characteristics of the IDIADA-Fraga-IDIADA route.

Concept	Remarks
Trip duration	≈ 12,000 s
Trip distance	237.5 km
Average speed (>95% highway-distance	≈ 72.5 km/h
Min / max altitude	87 / 573 m
Max up- and downhill slope [%]	6.6 / -6.8 %
Traffic conditions	low

Table 7: IDIADA-Fraga-IDIADA route characteristics

6.2.4.2. Traffic flow route

To validate the impact on traffic flow, we will use the testbed route that it is fully automated near to Girona. This open road track has a lot of cameras that we can use to evaluate the impact of platooning in a real situation. Using this route can validate the impact of platooning in low/high density traffic.

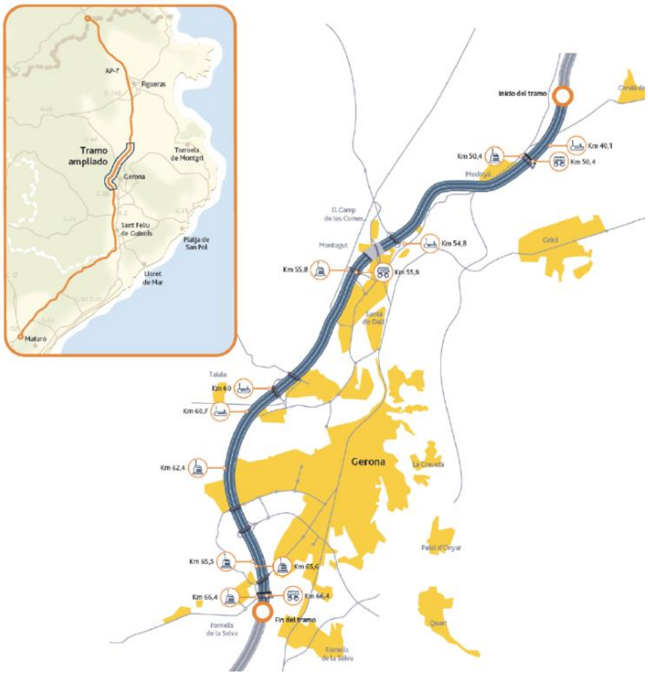

Figure 16: Girona road characteristics

Table 8 the main theoretical characteristics of the Girona route.

Concept	Remarks
Trip distance	20 km
Number of lanes	x3/4
Speed limitation	120kmh
Traffic conditions	Low/high
RSUs antennas (G5)	x10
Others	Weather Station, sensors

Table 8: Girona route characteristics

7. DATA MANAGEMENT

The main objective is to create a methodology and the tools for collecting and managing test data collected for the different tasks, processing and integrating data needed for the impact evaluation during WP5.

Building upon the relevant results from field operational tests and automation projects an inventory of these tools for the whole procedure of tests, including data acquisition, transmission, database structure, quality assurance, and data storage was created.

Figure 17 shows a block diagram of the proposed data management plan in ENSEMBLE. The main idea is to create a server to upload all data collected during the corresponding project validation phase.

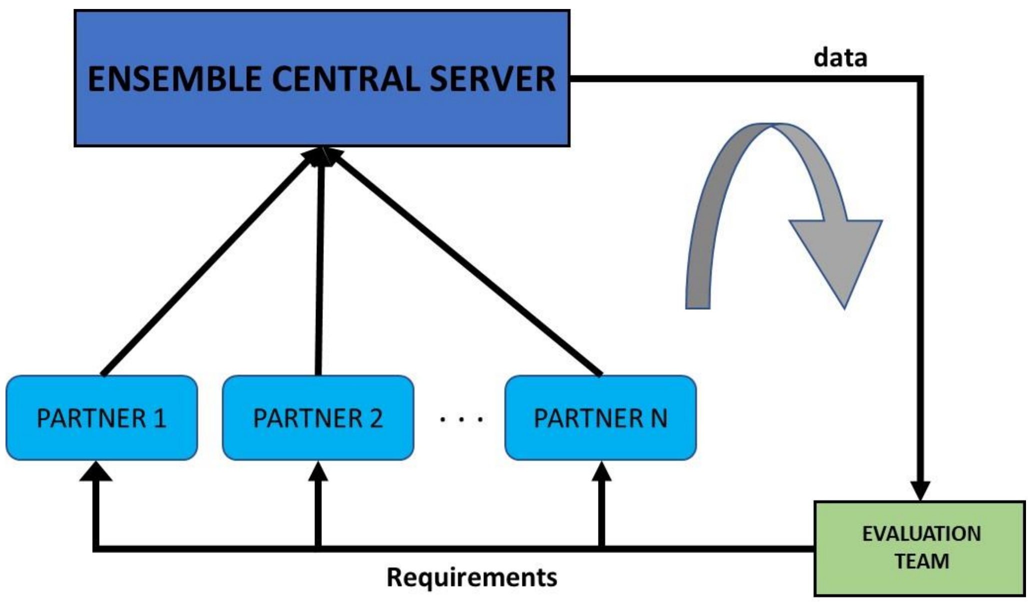

Figure 17: Data management methodology in ENSEMBLE

7.1 Data Requirements

Each data provider will transfer the log files needed for the evaluation to the IDIADA Test Server. Before uploading these files, a technical data check will be done to ensure the required level of quality. Once the data is validated, it will be uploaded to the Ensemble Central Test Server. Together with the log files of the different sources, additional information related to the test runs such as context, test run description or safety intervention, will also be uploaded.

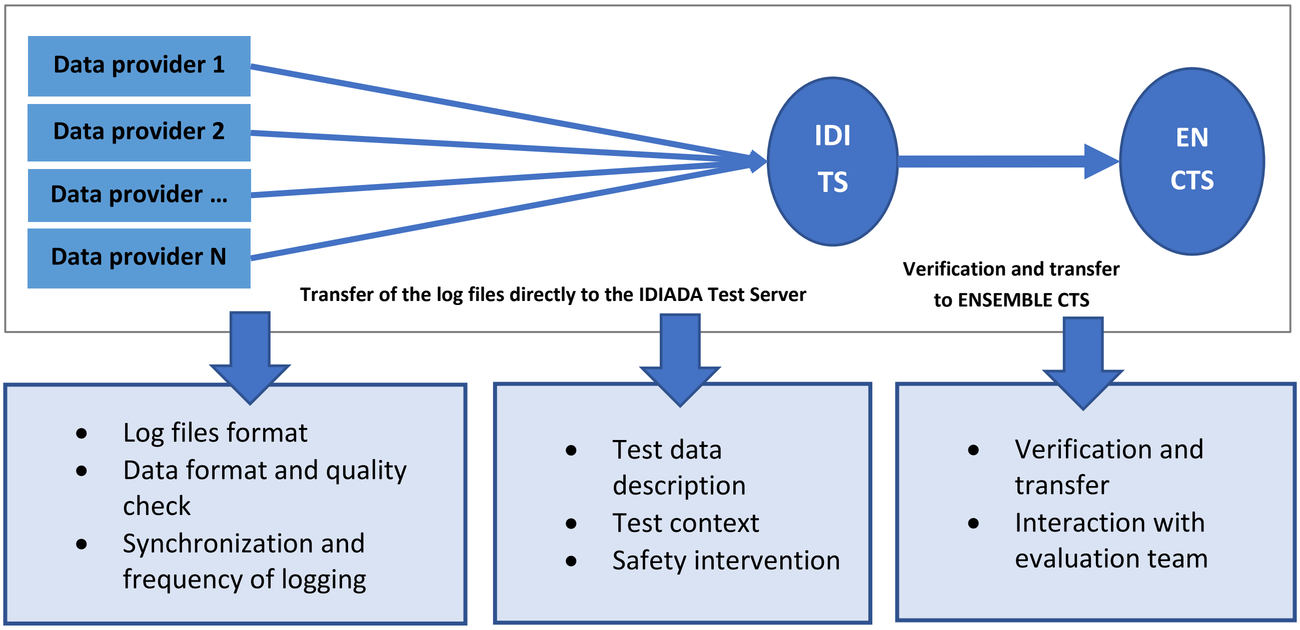

Figure 18: Data uploading process

Data Format and quality check

Format for data logging shall be agreed, including the information below:

- **Signal**. Name of the measurement.
- **Quantity.** Source and placement of the logging device. Also, if the measurement needs to be logged per truck or per platoon.
- **Technical information.** Unit, frequency of logging, minimum and maximum values and accuracy.
- **Work Package main user**. Who will use the information provided.
- **Logistic information**. Equipment provider, installation responsible and test location.
- **Compliance and security**. Reason for usage and approval.

The data quality check will be done following the next steps:

1 Assess and quantify missing data
2 Control data values and units of measure
3 Check that all the data are timestamped
4 Check that all the data are synchronised
5 Check the all the data are compliant to the predefined data format
6 Check that the data are clearly identified by station id and application id

Synchronisation and frequency of logging

All the information must be synchronised to establish consistency among data from all the sources and devices in order to ensure data consistency.

In order to achieve it, we should have a global timestamp and each time a message is sent and received, the device should log the timestamp when received and the timestamp when delivered.

The frequency of logging shall be modified depending on the scenario. We need higher frequency of logging on higher velocity scenarios, while we could need less frequency of logging on the scenarios done at low speed.

7.2 Data Storage

The amount of data to be recorded will be approximately 1MB/min for the V2X messages, 20MB/min for each camera, and 968MB/min for the raw lidar data.

Each V2X message is expected to be around 200B, assuming a frequency of 10Hz this would be 2KB/s and 120KB/min. Considering multiple trucks the data load should be less than 1MB/min.

For each camera, the amount of data recorded will depend on the resolution and frame rate along with the encoding of the video. Approximately 5-20MB for HD or full HD.

The lidar packets have 12608 bytes each. And the maximum output rate is 1280 packets/sec. So 968MB/min. This depends on the resolution and frequency and could also be 484MB/min or 242MB/min.

8. TIMING

Figure 19 shows the ENSEMBLE validation test plan for mono-brand, three-brand, complex-brand and open road testing. Currently, these dates are provisional until the complete set of test cases are defined. The final date will be added in deliverable D5.7 after agreement with all the involved project partners

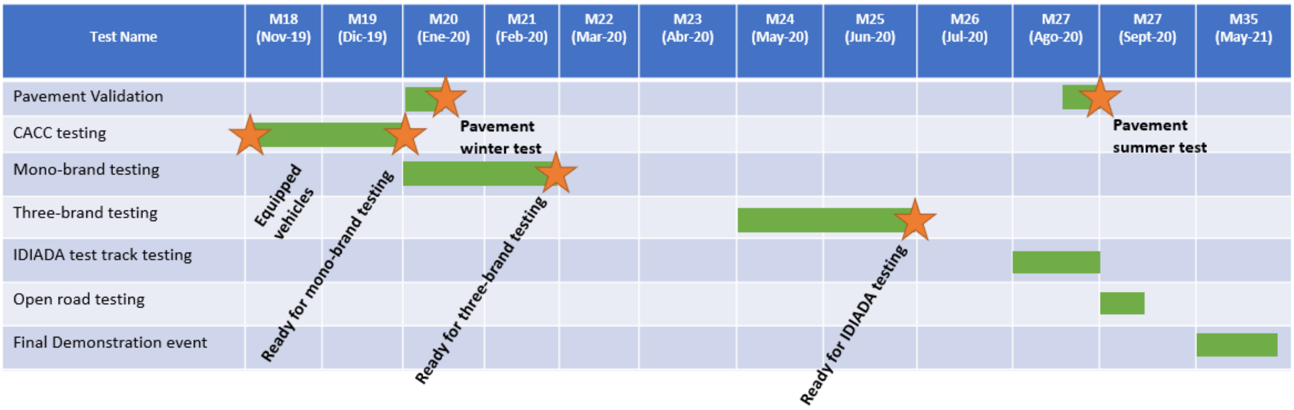

Figure 19: ENSEMBLE testing time

9. SUMMARY AND CONCLUSION

This report defines the common testing methodology that will be used for the verification, validation and demonstration of the implemented multi-brand solutions in previous WPs and will elaborate the plans for testing and demonstration activities. Moreover, data management plan will be verified during the evaluation tests.

We have collected the different KPIs from WP3 & WP4 to consider in the test cases definition. The mono-brand and three-brand test cases will be carried out by the OEM's at system level. The multi-brand testing has two different parts:

- IDIADA test track: the platoon will be tested in IDIADA testing facilities under complex scenarios defined in task 5.1 and using information from deliverable D2.2 for the use cases and D2.4 for functional specifications. Through the test cases we will validate the project requirements.

- Open Road test track: different performance measures will be validated on the Catalonian open roads. Emissions & fuel consumption, impact of platooning in real traffic, Infrastructure.

The test plan will be further refined in Task 5.1 will result in project deliverable D5.7 in accordance to the evolution of the project and the agreement between project partners and agreements with key external partners (e.g. road traffic authorities).

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11. APPENDIX A. COMPLEX TEST CASES DETAILS

The following table shows the latest status of the complex test cases for multi-brand testing. This table is still in definition and will be presented to the work package partners for discussion in October at the next WP5 workshop.

USE CASE			Description test case	Nº test	Velocity (km/h)	Nº Lanes	Distance (s)	Metrics	ID
Platoon engagement	Engagement from behind	Different platoon speeds	The trucks are joining to the platoon as the velocity increases starting at 30 km/h	1	30, 40, 50, 60, 70, 80, 90	2	0,8		1
	Engagement from behind	Different joiner speeds					0,8		
platoon	Steady state	Time gap stability	Stability of time gap in 7 km	2	90 and 60	1	0,8	Fuel consumption [l/km]	2
		Speed modification readjustment of platoon	velocity adaptation from 90 to 50	1	90-50	1	0,8		3
		Avoid an obstacle/slower vehicle	the platoon needs to dissolve, change lane and re-engagement	1	90-30	2	0,8		4
	Follow to Stop Main Flow	Reduce to 30 km/h then accelerate again	Platooning is going at 80 km/h and leading tuck reduces velocity to 25 km/h but does not dissolve and goes back to 80 km/h		80 km/h leading truck < 30 platoon back to 80	1	0,8		5
	Follow to Stop Alternative Flow	The driver should get control after slowing to 30km/h, if not, the truck will leave	Platooning is going at 80 km/h and leading tuck reduces velocity to 25 km/h but the platooning dissolve		80 km/h leading truck < 30	1	0,8		6
	Emergency Braking	Due to EB from the lead truck	Lead truck EB, velocity goes to 0 km/h, as the rest of the platoon	3	40-0 (60- 0) (90-0)	1	0,8	Time to collision	7
				3	40-0 (60- 0) (90- 0)	1	0,8	Deceleration	8

		Due to EB from the following truck	The platooning goes at 50 km/h and the following truck EB (nº 4), velocity goes to 0 km/h as well the others behind it and Lead truck keeps at 40 km/h with the others in front of the platoon.						
	Platoon gap adaptation because of I2V interaction	crossing a border, change of regulation in platoon gap	Notification of zone policy (roadside unit) that truck platooning should have a distance of X during 2 km. After 2 km implementation of the previous configuration		90 to 50	1	0,8		10
	Platoon speed adaptation because of I2V interaction	traffic jam, road work, tight bend	When platoon approaches the curve (tight bend) reduce velocity to 50km/h during 1 km. After 1 km implementation of the previous configuration		90-30	1	0,8		11
	Cut-in vehicle in for a long period	vehicle intruding the platoon	The platooning goes at 90 and a vehicle cut-in and stays for 1 lap at the test track and then exits the track reducing velocity at 60 km/h. There is now a gap formation between the head of the platoon that goes at 90km/h and the rest that goes at 60km/h.	3	90 and 60	2	0,8	maximum brake value	12
	Cut-in + cut-out	vehicle crossing the platoon to exit on a highway	the trucks are going at 80 km/h in the test track and a vehicle cut-in and stay for 30 seconds and leaves.	3	90 - 80	2	0,8		13
	Time gap adaptation because of system status	Safety adaptation of time gap due to GPS/platoon service failure			90-30	1	0,8		14
Disengage	Leaving platoon by trailing truck	trailing truck increases gap or exits highway	the platoon goes at 90 and the trailing truck leave platoon decrease velocity to 60 and exits the test track	3	90	2	0,8		15

		Leaving truck is faster and overtakes all trucks	the platoon goes at 70 and the trailing truck leave platoon and change the lane and accelerates to overtake all the platoon	3	90 and 70	2	0,8		16
	Leaving platoon by leading truck	Leading truck decides to exit the highway	the leading truck leaves the platoon at 90 km/h and the inter-vehicle gap increases and the others start a new platoon at 70 km/h	3	90 and 70	2	0,8		17
		Leaving truck is slower, is overtaken by the rest of the trucks behind him	the leading will be the best of the platoon and this will not happen						18
	Leaving platoon by follower truck	Leaving truck is faster and overtakes all trucks	The follower truck leaves the platoon that goes at 70 and overtakes the platoon at 90		70 and 90	2	0,8		19
		Leaving truck takes the highway exit	The platoon goes at 90 km/h and the follower truck leaves the platoon at 60 km/h to exit the track		90 and 60	2	0,8		20
		Leaving truck is slower, is overtaken by the rest of the trucks behind him	A platoon goes at 80 km/h and a follower truck leaves the platoon due to it goes slower 40km, the rest of the platoon has to overtake it and adapt time gap to the front part of the platoon that goes at 80 km/h		80 and 40	2	0,8		21
	Split platoon by follower truck	Split due to different routes, each platoon takes one direction	the highway offers a fork (France and Barcelona) the platoon goes at 90 km/h and will split into two platoons, one at the left lane (to France) and the other at the right lane (Barcelona)		90	2	0,8		22
		Split due to speed difference induced by	The platoon goes at 90 km/h uphill and due to load reasons, several trucks are slower than the others. The platoon will		90 and 50	2	0,8		23

		the load and power of trucks	split in two one at 90 km/h the other at 50 km/h.						
		Emergency Split due to an emergency situation	The platoon goes at 80km/h a follower truck has an emergency situation and is slowing down, the platoon split in two and the followers disengage and re-group. Two platoons are formed going at 80 km/h		80	2	0,8		24

12. APPENDIX B.

12.1.Glossary

12.1.1. Definitions

Term	Definition
Convoy	A truck platoon may be defined as trucks that travel together in convoy formation at a fixed gap distance typically less than 1 second apart up to 0.3 seconds. The vehicles closely follow each other using wireless vehicle-to-vehicle (V2V) communication and advanced driver assistance systems
Cut-in	A lane change manoeuvre performed by vehicles from the adjacent lane to the ego vehicle’s lane, at a distance close enough (i.e., shorter than desired inter vehicle distance) relative to the ego vehicle.
Cut-out	A lane change manoeuvre performed by vehicles from the ego lane to the adjacent lane.
Cut-through	A lane change manoeuvre performed by vehicles from the adjacent lane (e.g. left lane) to ego vehicle’s lane, followed by a lane change manoeuvre to the other adjacent lane (e.g. right lane).
Ego Vehicle	The vehicle from which the perspective is considered.
Emergency brake	Brake action with an acceleration of <-4 m/s2
Event	An event marks the time instant at which a transition of a state occurs, such that before and after an event, the system is in a different mode.
Following truck	Each truck that is following behind a member of the platoon, being every truck except the leading and the trailing truck, when the system is in platoon mode.
Leading truck	The first truck of a truck platoon
Legal Safe Gap	Minimum allowed elapsed time/distance to be maintained by a standalone truck while driving according to Member States regulation (it could be 2 seconds, 50 meters or not present)
Manoeuvre (“activity”)	A particular (dynamic) behaviour which a system can perform (from a driver or other road user perspective) and that is different from standing still, is being considered a manoeuvre.

Term	Definition
ODD (operational design domain)	The ODD should describe the specific conditions under which a given automation function is intended to function. The ODD is the definition of where (such as what roadway types and speeds) and when (under what conditions, such as day/night, weather limits, etc.) an automation function is designed to operate.
Operational layer	The operational layer involves the vehicle actuator control (e.g. accelerating/braking, steering), the execution of the aforementioned manoeuvres, and the control of the individual vehicles in the platoon to automatically perform the platooning task. Here, the main control task is to regulate the inter-vehicle distance or velocity and, depending on the Platooning Level, the lateral position relative to the lane or to the preceding vehicle. Key performance requirements for this layer are vehicle following behaviour and (longitudinal and lateral) string stability of the platoon, where the latter is a necessary requirement to achieve a stable traffic flow and to achieve scalability with respect to platoon length, and the short-range wireless inter-vehicle communication is the key enabling technology.
Platoon	A group of two or more automated cooperative vehicles in line, maintaining a close distance, typically such a distance to reduce fuel consumption by air drag, to increase traffic safety by use of additional ADAS-technology, and to improve traffic throughput because vehicles are driving closer together and take up less space on the road.
Platoon Automation Levels	In analogy with the SAE automation levels subsequent platoon automation levels will incorporate an increasing set of automation functionalities, up to and including full vehicle automation in a multi-brand platoon in real traffic for the highest Platooning Automation Level. The definition of "platooning levels of automation" will comprise elements like e.g. the minimum time gap between the vehicles, whether there is lateral automation available, driving speed range, operational areas like motorways, etc. Three different levels are anticipated; called A, B and C.
Platoon candidate	A truck who intends to engage the platoon either from the front or the back of the platoon.
Platoon cohesion	Platoon cohesion refers to how well the members of the platoon remain within steady state conditions in various scenario conditions (e.g. slopes, speed changes).
Platoon disengaging	The ego-vehicle decides to disengage from the platoon itself or is requested by another member of the platoon to do so. When conditions are met the ego-vehicle starts to increase the gap between the trucks to a safe non-platooning gap. The disengaging is completed when the gap

Term	Definition
	is large enough (e.g. time gap of 1.5 seconds, which is depends on the operational safety based on vehicle dynamics and human reaction times is given). A.k.a. leave platoon
Platoon dissolve	All trucks are disengaging the platoon at the same time. A.k.a. decoupling, a.k.a. disassemble.
Platoon engaging	Using wireless communication (V2V), the Platoon Candidate sends an engaging request. When conditions are met the system starts to decrease the time gap between the trucks to the platooning time gap. A.k.a. join platoon
Platoon formation	Platoon formation is the process before platoon engaging in which it is determined if and in what format (e.g. composition) trucks can/should become part of a new / existing platoon. Platoon formation can be done on the fly, scheduled or a mixture of both. Platoon candidates may receive instructions during platoon formation (e.g. to adapt their velocity, to park at a certain location) to allow the start of the engaging procedure of the platoon.
Platoon split	The platoon is split in 2 new platoons who themselves continue as standalone entities.
Requirements	Description of system properties. Details of how the requirements shall be implemented at system level
Scenario	A scenario is a quantitative description of the ego vehicle, its activities and/or goals, its static environment, and its dynamic environment. From the perspective of the ego vehicle, a scenario contains all relevant events. Scenario is a combination of a manoeuvre ("activity"), ODD and events
Service layer	The service layer represents the platform on which logistical operations and new initiatives can operate.
Specifications	A group of two or more vehicles driving together in the same direction, not necessarily at short inter-vehicle distances and not necessarily using advanced driver assistance systems
Steady state	In systems theory, a system or a process is in a steady state if the variables (called state variables) which define the behaviour of the system or the process are unchanging in time. In the context of platooning this means that the relative velocity and gap between trucks is unchanging within tolerances from the system parameters.

Term	Definition
Strategic layer	The strategic layer is responsible for the high-level decision-making regarding the scheduling of platoons based on vehicle compatibility and Platooning Level, optimisation with respect to fuel consumption, travel times, destination, and impact on highway traffic flow and infrastructure, employing cooperative ITS cloud-based solutions. In addition, the routing of vehicles to allow for platoon forming is included in this layer. The strategic layer is implemented in a centralised fashion in so-called traffic control centres. Long-range wireless communication by existing cellular technology is used between a traffic control centre and vehicles/platoons and their drivers.
Tactical layer	The tactical layer coordinates the actual platoon forming (both from the tail of the platoon and through merging in the platoon) and platoon dissolution. In addition, this layer ensures platoon cohesion on hilly roads, and sets the desired platoon velocity, inter-vehicle distances (e.g. to prevent damaging bridges) and lateral offsets to mitigate road wear. This is implemented through the execution of an interaction protocol using the short-range wireless inter-vehicle communication (i.e. V2X). In fact, the interaction protocol is implemented by message sequences, initiating the manoeuvres that are necessary to form a platoon, to merge into it, or to dissolve it, also taking into account scheduling requirements due to vehicle compatibility.
Target Time Gap	Elapsed time to cover the inter vehicle distance by a truck indicated in seconds, agreed by all the Platoon members; it represents the minimum distance in seconds allowed inside the Platoon.
Time gap	Elapsed time to cover the inter vehicle distance by a truck indicated in seconds.
Trailing truck	The last truck of a truck platoon
Truck Platoon	Description of system properties. Details of how the requirements shall be implemented at system level
Use case	Use-cases describe how a system shall respond under various conditions to interactions from the user of the system or surroundings, e.g. other traffic participants or road conditions. The user is called actor on the system, and is often but not always a human being. In addition, the use-case describes the response of the system towards other traffic participants or environmental conditions. The use-cases are described as a sequence of actions, and the system shall behave according to the specified use-cases. The use-case often represents a desired behaviour or outcome. In the ensemble context a use case is an extension of scenario which add more information regarding specific internal system interactions, specific interactions with the actors (e.g. driver, I2V) and will add different flows (normal &

Term	Definition
	alternative e.g. successful and failed in relation to activation of the system / system elements).

12.1.2. Acronyms and abbreviations

Acronym / Abbreviation	Meaning
ACC	Adaptive Cruise Control
ADAS	Advanced driver assistance system
AEB	Autonomous Emergency Braking (System, AEBS)
ASIL	Automotive Safety Integrity Level
ASN.1	Abstract Syntax Notation One
BTP	Basic Transport Protocol
C-ACC	Cooperative Adaptive Cruise Control
C-ITS	Cooperative ITS
CA	Cooperative Awareness
CAD	Connected Automated Driving
CAM	Cooperative Awareness Message
CCH	Control Channel
DEN	Decentralized Environmental Notification
DENM	Decentralized Environmental Notification Message
DITL	Driver-In-the-Loop
DOOTL	Driver-Out-Of-the Loop
DSRC	Dedicated Short-Range Communications
ETSI	European Telecommunications Standards Institute
EU	European Union
FCW	Forward Collision Warning
FLC	Forward Looking Camera
FSC	Functional Safety Concept

Acronym / Abbreviation	Meaning
GN	GeoNetworking
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GUI	Graphical User Interface
HARA	Hazard Analysis and Risk Assessment
HIL	Hardware-in-the-Loop
HMI	Human Machine Interface
HW	Hardware
I/O	Input/Output
IEEE	Institute of Electrical and Electronics Engineers
ISO	International Organization for Standardization
ITL	In-The_Loop
ITS	Intelligent Transport System
IVI	Infrastructure to Vehicle Information message
LDWS	Lane Departure Warning System
LKA	Lane Keeping Assist
LCA	Lane Centring Assist
LRR	Long Range Radar
LSG	Legal Safe Gap
MAP	MapData message
MIO	Most Important Object
MRR	Mid Range Radar
OS	Operating system
ODD	Operational Design Domain
OEM	Original Equipment Manufacturer
OOTL	Out-Of The-Loop
PAEB	Platooning Autonomous Emergency Braking

Acronym / Abbreviation	Meaning
PMC	Platooning Mode Control
QM	Quality Management
RSU	Road Side Unit
SA	Situation Awareness
SAE	SAE International, formerly the Society of Automotive Engineers
SCH	Service Channel
SDO	Standard Developing Organisations
SEMS	Smart Emissions Measurement System
SIL	Software-in-the-Loop
HIL	Hardware-in-the-loop
SPAT	Signal Phase and Timing message
SRR	Short Range Radar
SW	Software
TC	Technical Committee
TOR	Take-Over Request
TOT	Take-Over Time
TTG	Target Time Gap
V2I	Vehicle to Infrastructure
V2V	Vehicle to Vehicle
V2X	Vehicle to any (where x equals either vehicle or infrastructure)
VDA	Verband der Automobilindustrie (German Association of the Automotive Industry)
WIFI	Wireless Fidelity
WLAN	Wireless Local Area Network
WP	Work Package