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ENSEMBLE

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

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FIGURES

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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 realise 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 harmonisation 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. During the years, the project goals are:

- Year 1: setting the specifications and developing a reference design with acceptance criteria
- Year 2: implementing this reference design on the OEM own trucks as well as perform 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 present deliverable aims to describe the events that occurred during the Public Demo, held in the Fira Congress Hotel in Barcelona the 23rd September 2021, whose main purpose was to show the results achieved by the EU research and Innovation project ENSEMBLE.

The Public Demo consisted in two main parts: a group of speeches (where the project coordinator and other relevant participants took the floor to speak about the project achievements) and a live platoon demonstration. This deliverable focuses in the second section, as the other information is available in the rest of the deliverables of the project. In the following pages an introduction and description of this public demo is shared. Finally, the conclusions are summarized.

2. INTRODUCTION

2.1. Background

This document refers to the Public Demonstration held in the Fira Congress Hotel in Barcelona the 23rd of September 2021, where the results achieved by the EU research and innovation project ENSEMBLE were shown in a live platoon demonstration.

2.2. Aim

This deliverable aims to describe and explain the main events occurred during the Public Demonstration held in Barcelona, focusing on the live platooning demo performed by the seven participant brands' trucks (Renault Trucks, Volvo Trucks, Scania, MAN, DAF, Daimler and IVECO - See Figure 1).

Figure 1. Seven brand's trucks prepared for the Public Demo in Barcelona

2.2.1. Positioning within ENSEMBLE WP5 Context

The objective of WP5 is the testing, validation and demonstration of the results achieved in the ENSEMBLE project. In this work package all testing is comprised, from integration testing until the final demonstration.

More precisely, the objective of the task that concludes with this deliverable is to showcase the benefits identified in task 5.4 with the demo vehicles developed within the scope of this project and validated in task 5.2.

2.3. Structure of this report

The core body of this report (Public demonstration, chapter 3) is divided in 5 parts. First of all, a summarized introduction is shown. The next step is the definition of the route and the explanation of why it was selected. In this chapter, the main description of the public demo is shown and this leads to an explanation of the main objectives achieved. Finally, the lessons learned and next steps are shown in order to continue developing the platooning technology.

3. PUBLIC DEMOSTRATION

3.1. Introduction

ENSEMBLE is the European Project whose main goal is to pave the way for the adoption of multi-brand truck platooning in Europe to improve fuel economy, traffic safety and throughput. [1]

Platooning technology has made significant advances in the last decade. Aiming for Europe-wide deployment of platooning, “multi-brand” solutions are paramount and that’s the ambition of ENSEMBLE project. [2]

Figure 2. Seven leading European brands

One of the main objectives of ENSEMBLE project is to implement and demonstrate multi-brand truck platooning on European roads and that is now a reality thanks to the public demonstration held in Barcelona the 23rd of September 2021. This was demonstrated by driving seven differently branded trucks in one (or more) platoon(s) under real world traffic conditions [1].

Figure 3. Seven trucks at the starting point of the route

In the following pages, a description of the selection of the route performed is explained, as well as the main objectives achieved, lessons learned and next steps for making platooning a reality.

3.2. Selection of the route

The route driven by the platoon during the public demonstration started in Barcelona. The trucks drove until the city of El Vendrell through a highway (AP7) and came back to Barcelona in an alternative route, also through a highway (C32) (see Figure 4).

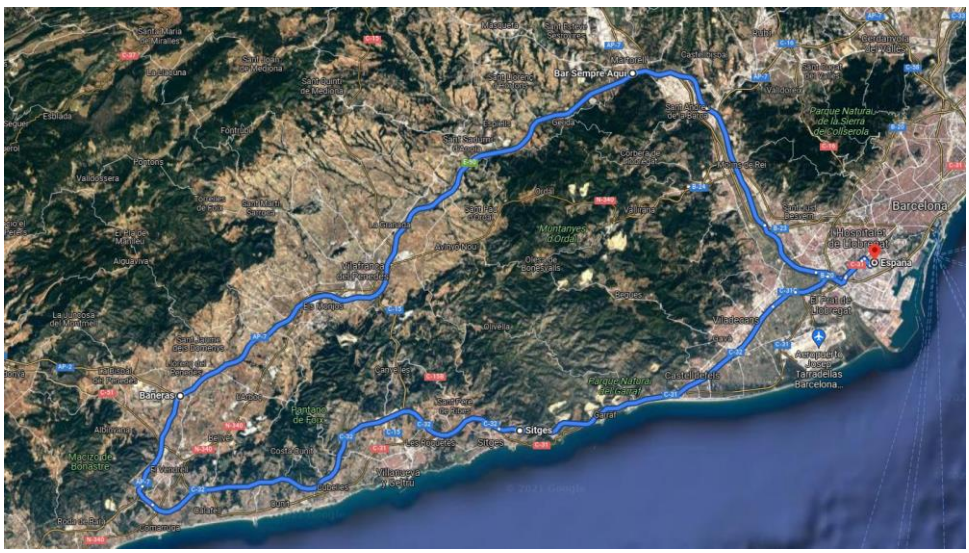

Figure 4. Route performed during the Public Demo

The total length of the route was 140km and it took approximately 2.5 hours to complete it. The trucks drove at around 80km/h (maximum allowed speed for trucks) during the route, despite

sometimes they needed to go lower to catch each other to stabilize the platoon. However, the speed never went down over 60km/h because that was the minimum speed allowed on the road.

This route was selected for the open road tests performed some days before the public demo in Barcelona (concretely 20th, 21st and 22nd of September). It is important to clarify that the trucks had already been tested before at IDIADA's proving ground. The main reason for this route selection is to show that ENSEMBLE platooning can be performed in different traffic situations (other quiet and busy traffic, tunnels, toll stations and bridges). For the selection of the Public Demonstration route, it is important to highlight that it was mandatory to start and finish the route in Barcelona (logistic hub).

The first half of the route was along the AP-7 route (Figure 5). The platooning system behaviour under conditions of gentle inclination gradients and under dense traffic conditions was checked.

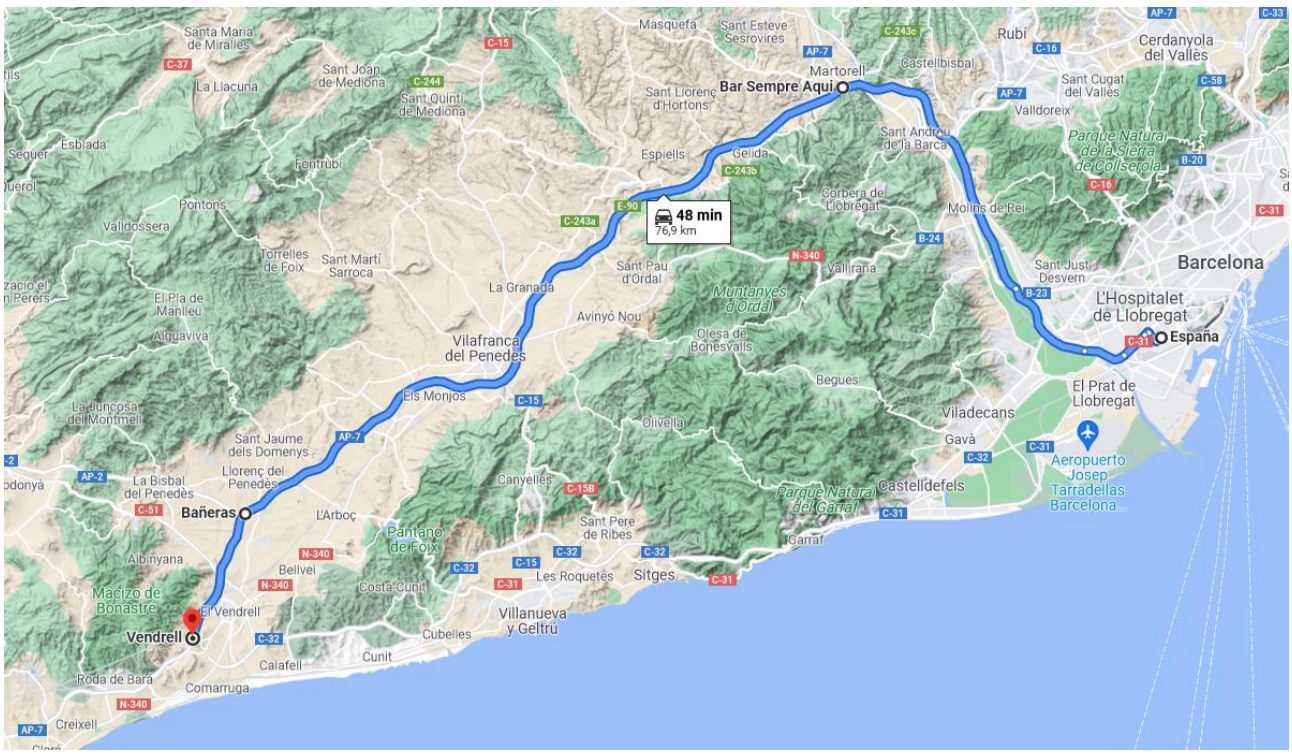

Figure 5. First half of the Public Demo route

The second half of the route was along the C-32 route. The platooning system behaviour (mainly communication part) under conditions with large concentration of bridges and tunnels was checked.

Figure 6. Second half of the Public Demo route

Figure 7 shows the concentration on the tunnels and bridges between Sitges and Castelldefels:

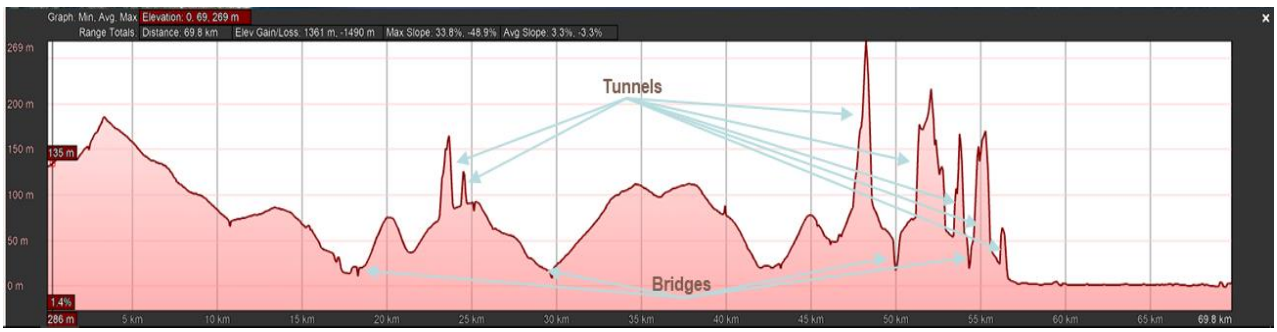

Figure 7. Relief variation, tunnels, and bridges of the 2nd half of the route

The start and end of the test route took place in the city of Barcelona where the congestion and complexity of the road network is very high (see figure 8).

Figure 8. Route's start and end point in Barcelona

There was traffic congestion in the area during the route. At the start of the journey the traffic police assisted in the smooth merge of platooning on the highway.

Figure 9. Trucks entering the highway

The entire test route has been drawn considering the recommendations of the Spanish traffic authorities and special approval for platooning has been granted.

3.3. Description of the Public Demo

On the 23rd of September the Public Demonstration event was held in Barcelona. Two possibilities were offered to participate in the event: physically or online. Because of this, many of the participants chose the online version, so a live broadcast of all speeches and events (such as the live broadcast of the platoon) was required. See Figure 10 for the program of the day.

Figure 10. Program of the Public Demo day, 23 Sept 2021

The day started with an Opening speech of the Catalan authorities, project partners representatives and the ENSEMBLE coordinator (Marika Hoedemaeker). After that, the seven trucks left the location of the public demo and started the route previously defined to show all the assistants the platoon driving mode. The truck platooning was followed by the audience by means of live stream and cameras on interesting spots and locations. While the trucks were performing the route, several presentations were held: Mr. Sarros gave an introduction on behalf of the EC and as the project officer of the ENSEMBLE project. Mr. Edoardo Mascalchi. and Mr. Joost van Doorn explained the communication protocol and the multi-brand specifications. Mrs. Willemsen explained the implementation in the trucks. Mr. Schmitting and Mrs. Sjoberg discussed the standardization necessity to continue the development of the platoon technology. Finally, Mrs. Schmidt explained the impacts of platooning, especially from the point of view of the asphalt. All these speeches can be found online on the official website, referenced in this document.

Between this sequence of speeches and presentations, two important milestones occurred with the performance of the platoon: its departure and its return. Meanwhile, the driving of the platoon was broadcasted live for the attendees (both physically and online).

Figure 11 shows the room where the attendees could enjoy the speeches and the experience of following the first multi-brand platoon route in the European roads.

Figure 11. Meeting room where the Public Demo was held

During the route, a set of cameras were installed in front of each truck and on different locations in the infrastructure. Also a car with a camera was following the platoon during the whole route.

The driving part of the Public Demo developed according to the timeline below:

- **10:45** all the trucks left parking area.
- **10:55** the platoon entered Gran Vía highway in Barcelona (ref. Figure 9).
- **11:30** the platoon passed filming camera location near Vilafranca del Penedes (AP-7 route).
- **11:55** the platoon passed toll station near Sitges (Figures 13,14).

Figure 12. Trucks leaving the Public Demo location

Figure 13. Trucks driving in platoon near to enter in the Toll Station

Figure 14. Trucks crossing the Toll Station near Sitges

- **12:15** the platoon left last tunnel near Garraf.

- **12:15-12:20** trucks order changed (Figure 15).

Figure 15. Trucks changing position in the platoon

- **12:40-12:45** trucks order changed – returned to the initial state.
- **13:00** trucks arrived at the final point – parking area (Figure 16).

Figure 16. Truck's arrival in the location of the Public Demo

During the public demo the trucks drove in three different orders (see Table 1).

Table 1. Trucks position in the platoon during the Public Demo

Time	10:45 – 12:15	12:15 – 12:45	12:45 – 13:00
Truck brand	**Truck's position in the platoon**		
IVECO	1	5	1
RENAULT TRUCKS	2	6	2
SCANIA	3	7	3
DAF	4	3	4
MAN	5	4	5
VOLVO TRUCKS	6	1	6
DAIMLER	7	2	7

During the Public Demo route execution the following test scenarios were encountered: Platoon join (including Joining from behind by single & multiple vehicle and merge in between), Steady State Platooning (incl. following a constant speed, acceleration & deceleration, gap variation), Cut-in, Cut-through, Cut-out and Steady state multiple vehicles cut-in.

There were several points where the platoon was temporarily disconnected or separated due to speed/distance, out of ODD (Operational Design Domain) range (on city roads) or V2V connection loss. Mainly this happened in the area of tunnels concentration between Sitges and Garraf.

One of the most challenging cases was going through toll stations. Here the trucks had to come to a stand-still and time was needed to restore platooning mode (Figures 13, 14). This shows one of the promising directions for further development of I2V communication to simplify the passage of such infrastructure objects.

The trucks' order was changed several times during the Public Demo execution in order to test the platoon's performance in different combinations (see Figure 15 and Table 1). Given that trucks of with different engine power participated in the Demo, this allowed the V2V close gap messages to be tested during driving uphill and high level of acceleration.

3.4. Main objectives achieved during the public demo

The main objective of ENSEMBLE project was to develop a V2V communication protocol which would support the correct behaviour and reaction of each of the trucks in the platoon for every envisioned traffic use case on the highway. This objective was achieved within the project duration and showed during the public demo. Thanks to the cameras installed in the trucks and on several strategic points of the road, the audience could see the platoon driving under different conditions, so the robustness of the system was also demonstrated.

To summarize, apart from the technical improvements that will be shown in the other deliverables from the WP5, the main achievements shown during the public demo were:

- V2X communication protocol that the trucks used to drive in platoon mode for 2,5 hours on the Catalan roads.
- Standardization and Interoperability between the trucks as all the 7-brands were able to communicate between them.
- Robustness of the system demonstrated by driving under different weather conditions (rainy and low visibility), road conditions (wet and dry) and traffic conditions (high and low density).

3.5. Lessons learned and next steps

The public demonstration showed the successful implementation of the current multi-brand platooning phase and the fulfilment of the main tasks of the work package.

The success of the day relied heavily on the intense testing and problem solving that was performed in the 2 full weeks preceding the public demo day. One of the main lessons learned is that testing on a test track is very important to make platooning between different brands of trucks actually work. In the first 2 years of the project, the specifications were discussed and agreed upon on paper. Then each OEM started implementing the agreed specifications and testing it first with their own brand (mono-brand). But only when different brands come together to test, it is possible to establish minor differences in implementation (of the same specifications), which can make the total platoon functioning fail. Therefore the 2, 3, and 4 brand testing as a preparation turned out to be very important. But the most important testing was the final testing with all 7 brands together.

Another lessons learned is that also testing on real public roads is necessary as a preparation for a successful public demonstration. During this testing, issues with driving through toll gates and tunnels were encountered. These issues could be fixed in time because after every testing day conclusions were drawn and possible updates were decided upon together and immediately implemented in the trucks.

The collaboration with all the partners throughout all the meetings, workshops, and the demonstrators was one of the main points of the good results obtained. We can all learn a lot from each other, strengthen ourselves through this collaboration and this ends up with a better end-result.

During the Public Demo session, we were able to see how the experts were interested on how the trucks were communicating and what really happened inside when finding a situation hard to handle. For sure, the live cameras allow them to see the trucks driving but with only the video images it wasn't enough to demonstrate all the hard work developed behind. For the next demonstrations, we received some recommendations to also try to show all the messages interchanged between brands to see, for example, how a truck asks to join or to leave a platoon complemented with the video images that were already shown.

Thanks to this public demo and all the different comments from all the experts who attend the event, it can be said that the research has to take the following direction:

- Further standardization of the platooning and the V2V communication protocol. We are just at the beginning of this Interbrand communication, and the protocol can be developed much further in order to achieve even better results.

- Perform the same type of event in different locations of EU, in order to showcase that the platoon is able to adapt to all European roads, traffic rules and traffic and climate conditions.

4. SUMMARY AND CONCLUSION

Overall, the public demonstration was as successful as the previous phases of project development.

During the test drive it was possible to demonstrate the correct operation of the system in the face of infrastructure and environmental influences: traffic on different types of roads, electromagnetic interference from urban infrastructure, tunnels, bridges, toll stations, etc.

The public demonstration showed the successful implementation of the current multi-brand platooning phase and the fulfilment of the main tasks of the work package.

The current implementation maturity phase allows the transition to the next phases of multi-brand platooning in accordance with the roadmap towards more autonomous platooning.

5. BIBLIOGRAPHY

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6. APPENDIX. DEFINITIONS & ACRONYMS

6.1.1. 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.
ODD (operational	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,

Term	Definition
design domain)	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 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

Term	Definition
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.
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

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

6.1.2. 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
GN	GeoNetworking
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GUI	Graphical User Interface

Acronym / Abbreviation	Meaning
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
PMC	Platooning Mode Control
QM	Quality Management
RSU	Road Side Unit
SA	Situation Awareness

Acronym / Abbreviation	Meaning
SAE	SAE International, formerly the Society of Automotive Engineers
SCH	Service Channel
SDO	Standard Developing Organisations
SIL	Software-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