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

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Revision history

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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 traffic safety, fuel economy, and throughput. This has been demonstrated by driving up to seven differently branded trucks in one (or more) platoon(s) under real world traffic conditions. During the years, the project was organised as follows:

- Year 1: setting the specifications and developing a reference design;
- Year 2 and 3: implementing this reference design on the OEM own trucks, as well as performing impact assessments with several criteria;
- Year 4: focus on testing the multi-brand platoons on test tracks and public road.

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

Platooning levels

Two levels of platooning have been defined:

- **Platooning Support Function**: the driver is responsible for the driving task. Hence (s)he is also responsible to choose a safe following distance and monitor the system e.g. whether the right platooning partner is being followed (though supported by the system as much as possible). To give the driver sufficient time to react, minimum time gaps around 1.5 s have to be respected. The Platooning support function is a longitudinal control function, but lateral driver assistance systems, such as e.g. lane keeping, might be optionally available as well.

- **Platooning Autonomous Function**: The leading truck has a driver responsible for the driving task, but the following trucks are fully automated, i.e. the system performs the complete driving task within the specified (limited) operational design domain. Taking the driver(s) out-of-the-loop offers the possibility to reduce time gaps to a minimum of 0.3 s.

In contrast to the Platooning Support Function, implementation of the Platooning Autonomous Function is not part of the ENSEMBLE project and the specification of the Platooning Autonomous Function and its use cases is solely done on theoretical considerations to sketch a future vision of platooning. The latter is also due to the low technology readiness level of certain required autonomous driving subfunctions at the time of writing.

1.2. Abstract of this Deliverable

This deliverable provides the SOTIF (ISO/PAS 21448 - Safety of The Intended Functionality (ISO/PAS21448, 2019)) requirements that are applicable to platooning autonomous function as defined in the deliverable D 2.3 - Platooning use-cases, scenario definition and Platooning Levels (Willemsen, 2022).

Chapter 2 provides an overview of the basic concepts of Safety of the Intended Functionality (SOTIF) (ISO/PAS21448, 2019).

Chapter 3, dedicated to the Platooning Support Function (PSF), provides the rationale for why the SOTIF analysis as previously carried out for Platooning level A function, was not repeated for the platooning support function.

Chapter 4, dedicated to the Platooning Autonomous Function (PAF), applies the System Theoretic Process Analysis (STPA) method to derive functional requirements to avoid or mitigate safety risks arising from performance limitations and functional insufficiencies of the PAF.

Chapter 5 consists of summary and conclusions pertaining to the SOTIF analysis of the Platooning Autonomous Function (PAF).

For the PAF, system theoretic process analysis (STPA) method was applied to firstly identify safety critical losses and vehicle level hazards and then, to define a control structure diagram for the PAF to facilitate identification of the unsafe control actions (UCAs) arising from each of the controllers. Once the safety critical UCAs were identified, around 100 different loss scenarios were defined to identify the causal factors (triggering conditions and the functional insufficiencies) that can lead to the safety critical UCAs. Finally, 180 different functional requirements were defined to avoid or mitigate the safety risk arising from the PAF.

2. INTRODUCTION

2.1. Background

Safety of the Intended Functionality (SOTIF) aims to avoid unreasonable risk caused by hazards associated with the nominal functionality and its implementation. This includes hazards arising from technological and system shortcomings, insufficiencies of specifications, performance limitations and reasonably foreseeable misuse. Hazards arising due to E/E failures are dealt separately through functional safety analysis and do not form part of this deliverable.

The current standard available on SOTIF is the ISO/PAS 21448 (ISO/PAS21448, 2019). This standard is generally applicable to Advanced Driver Assistance Systems (ADAS) with SAE automation levels (1 and 2) (SAEJ3016, 2014) where proper situational awareness derived from complex sensors and processing algorithms is critical to safety.

2.2. Key SOTIF definitions and concepts

2.2.1. Definitions

This section defines key vocabulary used for SOTIF activities.
Note: *The following definitions are taken from ISO 21448* (ISO/PAS21448, 2019)*, ISO 26262* (ISO26262, 2018) *and J3016* (SAEJ3016, 2014) *for consistency.*

Operation Design Domain (ODD):
Operating conditions under which a given driving automation system or feature thereof is specifically designed to function, including, but not limited to, environmental, geographical, and time-of-day restrictions, and/or the requisite presence or absence of certain traffic or roadway characteristics."

Use case
A specific situation in which a vehicle could potentially be used.

Operational situation
A scenario that can occur during a vehicle's life.

Scenario
Description of the temporal development between several scenes in a sequence of scenes.

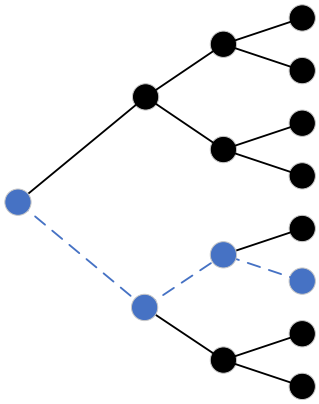

Figure 1 - Scenario (dashed) as a temporal sequence of events (edges) and scenes (nodes)

Scene
Snapshot of the environment including the scenery, dynamic elements, and all actor and observer self-representations, and the relationships between those entities.

Misuse
Usage of the system by a human in a way not intended by the manufacturer of the system.
Misuse can result from overconfidence in the performance of the system.
Misuse also includes human behaviour that is not specified but does not include deliberate system alternations.

Triggering Events
Specific conditions of a driving scenario that serve as an initiator for a subsequent system reaction possibly leading to a hazardous event.
E.g. while driving in a platoon, a vehicle misidentifies a road sign as a lead vehicle resulting in braking at X g for Y seconds.

Hazard
A potential source of harm caused by unintended behaviour of the function.

Hazardous Event
Combination of a hazard and an operational situation.

Harm
Physical injury or damage to the health of persons.

Hazardous Event Model
The diagram below provides a visualization of a potential SOTIF related hazardous event model.

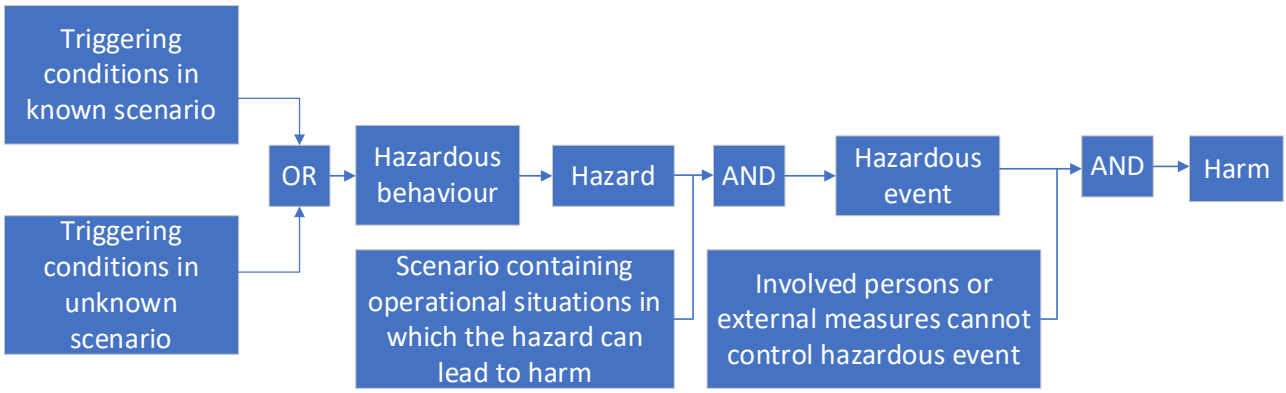

Figure 2 - Hazardous Event Model (ISO/PAS 21448)

The operational design domain (ODD) of the function consists of several use cases that contain triggering events related to external factors such as environmental conditions, road conditions, traffic conditions or driver misuse. The hazards arising from these triggering events, when combined with specific operational scenarios, lead to a hazardous event that can result in harm.

2.2.2. SOTIF Scenarios

The scenarios that can be encountered within the operational design domain (ODD) of any automated driving function can be categorised as below:

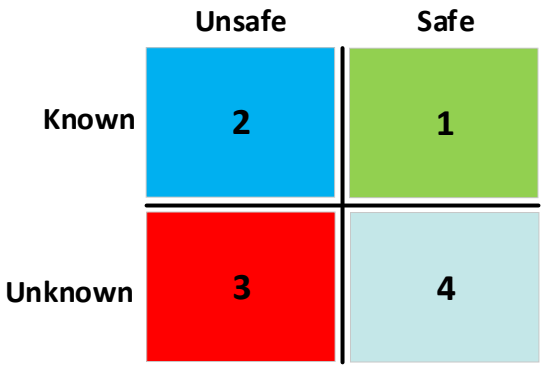

Figure 3 - SOTIF scenario categories

1. Known Safe Scenarios
2. Known unsafe scenarios
3. Unknown unsafe scenarios
4. Unknown safe scenarios

The diagram below provides a graphical view of how all the scenarios that can be encountered by an autonomous system in the field are categorised. The area under each region is roughly representing the number of scenarios in each category.

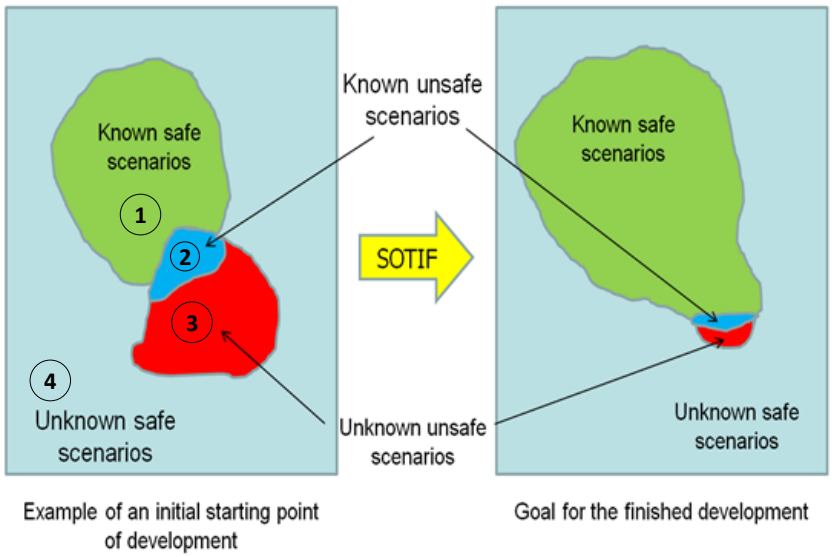

Figure 4 - Evolution of scenario categories (ISO /PAS 21448)

At the start of the SOTIF activities, the area under the unsafe scenarios (both known and unknown) is large resulting in unacceptable residual risk. The objective of the SOTIF activities is to identify and reduce the number of unsafe scenarios such that the residual risk falls to an acceptable level.

The goals of the SOTIF activities with respect to Area1, Area2, and Area3 (see Figure 4 - Evolution of scenario categories (ISO /PAS 21448)) and relevant scenarios are:

- **Area1:** Maximize or maintain area, by minimizing the areas 2 & 3. This retains or improves safe functionality.
- **Area2:** Minimize area by identifying the risks arising from the known unsafe scenarios and implement technical measures to improve the function (if possible) or by restrict performance or use of the function (e.g. redefining ODD). Once the measures are evaluated through testing, the scenarios can be moved to Area 1.
- **Area3:** Minimize area (the risk of the unknown) using field operational (validation) tests to identify previously unidentified unsafe scenarios and move them to Area 2.

2.3. Aim

This deliverable aims to provide preliminary set of functional requirements resulting from the SOTIF analysis of the ENSEMBLE Platooning Support Function and the Platooning Autonomous Function. The activities carried out for this deliverable form part of the SOTIF design phase, where known unsafe scenarios are explored to identify functional insufficiencies and performance limitations that can lead to hazardous behaviour by the system. Finally, functional requirements are defined to avoid

or mitigate the identified SOTIF related safety risks arising from the identified performance limitations and functional insufficiencies.

An exploratory analysis method called System Theoretic Process Analysis method (STPA) (N. G. Levenson, 2018) has been used to complete the above-mentioned activities.

3. PLATOONING SUPPORT FUNCTION (PSF)

Since the ENSEMBLE Platooning Support Function (PSF) maintains the same time gaps as the existing production approved adaptive cruise control (ACC) systems, including the use of same perception sensors for situational awareness, additional SOTIF analysis was deemed unnecessary for this function. Instead, the SOTIF work of this deliverable is dedicated to the ENSEMBLE Platooning Autonomous Function (PAF).

4. PLATOONING AUTONOMOUS FUNCTION (PAF)

4.1. Introduction to the ENSEMBLE Platooning Autonomous Function (PAF)

The main characteristics of the Platooning Autonomous Function (PAF) defined within the ENSEMBLE project can be summarised as follows:

- Automation level: similar to SAE L4 (SAEJ3016, 2014) (for the following trucks when part of the platoon).
- Both longitudinal and lateral motion of the following trucks is automated.
- Driver is mandatory in the leading truck. Drivers in the following trucks are optional (out of the loop).
- Leading truck is manually driven. Can use ADAS functions (similar to L2) but is not part of the platooning function.
- The autonomous system in the following trucks is responsible for DDT (Dynamic Driving Task) and the system is the fallback.
- Operational Design Domain (ODD): Specific Hub to Hub driving routes on EU roads fall within the ODD. The vehicles drive autonomously on the highways and also on the route between the highways and the nearby transportation hubs.
- Time gap: Since drivers are no longer responsible for DDT or are used as fallback, time gaps (TGs) can be lower than 1.4s. The time gap is calculated following a brake performance estimation.

Note: Detailed specifications can be found in D2.5 - Functional specification for while-label trucks (Mascalchi E., 2022). A detailed level definition and the respective use cases can be found in D2.3 – Platooning use cases, scenario definition and platooning levels (Willemsen, 2022).

Important assumptions on safety analysis:

- Leading truck driver is not responsible for the safety of the following trucks. The driver's role is to follow the traffic rules for the entire platoon and guide the leading truck and the following trucks to the destination.
- Each following truck is responsible for its own Object and Event Detection and Response (OEDR) and does not depend on the leading truck or the forward truck to avoid collisions. Following trucks are not responsible for following traffic rules nor to reach destination.

4.2. Introduction to the System Theoretic Process Analysis (STPA)

STPA (System Theoretic Process Analysis) is a hazard analysis technique based on an extended model of accident causation, a systematic method of ascertaining the causes of an accident. Unlike traditional safety analysis methods like Failure mode and effects analysis (FMEA), Hazard Operability (HAZOP) or other, similar ones, STPA assumes that accidents are not only caused by failures of components but can also be caused by unsafe interactions between components of a system.

Why is STPA used?

Traditional hazard analysis methods define hazards by describing potential deviations from specified function or by describing physical component failures. For SOTIF, since we are analysing the safety of the intended function, it cannot be assumed that the specified function is always safe and correctly defined and that operators will always behave as expected.

Hazards identification using STPA is about identifying vehicle states that are inherently unsafe – regardless of the cause. For e.g. the hazard “Vehicle exceeds maximum speed limit” is unsafe irrespective of whether the hazard was caused by an E/E malfunction or incorrect recognition of the speed limit sign.

STPA method identifies the hazards by first determining the losses (e.g. loss of life) that we want to avoid and then identifies the vehicle states which can result in those loses without analysing the specified function and it’s deviations.

The STPA analysis consists of 4 main steps:

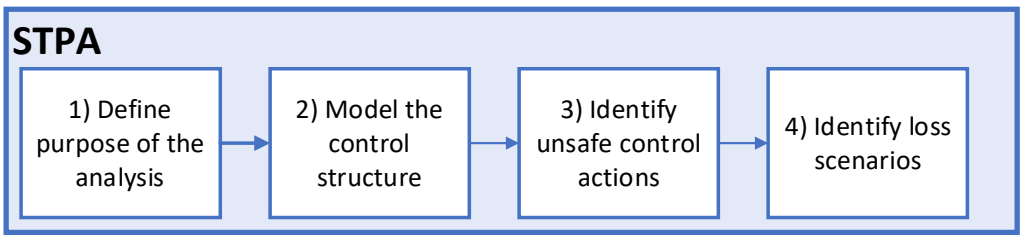

Figure 5 - STPA steps

4.3. STPA Step 1: Define the purpose of the analysis

The first step in STPA is to define the purpose of the analysis. This step consists of four parts:

- Identifying losses.
- Identifying system-level hazards.
- Identifying system-level constraints.

- Refining hazards (optional).

Part 1: Identify Losses:

The main goal of the STPA is to prevent “losses”. A loss is deprivation of something of value to the stakeholders. STPA can be used to target any loss that is unacceptable to the stakeholders. If more than one loss is identified, they can be ranked and prioritized.

For the analysis of the Platooning Autonomous Function, the following losses can be considered:

Table 1 - Losses

Loss ID	Description
L1	Loss of life or injury to people
L2	Loss of or damage to the vehicle
L3	Loss of or damage to objects outside the vehicle
L4	Loss of mission (vehicles do not reach their destination, cannot form a platoon, ...)
L5	Loss of customer satisfaction (ride not comfortable, does not obey traffic rules, etc)
L6	Loss of sensitive information (e.g. cyber security issues)
L7	Environmental loss (depending on what is being carried by the trucks. E.g. toxic materials)

For SOTIF, we are only concerned with the safety of the occupants and other road users. Therefore, only the loss “L1: Loss of life or injury to people” is considered for further analysis.

Part 2: Identify system level hazards:

A hazard is a system state or set of conditions that, together with a particular set of worst-case environmental conditions, will lead to a loss.

The generic term “system” is used in the STPA method to include any systems like aeroplanes, road vehicles, power plants, organisations, etc. So, a system as per STPA is equivalent to a vehicle in the context of automotive engineering.

Basic guidelines to define vehicle/system Hazards:

1. Hazards are system states or conditions (not component-level causes or environmental states). i.e. do not define hazards based on the causes of the hazards like unintended hydraulic leak, insufficient fluid, incorrect trajectory prediction, etc…

2. Hazards should refer to factors that can be controlled or managed by the system designers and operators.

E.g. “Obstacle on the road” or “adverse weather condition” are not vehicle hazards since they cannot be controlled by the system.

3. Hazards must describe states or conditions to be prevented. E.g. vehicle decelerates (this is a state we want the vehicle to be in under certain conditions, so just the state of “vehicle decelerates” without context should not be defined as a hazard).

4. Avoid ambiguous or recursive wording like "unsafe", “unintended”, etc... E.g. unsafe deceleration (unsafe deceleration has no context)

5. Hazards will lead to a loss in some worst-case environment.

Platooning Hazards:

Applying the above rules, 8 main vehicle level hazards can be derived for the Platooning Autonomous Function:

Table 2 - Hazards

Hazard ID	Description	Linked Losses
H1	Vehicle does not maintain safe distance to nearby objects (laterally and/or longitudinally).	L1, L2, L3, L5
H2	Vehicle exceeds safe operational envelope for lateral and/or longitudinal forces (unsafe for the occupants).	L1, L5
H3	Vehicle occupants are exposed to harmful cargo or health hazards from within the vehicle. E.g. spill of toxic cargo, fire, electric shock	L1, L2, L5, L7
H4	Platoon is split before reaching the destination.	L4, L5
H5	Platoon violates traffic rules.	L5
H6	Platoon cannot be formed.	L4, L5
H7	Platoon cannot be disengaged.	L5
H8	Trucks join the platoon without lead driver's approval.	L5, L6

Since SOTIF is only concerned with safety of the occupants and other road users, only the hazards that can lead to “L1: Loss of life or injury to people” will be considered for further analysis. From the above table, these would be Hazards H1, H2 and H3.

Part 3: Identifying system level constraints:

A system/vehicle-level constraint specifies system conditions or behaviours that need to be satisfied to prevent hazards (and ultimately prevent losses). These are akin to safety goals in functional safety. They can be derived by simply inverting the hazardous condition.

The vehicle-level constraints should not specify a particular solution or implementation.

The paragraphs below derive vehicle level constraints for the safety relevant hazards:

Table 3 - H-1 safety constraints

H-1	Vehicle does not maintain safe distance to nearby objects (laterally and/or longitudinally).
SC-1	Vehicle shall maintain minimum safe distance to nearby objects.
SC-2	When minimum safe distance to nearby objects is violated, then the violation must be detected, and measures shall be taken to avoid collision.

Since safe distance can be violated by unsafe actions of other road participants (e.g. cut ins), system constraint (SC2) is defined to minimise losses when this occurs.

Table 4 - H-2 safety constraints

H-2	Vehicle exceeds safe operational envelope for lateral and/or longitudinal forces (unsafe for the occupants).
SC-3	When not in conflict with SC2, the vehicle shall only operate within the safe envelope for lateral and longitudinal forces.

When SC 1 is violated (e.g. obstacle falling from a preceding truck), then the SC3 can be violated to avoid collision.

Table 5 - H-3 safety constraints

H-3	Vehicle occupants are exposed to harmful cargo or health hazards from within the vehicle. E.g. spill over of toxic cargo, fire, electric shock
SC-4	The vehicle occupants shall not be exposed to harmful cargo or other health hazards from within the vehicle.

Part 4: Refine vehicle level hazards:

This step is not mandatory, but in complex systems it can guide further actions like modelling the control structure (see step 2). For the current project, this step is skipped since the refined hazards are similar to unsafe control actions defined in step 3.

4.4. STPA Step 2: Modelling the control structure

The next step in STPA is to model the hierarchical control structure. A control structure is a system model that is composed of control and feedback loops. It is used to define the unsafe control actions (UCAs) required for the next phase of STPA.

The control structure shall follow the below architecture:

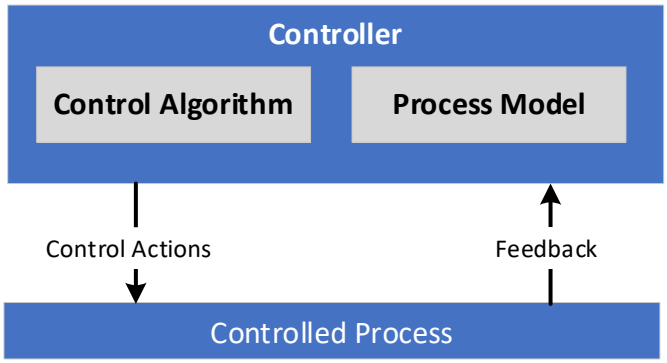

Figure 6 - Standard architecture of a control structure

A controller provides control actions to control some process and to enforce constraints on the behaviour of the controlled process.

The control algorithm represents the controller's decision-making process. It determines the control actions to provide based on the feedback from the sensors and its current understanding of the world.

Process models represent the controller's internal beliefs used to make decisions. Process models may include beliefs about the process being controlled or other relevant aspects of the system or the environment. Process models may be updated in part by feedback used to observe the controlled process.

Note: *The standard architecture and the above text is taken from the STPA handbook* (N. G. Levenson, 2018) *for consistency.*

Basic guidelines to build control structures:

1. Each entity must have control and authority over the entities immediately below it.
2. All downward arrows represent control actions (commands) while the upward arrows represent feedback.

3. If there are interactions that are neither control nor feedback interaction, horizontal arrows can be used. E.g. for passing information between elements.

4. Interpretation of feedback should not be considered as control action. Control involves making purposeful decisions to achieve a goal. E.g. detecting lane lines is not a control action, whereas requesting to activate “lane following mode (LFM)” to the following trucks is a control action.

5. Capture functional relationships and functional interactions instead of technical details of the components. E.g. CAN communication, SOC computers, etc.

6. Specifying sensors and actuators are not needed. At this stage, what is informed or controlled is important, not how. E.g. control action to apply brakes is necessary but not details of hydraulics or electromechanical actuators.

The following diagram presents the control structure diagram for the Platooning Autonomous Function:

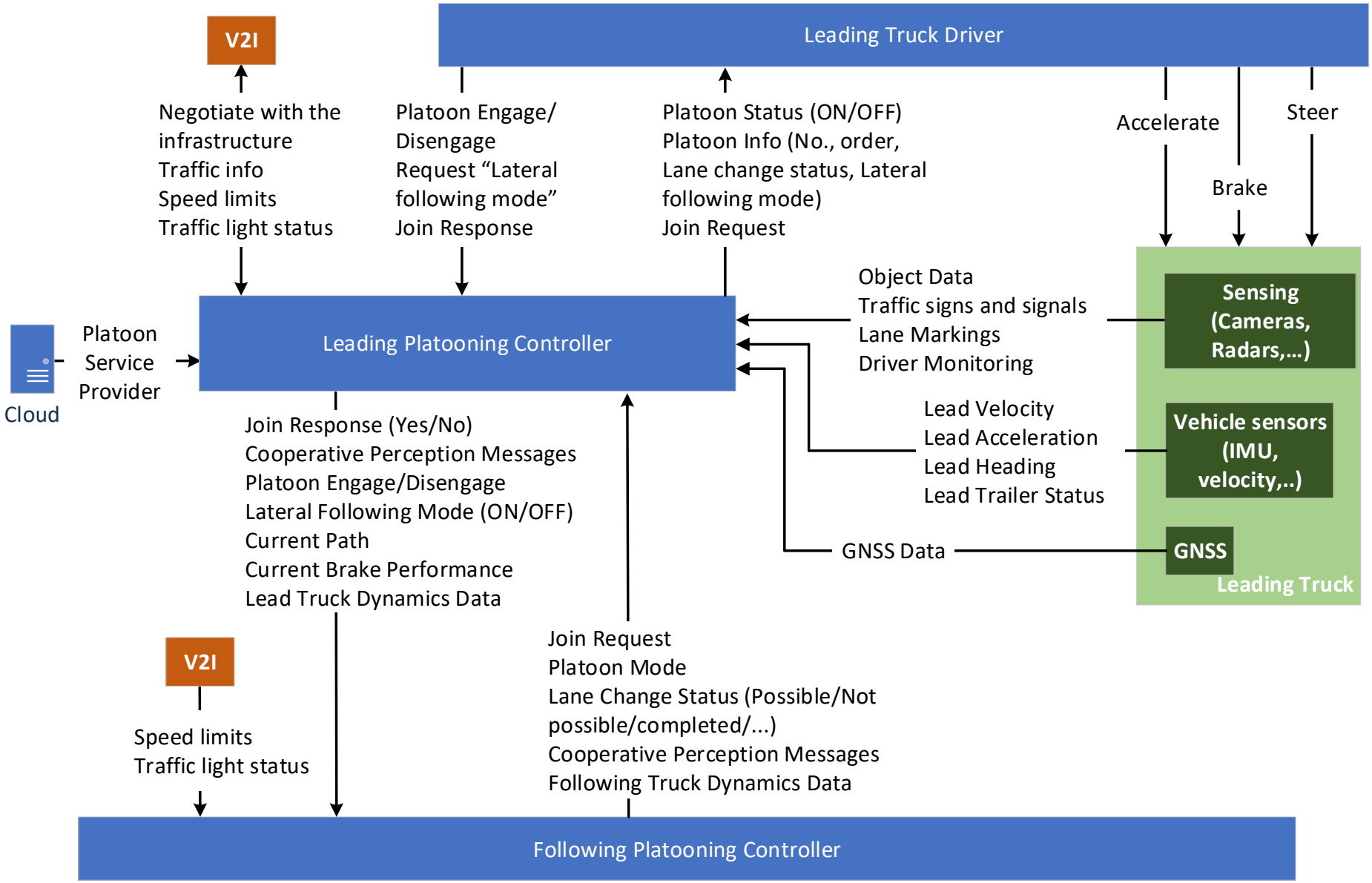

Figure 7 - Platooning Autonomous Function Control Structure

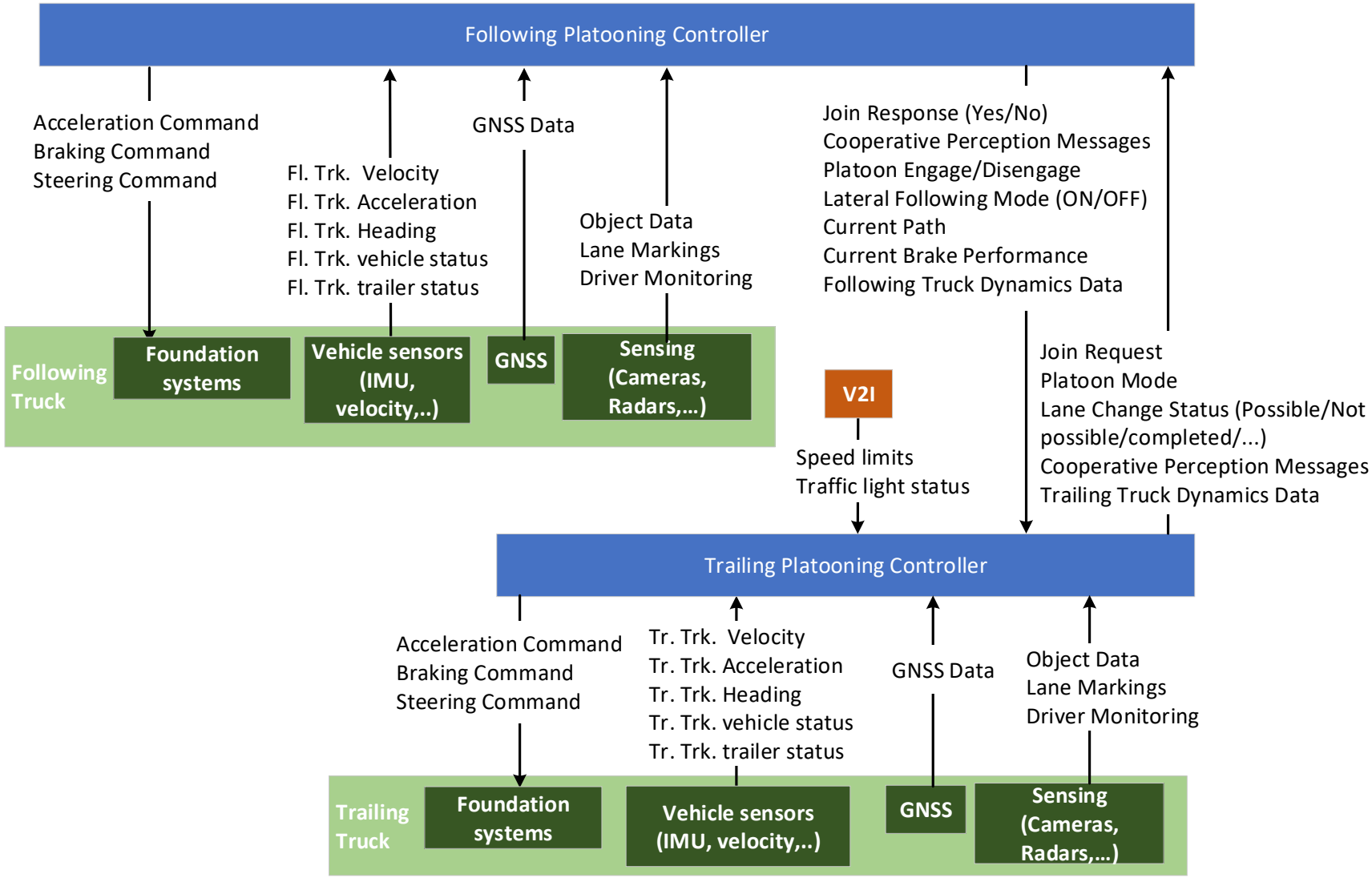

Figure 8 - Platooning Autonomous Function Control Structure (Fl. Trk. = Following Truck, Tr. Trk. = Trailing Truck)

Three main controllers are present in the Platooning Autonomous Function's control structure that interact with each other and the environment:

1. **Leading truck driver ('lead driver')**: The driving task of the leading truck is not automated by the platooning function. The lead driver is responsible to drive the leading truck and is responsible to follow the road rules for the entire platoon and guide the platoon to the destination.

   The lead driver also activates/deactivates the platooning function and receives and approves/disapproves join requests from other trucks.

   The lead driver is not responsible for the safety of the following trucks.

2. **Leading truck platooning controller**: The leading truck platooning controller is responsible to respond to join request and communicate cooperative perception messages, platoon mode, leading truck path, brake performance and the leading truck dynamics data (e.g. current acceleration) to the following truck. It is also responsible to negotiate with the infrastructure for the entire platoon.

   The leading truck platooning controller also receives feedback from the following truck about platoon modes, lane change status and join/leave requests.

3. **Following truck platooning controller**: The following trucks can be manned but are driverless. i.e. no driver is available for fallback. Therefore, the platooning controller of each following truck is responsible to drive the ego vehicle. It perceives the environment around the truck through onboard perception sensors and the messages of cooperative perception received from the forward truck. Based on this information, it determines the trajectory to follow and sends control commands to the foundation systems (propulsion, braking and steering).

   The following trucks do not depend on the other vehicles for the task of Objects and Events detection and response (OEDR). Each truck is responsible for its own safety.

4.5. STPA Step 3: Identifying Unsafe Control Actions

The next step of the STPA procedure is to identify the Unsafe Control Actions (UCAs). An UCA is a control action that, in a particular context and worst-case environment, will lead to a vehicle-level hazard.

There are four ways a control action can be unsafe:

1. Not providing the control action leads to a hazard (loss of a function).

2. Providing the control action leads to a hazard (unintended, incorrect parameters, reverse, too quick, too slow, insufficient, excessive, etc.)

3. Providing a potentially safe control action but too early, too late, or in the wrong order

4. The control action lasts too long or is stopped too soon (for continuous control actions, not discrete ones)

The following section applies the above 4 categories of deviations of a control action to identify the unsafe control actions that can originate from each of the three controllers (leading truck driver, leading truck platooning controller and following truck platooning controller).

Each unsafe control action has its associated hazards mentioned next to it in square brackets for reference. As previously stated, “unsafe” in the context of STPA refers to any hazard that leads to the identified losses, with also include non-life-threatening hazards like loss of mission, loss of customer satisfaction, loss of sensitive information, etc. For e.g. the UCA “Leading truck driver does not activate the platooning function before starting the journey [H6]” this implies that the UCA of not activating the platooning function results in hazard H6: Platoon cannot be formed.

Since the main purpose of this deliverable is to define requirements to avoid or mitigate unsafe SOTIF scenarios, only the unsafe control actions that are linked to safety critical hazards (H1, H2 and H3) will be analysed further to define the loss scenarios (STPA step 4). (see :

Table **2 - Hazards** for the entire hazard list).

4.5.1. Control Actions by the leading truck driver

This section derives the unsafe control actions that can result from the actions of the leading truck driver.

Table 6 - UCAs Platoon Engage/Disengage

Control Action	Not providing causes hazard	Providing causes hazard	Too early, too late, out of order	Stopped too soon, applied too long
Platoon Engage/Disengage	Leading truck driver does not activate the platooning function before starting the journey [H6]	Leading truck driver deactivates the platooning function before reaching the destination [H4]	N/A	N/A
	Leading truck driver does not deactivate platooning function at the end of the journey [H7]			

Conclusions: As per the current definition of the Platooning Autonomous Function, each following truck is responsible for its own (Object and event detection and response) OEDR and does not depend on the leading truck or the forward truck to avoid collisions. Therefore, unsafe control actions during engaging/disengaging the platoon do not lead to Hazards H1, H2 or H3. Each following truck is still able to perceive its surroundings and stop safely when required. Therefore, this control action is not analysed further in this document.

Table 7 - UCAs Request "Lateral following mode"

Control Action	Not providing causes hazard	Providing causes hazard	Too early, too late, out of order	Stopped too soon, applied too long
Request "Lateral following mode"	Leading truck driver does not activate "Lateral following mode" at road works [H4, H5].	Leading truck driver activates "Lateral following mode" when not required [H5].	Leading truck driver activates the "Lateral following mode" after a delay at road works [H4, H5].	N/A
	Leading truck driver does not		Leading truck driver activates the "Lateral	

	activate "Lateral following mode" at toll gates [H4, H5].		following mode" after a delay at toll gates. [H4, H5].	
			Leading truck driver deactivates the "Lateral following mode" before reaching the end of the road works [H4, H5].	
			Leading truck driver deactivates the "Lateral following mode" before the entire platoon crosses the toll gate [H4, H5].	

Conclusions: The lateral following mode (LFM) assists the following trucks to follow the path precisely and maintain cohesion in complex driving scenarios. But each following truck is still responsible for the task of object and event detection and response (OEDR). Therefore, the UCA related to LFM lead to loss of mission (e.g. platoon is split) but does not cause safety critical accidents. Therefore, this control action is not analysed further in this document.

Table 8 - UCAs Join Request's Response

Control Action	Not providing causes hazard	Providing causes hazard	Too early, too late, out of order	Stopped too soon, applied too long
Join Request's Response	Leading truck driver does not respond to the join request [H4].	Leading truck driver accepts join request even when three trucks are already present in the platoon [H5].	Leading truck responds to the join request after a delay [No Hazard].	N/A

Conclusions: Unsafe control actions when responding to the join request by the lead driver will not result in safety critical accidents. They are mainly related to hazards that lead to loss of mission or loss of customer satisfaction. Therefore, this control action is not analysed further in this document.

Main conclusion on Unsafe Control Actions (UCAs) of the leading truck driver:
In conclusion, incorrect control actions by the leading truck driver only lead to loss of mission related hazards but does not lead to safety critical accidents. They will not be considered for deriving the loss scenarios.

4.5.2. Control actions common to both the leading truck platoon controller and the following truck's platooning controller:

This section derives unsafe control actions (UCAs) that can result from the actions that are common to both the leading truck platooning controller and the following truck platooning controller.

Table 9 - UCAs Communicate Join Request's Response

Control Action	Not providing causes hazard	Providing causes hazard	Too early, too late, out of order	Stopped too soon, applied too long
Communicate Join Request's Response	Platooning controller does not communicate lead driver's response to join request [H6].	Platooning controller communicates "Yes" when "No" was responded by the driver to join request [H8]	Platooning controller communicates driver's response to join request after a delay [No hazard]	N/A
		Platooning controller communicates "No" when "Yes" was responded by the driver to join request [H6].		

Conclusions: Unsafe control actions when responding to the join request by the platooning controller will not result in safety critical accidents. They are mainly related to hazards that lead to loss of mission or loss of customer satisfaction. Therefore, this control action is not analysed further in this document.

Table 10 – UCAs Communicate co-operative perception messages

Control Action	Not providing causes hazard	Providing causes hazard	Too early, too late, out of order	Stopped too soon, applied too long
Communicate co-operative perception messages	Platooning controller does not communicate co-operative perception messages to the following trucks [No Hazard].	Platooning controller communicates incorrect co-operative perception messages to the following trucks [No Hazard].	Platooning controller communicates co-operative perception messages after a delay [No Hazard].	N/A

Conclusions: Since each following truck has its own perception sensors, the co-operative perception messages shall only be used as an add-on but will not be used as the only source of information to make safety critical decisions. Each truck will depend on its own on-board sensors for safety critical decisions related to situational awareness. Therefore, this control action is not analysed further in this document.

Table 11 - UCAs Communicate Lateral following mode request (ON/OFF)

Control Action	Not providing causes hazard	Providing causes hazard	Too early, too late, out of order	Stopped too soon, applied too long
Communicate Lateral following mode request (ON/OFF)	Platooning controller does not activate "Lateral following mode" at road works [H4, H5]	Platooning controller activates the "Lateral following mode" when not required [H5].	Platooning controller activates the "Lateral following mode" after a delay at road works [H4, H5].	Platooning controller deactivates the "Lateral following mode" before reaching the end of the road works [H4, H5].
	Platooning controller does not activate "Lateral following mode" at toll gates [H4, H5]		Platooning controller driver activates the "Lateral following mode" after a delay at toll gates [H4, H5].	Platooning controller deactivates the "Lateral following mode" before the entire platoon crosses the toll gate [H4, H5].

Conclusions: The LFM assists the following trucks to follow the path precisely and maintain cohesion in complex driving scenarios. But each following truck is still responsible for the object and event detection and response (OEDR). Therefore, the UCA related to LFM lead to loss of mission (e.g. platoon is split), but not safety critical accidents. Therefore, this control action is not analysed further in this document.

Table 12 – UCAs Communicate current path

Control Action	Not providing causes hazard	Providing causes hazard	Too early, too late, out of order	Stopped too soon, applied too long
Communicate current path	Platooning controller does communicate its current path while driving [H4, H5].	Platooning controller does communicate incorrect path while driving [H4, H5].	N/A, delay will be treated as incorrect path.	N/A.

Conclusions: The path data is required to reach the destination without splitting the platoon, but each following truck is still responsible for the object and event detection and response (OEDR). Therefore, if the path data is lost or incorrect data is provided, the platoon will split but will not lead to accidents.

Table 13 – UCAs Communicate current brake performance

Control Action	Not providing causes hazard	Providing causes hazard	Too early, too late, out of order	Stopped too soon, applied too long
Communicate current brake performance	Platooning controller does not provide its current brake performance to the following truck [No Hazard].	Platooning controller provides higher than actual brake performance value to the following truck [No Hazard].	N/A	N/A
		Platooning controller provides lower than actual brake performance value to the following truck [H1].		

Conclusions: Communicating lower than actual brake performance value is safety critical because the following truck might maintain a lower time gap due to false confidence in its ability to avoid collision in emergency braking situations. This UCA (that can lead to hazard H1) will be considered for deriving loss scenarios in the next phase.

Table 14 - UCAs Communicate truck dynamics data

Control Action	Not providing causes hazard	Providing causes hazard	Too early, too late, out of order	Stopped too soon, applied too long
Communicate truck dynamics data (velocity, acceleration, etc..)	Platooning controller does not provide its dynamic data to the following truck [H1].	Platooning controller provides incorrect dynamic data to the following truck [H1].	N/A	N/A

Conclusions: Since the autonomous platoon would like to maintain a lower time gap (between 0.3s to 1.2s in dry conditions), providing incorrect dynamic data while driving (e.g. braking situations) can cause safety critical accidents. The UCAs (that can lead to hazard H1) will be considered for deriving loss scenarios in the next phase.

4.5.3. Control actions specific to the leading truck platoon controller

This section derives unsafe control actions (UCAs) that can result from the actions that are specific to the leading truck platoon controller.

Table 15 – UCAs Negotiate with the infrastructure

Control Action	Not providing causes hazard	Providing causes hazard	Too early, too late, out of order	Stopped too soon, applied too long
Negotiate with the infrastructure	Leading truck platooning controller does not negotiate with the infrastructure before crossing it [H1, H4, H5].	Leading truck platooning controller incorrectly informs that the platoon has completed crossing the infrastructure (e.g. junction, roundabout) [H1, H4, H5]	Leading truck platooning controller starts the task of negotiating with the infrastructure later than expected [H1, H4, H5].	Leading truck platooning controller stops negotiating (with the infrastructure) sooner than expected (before the crossing is complete) [H1, H4, H5].

Conclusions: Since each truck is still responsible for OEDR, incorrect negotiation with the infrastructure does not cause the following trucks to collide with other road participants, but these unexpected actions may cause other vehicles to collide with the following trucks. Therefore, these UCAs (that can lead to hazard H1) will be considered for deriving loss scenarios in the next phase.

4.5.4. Control actions specific to the following truck platoon controller

This section derives unsafe control actions (UCAs) that can result from the actions that are specific to the following truck platoon controller.

Table 16 - UCAs Accelerate command

Control Action	Not providing causes hazard	Providing causes hazard	Too early, too late, out of order	Stopped too soon, applied too long
Accelerate command	Following truck platooning controller does not request acceleration while platooning [H4]	Following truck platoon controller requests acceleration during a cut-in manoeuvre [H1].	Following truck platoon controller requests acceleration too early during a cut-out manoeuvre [H1].	N/A.
		Following truck platoon controller requests acceleration while an obstacle is present in the lane [H1].		

Control Action	Not providing causes hazard	Providing causes hazard	Too early, too late, out of order	Stopped too soon, applied too long
		Following truck controller requests acceleration while a pedestrian is present in lane [H1].		
		Following truck controller requests acceleration while driving towards an in-lane cyclist/motorcyclist [H1].		
		Following truck platoon controller requests excessive acceleration while following the forward truck [H1].		
		Following truck controller requests excessive acceleration while passing through a junction [H1, H2, H5].		
		Following truck controller requests excessive acceleration while passing through a roundabout [H1, H2, H5].		
		Following truck controller requests excessive acceleration while passing through a toll gate [H1, H5].		
		Following truck controller requests excessive acceleration while driving at the hub [H1, H5].		

Control Action	Not providing causes hazard	Providing causes hazard	Too early, too late, out of order	Stopped too soon, applied too long
		Following truck controller requests excessive acceleration while driving through road works [H1, H5].		
		Following truck controller requests acceleration while stationary at a red light [H1, H5].		
		Following truck controller requests acceleration while stationary at the hub [H1]		
		Following truck controller accelerates towards other vehicles during a lane change/merger [H1, H5].		
		Following truck controller accelerates in the reverse direction while at a traffic light [H1, H5].		
		Following truck controller accelerates in the reverse direction while starting at a hub [H1].		

Comments: Stopped too soon not safety critical as it leads to insufficient acceleration [H4]. Applied for too long is covered in cases of excessive acceleration.

Conclusions: All the UCAs (that can lead to hazards H1, H2 or H3) will be considered for deriving loss scenarios in the next phase.

Table 17 - UCAs Brake command

Control Action	Not providing causes hazard	Providing causes hazard	Too early, too late, out of order	Stopped too soon, applied too long
Brake command	Following truck platooning controller does not request braking while the platoon is in a braking situation [H1]	Following truck platoon controller requests braking during a normal driving situation (non-braking situation) [H1].	Following truck platooning controller requests braking too late while the platoon is in a braking situation [H1]	Following truck platooning controller stops braking request too soon while the platoon is in a braking situation [H1]
	Following truck platoon controller does not request braking during a cut-in manoeuvre [H1].	Following truck platoon controller requests insufficient braking while the platoon is in a braking situation [H1].	Following truck platoon controller requests braking too late during a cut-in manoeuvre [H1].	Following truck platoon controller stops braking request too soon during a cut-in manoeuvre [H1].
	Following truck platoon controller does not request braking while a pedestrian is present in lane [H1].	Following truck platoon controller requests insufficient braking during a cut-in manoeuvre [H1].	Following truck platoon controller requests braking too late while a pedestrian is present in lane [H1].	Following truck platoon controller stops braking request too soon while a pedestrian is present in lane [H1].
	Following truck platoon controller does not request braking while a cyclist/motor cyclist is present in lane [H1].	Following truck platoon controller requests insufficient braking while a pedestrian is present in lane [H1].	Following truck platoon controller requests braking too late while a cyclist/motor cyclist is present in lane [H1].	Following truck platoon controller stops braking request too soon while a cyclist/motor cyclist is present in lane [H1].
	Following truck platoon controller does not request braking to give way to other vehicles during a lane merger [H1].	Following truck platoon controller requests insufficient braking while a cyclist/motor cyclist is present in lane [H1].	Following truck platoon controller requests braking too late to give way to other vehicles during a lane merger [H1].	Following truck platoon controller stops braking request too soon to give right of way during a lane merger [H1].
	Following truck platoon controller does not request braking for an	Following truck platoon controller requests insufficient braking while giving	Following truck platoon controller requests braking too late for an	Following truck platoon controller stops braking request

	obstacle present in lane [H1].	way to other vehicles during a lane merger [H1].	obstacle present in lane [H1].	too soon for an obstacle present in lane [H1].
		Following truck platoon controller requests insufficient braking for an in-lane obstacle [H1].		-
		Following truck platoon controller requests insufficient braking while the platoon is passing through a junction [H1, H5].		-
		Following truck platoon controller requests insufficient braking while the platoon is passing through a roundabout [H1, H5].		-
		Following truck platoon controller requests insufficient braking while the platoon is passing through a tollgate [H1, H5].		-
		Following truck platoon controller requests excessive braking while the platoon is in a braking situation [H1].		-
		Following truck platoon controller requests excessive braking during a cut-in manoeuvre [H1].		-
		Following truck platoon controller requests excessive braking while a		-

		pedestrian is present in lane [H1].		
		Following truck platoon controller requests excessive braking while a cyclist/motor cyclist is present in lane [H1].		-
		Following truck platoon controller requests excessive braking while giving way to other vehicles during a lane merger [H1].		-
		Following truck platoon controller requests excessive braking for an in-lane obstacle [H1].		-

Comments: Early braking is not considered hazardous as it is still a true braking situation. Asymmetrical braking is not considered here since the platooning controller does not control brake force distribution. Out of order does not apply as this is not a request that has sequence of tasks to execute.

Conclusions: All the UCAs (that can lead to hazards H1, H2 or H3) will be considered for deriving loss scenarios in the next phase.

Table 18 - UCAs steer command

Control Action	Not providing causes hazard	Providing causes hazard	Too early, too late, out of order	Stopped too soon, applied too long
Steer command	Following truck platoon controller does not request steering while driving in the target lane (no lane keeping) [H1].	Following truck platoon controller requests steering towards traffic during a lane change [H1].	Following truck platoon controller requests steering too early while changing lane [H1].	Following truck platoon controller stops steering earlier than expected while changing lane [H1].
	Following truck platoon controller does not request steering during a lane change [H1].	Following truck platoon controller requests steering towards traffic during a lane merge [H1].	Following truck platoon controller requests steering too late while changing lane [H1].	Following truck platoon controller stops steering later than expected while changing lane [H1].
	Following truck platoon controller does not request steering during a lane merger [H1].	Following truck platoon controller requests steering in the opposite direction while changing lanes [H1].	Following truck platoon controller requests steering too early during a lane merger [H1].	Following truck platoon controller stops steering earlier than expected during a lane merger [H1].
	Following truck platoon controller does not request steering while passing through a roundabout [H1].	Following truck platoon controller requests excessive steering while driving in the target lane [H1].	Following truck platoon controller requests steering too late during a lane merger [H1].	Following truck platoon controller stops steering later than expected during a lane merger [H1].
	Following truck platoon controller does not request steering while passing through a junction [H1].	Following truck platoon controller requests excessive steering while passing through a roundabout [H1].		**Note:** For other scenarios, the cases are covered in insufficient and excessive.
	Following truck platoon controller does not request steering while driving on a curved lane [H1].	Following truck platoon controller requests excessive steering during a normal lane keeping manoeuvre [H1].		

Control Action	Not providing causes hazard	Providing causes hazard	Too early, too late, out of order	Stopped too soon, applied too long
	Following truck platoon controller does not request steering while driving through road works [H1].	Following truck platoon controller requests excessive steering while passing through a junction [H1].		
	Following truck platoon controller does not request steering while driving through a toll gate [H1].	Following truck platoon controller requests excessive steering while changing lanes [H1].		
	Following truck platoon controller does not request steering to avoid collision [H1].	Following truck platoon controller requests excessive steering during a lane merger [H1].		
		Following truck platoon controller requests excessive steering while passing through a toll gate [H1].		
		Following truck platoon controller requests excessive steering while passing through road works [H1].		
		Following truck platoon controller requests insufficient steering while driving in the target lane [H1].		
		Following truck platoon controller requests insufficient steering while passing through a roundabout [H1].		
		Following truck platoon controller requests insufficient		

Control Action	Not providing causes hazard	Providing causes hazard	Too early, too late, out of order	Stopped too soon, applied too long
		steering while passing through a junction [H1].		
		Following truck platoon controller requests insufficient steering while changing lanes [H1].		
		Following truck platoon controller requests insufficient steering during a lane merger [H1].		
		Following truck platoon controller requests insufficient steering while passing through a toll gate [H1].		
		Following truck platoon controller requests insufficient steering while passing through road works [H1].		

Conclusions: All the UCAs (that can lead to hazards H1, H2 or H3) will be considered for deriving loss scenarios in the next phase.

4.6. STPA Step 4: Identifying loss scenario

Once the unsafe control actions (UCAs) have been identified, the next step is to identify “loss Scenarios” and the triggering conditions that can lead to these loss scenarios. Once the triggering conditions are identified, requirements can be derived to avoid or mitigate the hazards caused by the identified triggering conditions.

A loss scenario describes the causal factors that can lead to the unsafe control.

STPA method explores two important questions to identify loss scenarios:

1. Why would Unsafe Control Actions occur?
2. Why would control actions be improperly executed or not executed, leading to hazards?

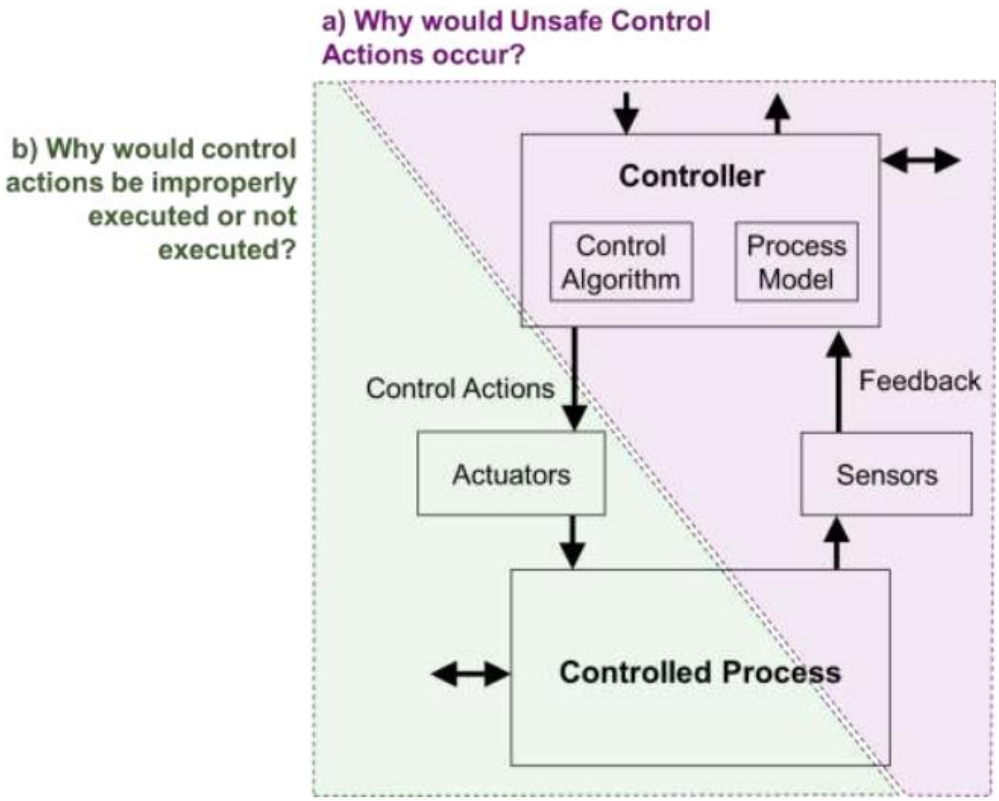

Figure 9 - Types of loss scenarios (Source: STPA handbook (N. G. Levenson, 2018))

The question of why the control actions were not correctly executed by the foundation systems (propulsion, braking and steering) will not be explored in the current project. The main purpose of this analysis is to identify SOTIF triggering conditions, therefore, the analysis will be limited to that.

Identifying loss scenarios that lead to unsafe control actions

This type of scenarios can be created by starting with an unsafe control action (UCA) and working backward to explain what could cause the controller to provide (or not provide) that control action.

In general, scenarios that lead to unsafe control action may include (source STPA handbook **Error! Reference source not found.**):

a. Failures related to the controller (for physical controllers)
   i. Physical failure of the controller itself
   ii. Power failure, etc.

b. Inadequate control algorithm
   i. Flawed implementation of the specified control algorithm
   ii. The specified control algorithm is flawed
   iii. The specified control algorithm becomes inadequate over time due to changes or degradation

c. Unsafe control input
   i. UCA received from another controller (already addressed when considering UCAs from other controllers)

d. Inadequate process model
   i. Controller receives incorrect feedback/information
   ii. Controller receives correct feedback/information but interprets it incorrectly or ignores it
   iii. Controller does not receive feedback/information when needed (delayed or never received)
   iv. Necessary controller feedback/information does not exist

Since the current deliverable is focussed on identifying SOTIF triggering conditions and insufficiency of specifications, loss scenarios pertaining to functional safety (e.g. physical failures related to controllers) are not explored in the following section.

The loss scenarios tables used to identify the loss scenarios, contain the below columns:

Table 19 - Loss scenarios table contents

Column title	Description
Loss scenario	Identification of the loss scenario.
Loss Scenarios (Functional Insufficiency/Performance Limitation)	Description of the loss scenario along with the category of loss: inadequate control algorithm, inadequate process model or unsafe control input.
Unsafe Control Actions	The unsafe control actions resulting from the current loss scenario.
Causal Factor (Potential Triggering Conditions)	Potential triggering conditions that can cause the loss scenario.
Requirements	Function modifications or requirements defined against the causal factors.

Note: Since the platooning autonomous function is only a vision for the future of platooning and no implementation is available to validate the assumptions, the values provided for ranges, accuracies, tolerances, etc in the requirements are only indicative and based on engineering judgement. Further research is required to validate these values.

Similarly, assumptions have been made on the requirements which might not apply to all the trucks due to different implementations used by each OEM to meet the same functional requirements. For example, requirements on HD maps do not apply when the trucks depend on simultaneous localization and mapping (SLAM) for navigation instead of HD maps.

4.6.1. Loss Category: Lack of detection

Table 20 - Loss scenarios: Lack of detection

Loss Scenario	Loss Scenarios (Functional Insufficiency/Performance Limitation)	Unsafe Control Action	Causal Factor (Potential Triggering Conditions)	Requirements
LS-1	System does not detect an intruder [Inadequate process model]	- Following truck platoon controller requests acceleration during a cut-in manoeuvre [H1]. - Following truck platoon controller does not request braking during a cut-in manoeuvre [H1]. - Following truck platoon controller does not request steering to avoid collision [H1].	- Motorcycle or cyclist cuts-in (Target too small) - Low visibility due to bad weather or light conditions within the ODD - Sensors mounted incorrectly, sensor focus or position compromised, sensor blocked, etc. - Vehicles with confusing images on the back (e.g. picture of a road)	- The following trucks shall be able to localize and track intruders in all weather and light conditions within the ODD. - The following trucks shall be able to detect and track relevant motorcycles and cyclists in all weather and light conditions within the ODD. - The following trucks shall be able to detect vehicles with unusual livery (e.g. road or people or animals painted on them). - The following trucks shall be able to detect perception sensor blockages, incorrect mounting and other perception related errors.
LS-2	System does not detect an obstacle in-lane [Inadequate process model]	-Following truck platoon controller requests acceleration while an obstacle is present in the lane [H1]. - Following truck platoon controller does not request braking for an obstacle present in-lane [H1]. - Following truck platoon controller does not request steering to avoid collision [H1].	- Material/colour difficult to detect (or gets low confidence in detection/classification) - Low visibility due to bad weather or bad light conditions within the ODD - Animals not considered for detection - Obstacle warning signs with flickering lights - Non detection of road signs	The following trucks shall be able to localize and track obstacles in all weather and light conditions within the ODD. - The following trucks shall be able to localize and track relevant obstacles/debris that are large enough to cause accidents (e.g. blown out tyres, boxes from other vehicle, ..) in all weather and light conditions within the ODD.

			warning of obstacles - Glare facing the camera	- The following trucks shall be able to detect and track relevant animals large enough to cause accidents (e.g. elks, cattle, sheep, etc..) in all weather and light conditions within the ODD.
LS-3	System does not detect a pedestrian [Inadequate process model]	- Following truck controller requests acceleration while a pedestrian is present in-lane [H1]. - Following truck platoon controller does not request braking while a pedestrian is present in-lane [H1]. - Following truck platoon controller does not request steering to avoid collision [H1].	- Sensors mounted incorrectly, sensor focus or position compromised, sensor blocked, etc. - Low visibility due to bad weather or light conditions within the ODD - pedestrian around high glare and reflective road surfaces - pedestrian appears suddenly from behind road furniture/object (trash can, lamp post, ..)/parked vehicles - Pedestrian dressed in abnormal attire (e.g. Halloween costumes, …) - Multiple pedestrians walking in close proximity to each other - Glare facing the camera	- The following trucks shall be able to localize and track relevant pedestrians in all weather and light conditions within the ODD. - The following trucks shall localize and track relevant pedestrians even if they are walking behind road furniture/object (trash bins, lamp posts, ..)/parked vehicles. - The following trucks shall be able to localize and track pedestrians in abnormal attire (e.g. Halloween costumes, hot dog vendor costume, ..). - The following trucks shall localize and track pedestrians around high glare and reflective road surfaces. - The following trucks shall be able to detect perception sensor blockages, incorrect mounting and other perception related errors.
LS-4	System does not detect a cyclist/motorcyclist [Inadequate process model].	- Following truck controller requests acceleration while driving towards an in-lane cyclist/motorcyclist [H1]. - Following truck platoon controller does not request braking while a cyclist/motor cyclist is present in-lane [H1].	- Sensors mounted incorrectly, sensor focus or position compromised, sensor blocked, etc. - Low visibility due to bad weather or light conditions within the ODD	- The following trucks shall localize and track relevant motorcyclist and cyclists in all weather and light conditions within the ODD. - The following trucks shall localize and track motorcyclists and cyclist around high glare and reflective road

		- Following truck platoon controller does not request steering to avoid collision [H1].	- Cyclist/motorcyclist around high glare and reflective road surfaces - Cyclist does not use reflectors in low light conditions within the ODD - Driving close to other vehicles making it difficult to separate - Glare facing the camera	surfaces. - The following trucks shall be able to localize and track cycles and motorcycles even when they are being driven close to/adjacent to other vehicles. - The following trucks shall be able to detect perception sensor blockages, incorrect mounting and other perception related errors.
LS-5	System does not detect the presence of a junction [Inadequate process model]	- Following truck controller requests excessive acceleration while passing through a junction [H1]. - Following truck platoon controller requests insufficient braking while the platoon is passing through a junction [H1]. - Following truck platoon controller does not request steering while passing through a junction [H1]. - Following truck platoon controller requests excessive steering while passing through a junction [H1]. - Following truck platoon controller requests insufficient steering while passing through a junction [H1].	- Incorrect map data on the presence of the junction - Incorrect localisation near junctions - Presence of a junction not communicated by the lead vehicle - Inadequate perception of the junctions related features and traffic signs, …	- ITS systems shall communicate the location and status of junctions to the platoon. - The leading truck shall negotiate with the infrastructure for the entire platoon to pass through junctions. - The leading truck shall automatically detect junctions' related road signs and communicate them to the following vehicles (not the responsibility of the lead driver). - 'If HD maps are used for driving by the following trucks, junctions shall be mapped accurately to support localization and navigation.
LS-6	System does not detect the presence of a roundabout [Inadequate process model].	- Following truck controller requests excessive acceleration while passing through a roundabout [H1]. - Following truck platoon controller requests insufficient braking while the platoon is passing through a roundabout [H1].	- Incorrect map data on the presence of the roundabout - Incorrect localisation near roundabouts - Presence of a roundabout not communicated by the lead vehicle	- ITS systems shall communicate the location and status of roundabouts to the platoon. - The leading truck shall negotiate with the infrastructure for the entire platoon to pass through roundabouts. - The leading truck shall automatically

		- Following truck platoon controller does not request steering while passing through a roundabout [H1]. - Following truck platoon controller requests excessive steering while passing through a roundabout [H1]. - Following truck platoon controller requests insufficient steering while passing through a roundabout [H1].	- Inadequate perception of the roundabout features and traffic signs, …	detect roundabouts' related road signs and communicate them to the following vehicles (not the responsibility of the lead driver). - If HD maps are used for driving by the following trucks, roundabouts shall be mapped accurately to support localization and navigation.
LS-7	System does not detect the presence of the tollgate [Inadequate process model]	- Following truck controller requests excessive acceleration while passing through a toll gate [H1]. - Following truck platoon controller requests insufficient braking while the platoon is passing through a tollgate [H1]. - Following truck platoon controller does not request steering while driving through a toll gate [H1]. - Following truck platoon controller requests excessive steering while passing through a toll gate [H1]. - Following truck platoon controller requests insufficient steering while passing through a toll gate [H1].	- Incorrect map data on the location of the toll gates - Incorrect localisation near toll gates - Inadequate perception of a toll gate infrastructure - Communication from infrastructure not received (Functional safety) - Presence of a tollgate not communicated by the lead vehicle - Unable to detect boom barriers at toll gates - Incorrect map data on the dimensions of the toll gate - Perception sensors unable to measure geometry of toll gate	- ITS systems shall communicate the location and status of toll gates to the platoon. - The leading truck shall negotiate with the infrastructure for the entire platoon to pass through toll gates. - The leading truck shall automatically detect toll gates' related road signs and communicate them to the following vehicles (not the responsibility of the lead driver). - If HD maps are used for driving by the following trucks, toll gates shall be mapped accurately to support localization and navigation. - The following trucks shall be able to detect boom barriers at the tollgates.
LS-8	System does not detect the presence of the hub [Inadequate process model]	- Following truck controller requests excessive acceleration while driving at the hub [H1]. - Following truck platoon controller requests insufficient braking while	- Incorrect map data on the hub's location - Incorrect localisation - Inadequate perception of the "hub related signage" - Presence of a hub not	- ITS systems shall communicate the location and status of hubs to the platoon. - While driving at hubs, the following trucks shall maintain speeds within legal limits.

		the platoon is passing through a hub [H1].	communicated by the lead vehicle	- The leading truck shall automatically detect hubs' related road signs and communicate them to the following vehicles (not the responsibility of the lead driver). - If HD maps are used for driving by the following trucks, hubs shall be mapped accurately to support localization and navigation.
LS-9	System does not detect the presence of the road works [Unsafe sensor input or Inadequate process model]	- Following truck controller requests excessive acceleration while driving through road works [H1]. - Following truck platoon controller requests insufficient braking while the platoon is passing through roadworks [H1]. - Following truck platoon controller does not request steering while driving through road works [H1]. - Following truck platoon controller requests excessive steering while passing through road works [H1]. - Following truck platoon controller requests insufficient steering while passing through road works [H1]. - Following truck platoon controller does not request steering to avoid collision [H1].	- Incorrect map data on the road works - Incorrect localisation (e.g. assumes it is on different lane) - Inadequate perception of the "roadworks related signage" - Presence of a road works not communicated by the lead vehicle - Unable to perceive traffic cones, plastic barriers, ... - Unable to perceive manual signage (e.g. LED speed limits held by a personnel) - Presence of road works not communicated by the infrastructure	- ITS systems shall communicate the location and status of the road works to the platoon. - The leading truck shall negotiate with the infrastructure for the entire platoon to pass through road works. - Leading truck shall automatically detect road works related signs and communicate them to the following vehicles (not the responsibility of the lead driver). - If HD maps are used for driving by the following trucks, road works shall be mapped accurately to support localization and navigation. - The following trucks shall be able to detect lanes around road works marked using special items like traffic cones, special lane (type and colour), special barriers, etc..
LS-10	System does not detect vehicles in adjacent lanes [Inadequate process model]	- Following truck controller accelerates towards other vehicles during a lane change/merger [H1]. - Following truck platoon controller	- Sensors mounted incorrectly, sensor focus or position compromised, sensor blocked, etc.	- The following trucks shall be able to detect perception sensor blockages, incorrect mounting and other perception related errors.

		does not request braking to give right of way during a lane merger [H1]. - Following truck platoon controller requests steering towards traffic during a lane change [H1]. - Following truck platoon controller requests steering towards traffic during a lane merge [H1]. - Following truck platoon controller requests excessive steering while changing lanes [H1]. - Following truck platoon controller requests excessive steering during a lane merger [H1]. - Following truck platoon controller requests steering too early while changing lane [H1]. - Following truck platoon controller requests steering too early during a lane merger [H1]. - Following truck platoon controller does not request steering to avoid collision [H1].	- Other vehicle travelling too fast in the high speed lane (e.g. autobahn) - Ramp impeding the view of the ego vehicle - Low visibility due to bad weather or low light - Insufficient rear perception range of the ego truck - Driving on curved roads	- The following trucks shall be able to detect and track relevant vehicles (e.g. even in high speed situations like autobahns) in the adjacent lanes in all weather and light conditions within the ODD. - The following trucks shall be able to detect and track relevant vehicles in the adjacent lanes even when they are partially concealed due to ramps, pillars and other view obstructions typically found on public roads. - The following trucks shall be able to localize and track relevant vehicles in the adjacent lanes while driving on curved lanes including roundabouts and junctions.

4.6.2. Loss Category: Delays in detections

Table 21 - Delays in detections

Loss Scenario	Loss Scenarios (Functional Insufficiency/Performance Limitation)	Unsafe Control Action	Causal Factor (Potential Triggering Conditions)	Requirements
LS-11	System detects the intruder after a delay [Inadequate process model]	- Following truck platoon controller requests acceleration during a cut-in manoeuvre [H1]. - Following truck platoon controller requests insufficient braking during a cut-in manoeuvre [H1]. - Following truck platoon controller requests braking too late during a cut-in manoeuvre [H1]. - Following truck platoon controller does not request steering to avoid collision [H1].	- Cut-in on a curved lane (vehicle does not detect threat in-lane)/Cut-ins while on a roundabout. - Sensor feedback delayed and not received in time because the bus is busy, inadequate message priority or arbitration, EMI, etc. - Processing of the environment model is compute intensive. Delays under high processing load (e.g. too many obstacles in close proximity). - Low visibility due to bad weather or light conditions within the ODD.	- 'The following trucks shall be able to localize and track intruders while driving on curved lanes including roundabouts and junctions. - The following trucks shall be able to detect intruders in all weather and light conditions within the ODD. - The following trucks' autonomous driving HW shall have enough processing power, memory and bus resources to track and update the relevant metadata of at least 20 of the closest vehicles/pedestrians/obstacles in real-time.
LS-12	System detects the obstacle after a delay [Inadequate process model]	Following truck platoon controller requests acceleration while an obstacle is present in the lane [H1]. Following truck platoon controller requests insufficient braking for an in-lane obstacle [H1]. Following truck platoon controller requests braking too late for an	- Obstacle on a curved lane (vehicle does not detect threat in-lane) - Sensor feedback delayed and not received in time because the bus is busy, inadequate message priority or arbitration, EMI, etc.	- 'The following trucks shall be able to localize and track relevant obstacles on curved lanes including roundabouts and junctions. - The following trucks shall be able to localize and track obstacles in all weather and light conditions within the ODD.

Loss Scenario	Loss Scenarios (Functional Insufficiency/Performance Limitation)	Unsafe Control Action	Causal Factor (Potential Triggering Conditions)	Requirements
		obstacle present in-lane [H1]. - Following truck platoon controller does not request steering to avoid collision [H1].	- Processing of the environment model is compute intensive. Delays under high processing load (e.g. too many obstacles in close proximity). - Low visibility due to bad weather or light conditions within the ODD.	- The following trucks' autonomous driving HW shall have enough processing power, memory and bus resources to track and update the relevant metadata of at least 20 of the closest vehicles/pedestrians/obstacles in real-time.
LS-13	System detects the pedestrian after a delay [Inadequate process model]	- Following truck controller requests acceleration while a pedestrian is present in-lane [H1]. - Following truck platoon controller requests insufficient braking while a pedestrian is present in-lane [H1]. - Following truck platoon controller requests braking too late while a pedestrian is present in-lane [H1]. - Following truck platoon controller does not request steering to avoid collision [H1].	- Pedestrian on a curved lane (vehicle does not detect threat in-lane) - Sensor feedback delayed and not received in time because the bus is busy, inadequate message priority or arbitration, EMI, etc. - Processing of the environment model is compute intensive. Delays under high processing load (e.g. too many obstacles in close proximity). - Low visibility due to bad weather or light conditions within the ODD.	- 'The following trucks shall be able to localize and track relevant pedestrians while driving on curved lanes including roundabouts and junctions. - The following trucks shall be able to localize and track pedestrians in all weather and light conditions within the ODD. - The following trucks' autonomous driving HW shall have enough processing power, memory and bus resources to track and update the relevant metadata of at least 20 of the closest vehicles/pedestrians/obstacles in real-time.
LS-14	System detects the cyclist/motorcyclist after a delay [Inadequate process model]	- Following truck controller requests acceleration while driving towards an in-lane cyclist/motorcyclist [H1]. - Following truck platoon controller requests insufficient braking while a	- Cyclist/motorcyclist on a curved lane (vehicle does not detect threat in-lane) - Sensor feedback delayed and not received in time because	- The following trucks shall be able to localize and track relevant cyclist/motorcyclists on curved lanes. - The following trucks shall be able to localize and track cyclist/motorcyclists

Loss Scenario	Loss Scenarios (Functional Insufficiency/Performance Limitation)	Unsafe Control Action	Causal Factor (Potential Triggering Conditions)	Requirements
		cyclist/motor cyclist is present in-lane [H1]. - Following truck platoon controller requests braking too late while a cyclist/motor cyclist is present in-lane [H1]. - Following truck platoon controller does not request steering to avoid collision [H1].	the bus is busy, inadequate message priority or arbitration, EMI, etc. - Processing of the environment model is compute intensive. Delays under high processing load (e.g. too many obstacles in close proximity). - Low visibility due to bad weather or light conditions within the ODD. - Cyclist/motorcyclist appears suddenly from behind other vehicles (Humans usually recognise the motorcycles by sound)	in all weather and light conditions within the ODD. - The following trucks' autonomous driving HW shall have enough processing power, memory and bus resources to track and update the relevant metadata of at least 20 of the closest vehicles/pedestrians/ obstacles in real-time.
LS-15	System detects the vehicles in the adjacent lane after a delay [Inadequate process model]	- Following truck platoon controller requests insufficient braking while giving right of way to other vehicles during a lane merger [H1]. - Following truck platoon controller requests braking too late to give right of way during a lane merger [H1]. - Following truck platoon controller requests steering towards traffic during a lane change [H1]. - Following truck platoon controller requests steering towards traffic during a lane merge [H1].	- Vehicles on a curved lane (vehicle does not detect threat in-lane) - Sensor feedback delayed and not received in time because the bus is busy, inadequate message priority or arbitration, EMI, etc. - Processing of the environment model is compute intensive. Delays under high processing load (e.g. too many obstacles in close proximity).	- The following trucks shall be able to localize and track relevant vehicles in the adjacent lanes while driving on curved lanes including roundabouts and junctions. - The following trucks shall be able to localize and track vehicles in adjacent lanes in all weather and light conditions within the ODD. - The following trucks' autonomous driving HW shall have enough processing power, memory and bus resources to track and update the

Loss Scenario	Loss Scenarios (Functional Insufficiency/Performance Limitation)	Unsafe Control Action	Causal Factor (Potential Triggering Conditions)	Requirements
		- Following truck platoon controller requests excessive steering while changing lanes [H1]. - Following truck platoon controller requests excessive steering during a lane merger [H1]. - Following truck platoon controller requests steering too early while changing lane [H1]. - Following truck platoon controller requests steering too early during a lane merger [H1]. - Following truck platoon controller does not request steering to avoid collision [H1].	- Low visibility due to bad weather or light conditions within the ODD. - Low visibility of other vehicles due to ramp-up	relevant metadata of at least 20 of the closest vehicles/pedestrians/obstacles in real-time. - The following trucks shall be able to localize and track relevant vehicles in the adjacent lanes even when they are partially concealed due to ramps, columns and other view obstructions typically found on public roads.
LS-16	System detects the presence of a junction after a delay [Inadequate process model]	- Following truck platoon controller requests insufficient braking while the platoon is passing through a junction [H1]. - Following truck platoon controller requests insufficient steering while passing through a junction [H1].	- Incorrect map data on the location of the junction - Incorrect localisation near junctions - Inadequate perception of junction related infrastructure - Communication from infrastructure not received (Functional safety) - Presence of a junction not communicated by the lead vehicle	- ITS systems shall be able to communicate the location and status of the junctions to a range of at least 100 meters from the junction. - The leading truck shall be able to detect and communicate the presence of a junction to the platoon before entering the junction.
LS-17	System detects the presence of a roundabout	- Following truck platoon controller requests insufficient braking while	- Incorrect map data on the location of the roundabout	- ITS systems shall be able to communicate the location and status

Loss Scenario	Loss Scenarios (Functional Insufficiency/Performance Limitation)	Unsafe Control Action	Causal Factor (Potential Triggering Conditions)	Requirements
	after a delay [Inadequate process model]	the platoon is passing through a roundabout [H1]. - Following truck platoon controller requests insufficient steering while passing through a roundabout [H1].	- Incorrect localisation near roundabouts - Inadequate perception of roundabout related infrastructure - Communication from infrastructure not received (Functional safety) - Presence of a roundabout not communicated by the lead vehicle	of the roundabouts to a range of at least 100 meters from the roundabout. - The leading truck shall be able to detect and communicate the presence of a roundabout to the platoon before entering the roundabout.
LS-18	System detects the presence of a tollgate after a delay [Inadequate process model]	- Following truck platoon controller requests insufficient braking while the platoon is passing through a tollgate [H1]. - Following truck platoon controller requests insufficient steering while passing through a toll gate [H1].	- Incorrect map data on the location of the toll gate - Incorrect localisation near toll gates - Inadequate perception of toll gate related infrastructure - Communication from infrastructure not received (Functional safety) - Presence of a toll gate not communicated by the lead vehicle	- ITS systems shall be able to communicate the location and status of the toll gates to a range of at least 200 meters from the toll gate. - The leading truck shall be able to detect and communicate the presence of a toll gate to the platoon before entering the toll gate.
LS-19	System detects the presence of a hub after a delay [Inadequate process model]	- Following truck platoon controller requests insufficient braking while the platoon is passing through a hub [H1].	- Incorrect map data on the location of the hub - Incorrect localisation near hubs - Inadequate perception of hub related infrastructure	- ITS systems shall be able to communicate the location and status of the hubs to a range of at least 100 meters from the hub. - The leading truck shall be able to detect and communicate the

Loss Scenario	Loss Scenarios (Functional Insufficiency/Performance Limitation)	Unsafe Control Action	Causal Factor (Potential Triggering Conditions)	Requirements
			- Communication from infrastructure not received (Functional safety) - Presence of a hub not communicated by the lead vehicle	presence of a hub to the platoon before entering the hub.
LS-20	System detects the presence of roadworks after a delay [Inadequate process model]	- Following truck platoon controller requests insufficient braking while the platoon is passing through road works [H1]. - Following truck platoon controller requests insufficient steering while passing through a road works [H1].	- Incorrect map data on the location of the road works - Incorrect localisation near road works - Inadequate perception of road works related infrastructure - Communication from infrastructure not received (Functional safety) - Presence of a road works not communicated by the lead vehicle	- ITS systems shall be able to communicate the location and status of the road works to a range of at least 200 meters from the road works. - The leading truck shall be able to detect and communicate the presence of a road works to the platoon before entering the road works.

4.6.3. Loss Category: Incorrect detections

Table 22 - Loss scenarios: Incorrect detections

Loss Scenario	Loss Scenarios (Functional Insufficiency/Performance Limitation)	Unsafe Control Action	Causal Factor (Potential Triggering Conditions)	Requirements
LS-21	System perceives phantom objects in target lane [Unsafe sensor input or Inadequate process model]	- Following truck platoon controller requests braking during a normal driving situation (not a braking situation) [H1]. - Following truck platoon controller requests excessive steering while driving in the target lane [H1]. - Following truck platoon controller does not request steering during a lane change [H1]. - Following truck platoon controller does not request steering during a lane merger [H1]. - Following truck platoon controller requests insufficient steering while changing lanes [H1]. - Following truck platoon controller requests insufficient steering during a lane merger [H1]. - Following truck platoon controller requests steering too late while changing lane [H1]. - Following truck platoon controller requests steering too late during a lane merger [H1].	- Overpass above the current lane - Reflections from the metallic overhead boards or manhole covers - Curved road with metal railings - Parked vehicles next to the lane - Pedestrians at pavements with sharp bends - Metallic posts that narrow the vehicle's path - Bridges with ramps facing overhead metallic sign boards - Big but non-hazardous items (plastic bags, etc..) - Incorrect information from co-operative perception	The following elements shall not be classified as in-lane obstacles/pedestrians/vehicles by the following trucks: - Overpass above the current lane - Reflections from the metallic overhead boards or manhole covers - Curved road with metal railings - Parked vehicles next to the lane - Pedestrians on the pavements on curved roads - Metallic posts that narrow the vehicle's path - Bridges with ramps facing overhead metallic sign boards - Big but non-hazardous items (plastic bags, etc..) The following trucks shall independently confirm co-operative perception data before dynamically reacting to an obstacle/pedestrian/vehicle.

Loss Scenario	Loss Scenarios (Functional Insufficiency/Performance Limitation)	Unsafe Control Action	Causal Factor (Potential Triggering Conditions)	Requirements
		- Following truck platoon controller stops steering earlier than expected while changing lane [H1]. - Following truck platoon controller stops steering earlier than expected during a lane merger [H1].		
LS-22	System incorrectly assumes obstacles/vehicles are present in its path at junctions/roundabout [Inadequate process model]	- Following truck platoon controller requests excessive steering while driving in the target lane [H1]. - Following truck platoon controller does not request steering while passing through a roundabout [H1]. - Following truck platoon controller does not request steering while passing through a junction [H1]. - Following truck platoon controller requests insufficient steering while passing through a roundabout [H1]. - Following truck platoon controller requests insufficient steering while passing through a junction [H1].	- Incorrect information from cooperative perception - Confusing sculptures at the centre of the roundabout (statues, ..) - Metallic guardrails at the junction/roundabout - Incorrect interpretation of the behaviour of the vehicles in the adjacent lane (same road as the platoon)	The following elements shall not be classified as in-lane obstacles/pedestrians/vehicles by the following trucks: - Confusing sculptures at the centre of the roundabout (statues, ..) - Metallic guardrails at the junction/roundabout - The following trucks shall be able to predict the behaviour/trajectory of the vehicles in adjacent lanes including on curved lanes with an accuracy of +/- 1 meter. **Note:** Or else cannot accurately know if the vehicle will enter the target lane or not.
LS-23	System incorrectly assumes obstacles are present in its path around construction zones [Inadequate process model]	- Following truck platoon controller requests excessive steering while driving in the target lane [H1]. - Following truck platoon controller does not request steering while driving through road works [H1].	- Complex driving route (narrow, curvy...) around construction related road furniture (barriers, cones, ...) and vehicles (dumpers, excavators, etc…)	The following elements shall not be classified as in-lane obstacles/pedestrians/vehicles by the following trucks: - Construction related vehicles (dumpers, excavators,..) being used in

Loss Scenario	Loss Scenarios (Functional Insufficiency/Performance Limitation)	Unsafe Control Action	Causal Factor (Potential Triggering Conditions)	Requirements
		- Following truck platoon controller requests insufficient steering while passing through road works [H1].		close proximity to atypical target lanes around road works.
LS-24	System incorrectly assumes obstacles are present in its path around toll gates [Inadequate process model]	- Following truck platoon controller requests excessive steering while driving in the target lane [H1]. - Following truck platoon controller does not request steering while driving through a toll gate [H1]. - Following truck platoon controller requests insufficient steering while passing through a toll gate [H1].	- Incorrect information from co-operative perception - Complex road furniture near the toll gates (boom barriers, narrower lanes with barriers, toll booths between lanes, …)	The following elements shall not be classified as in-lane obstacles/pedestrians/vehicles by the following trucks: - Toll booth infrastructure constructed close to/on the lane lines while passing through toll gates - Open boom barriers

4.6.4. Loss Category: Temporary loss of objects of interest

Table 23 - Loss scenarios: Temporary loss of objects of interest

Loss Scenario	Loss Scenarios (Functional Insufficiency/Performance Limitation)	Unsafe Control Action	Causal Factor (Potential Triggering Conditions)	Requirements
LS-25	System temporarily loses tracking of the forward truck [Inadequate process model]	- Following truck platoon controller requests excessive acceleration while following the forward truck [H1]. - Following truck controller requests excessive acceleration while passing through a junction [H1].	- Platoon driving on a curve - Low visibility due to bad weather or light conditions	- The following trucks shall be able to localize and track the forward truck while driving on curved lanes including roundabouts and junctions. - The following trucks shall be able to localize and track the forward truck in

Loss Scenario	Loss Scenarios (Functional Insufficiency/Performance Limitation)	Unsafe Control Action	Causal Factor (Potential Triggering Conditions)	Requirements
		- Following truck controller requests excessive acceleration while passing through a roundabout [H1]. - Following truck platooning controller does not request braking while the platoon is in a braking situation [H1]. - Following truck platoon controller requests insufficient braking while the platoon is in a braking situation [H1]. - Following truck platooning controller requests braking too late while the platoon is in a braking situation [H1]. - Following truck platooning controller stops braking request too soon while the platoon is in a braking situation [H1].		all weather and light conditions within the ODD. - Each truck shall continuously transmit its current location to the following trucks.
LS-26	System temporarily loses tracking of the intruder [Inadequate process model]	- Following truck platoon controller requests insufficient braking during a cut-in manoeuvre [H1]. - Following truck platoon controller requests braking too late during a cut-in manoeuvre [H1]. -Following truck platoon controller stops braking request too soon during a cut-in manoeuvre [H1].	- Intruder driving on a curve - Low visibility due to bad weather or light conditions	- The following trucks shall be able to localize and track the intruders while driving on curved lanes including roundabouts and junctions. - The following trucks shall be able to localize and track the intruders in all weather and light conditions within the ODD.

Loss Scenario	Loss Scenarios (Functional Insufficiency/Performance Limitation)	Unsafe Control Action	Causal Factor (Potential Triggering Conditions)	Requirements
LS-27	System temporarily loses tracking of the pedestrian [Inadequate process model]	- Following truck platoon controller requests insufficient braking while a pedestrian is present in-lane [H1]. - Following truck platoon controller requests braking too late while a pedestrian is present in-lane [H1]. - Following truck platoon controller stops braking request too soon while a pedestrian is present in-lane [H1].	- pedestrian on a curve - Low visibility due to bad weather or light conditions	- The following trucks shall be able to localize and track relevant pedestrians while driving on curved lanes including roundabouts and junctions. - The following trucks shall be able to localize and track pedestrians in all weather and light conditions within the ODD.
LS-28	System temporarily loses tracking of the cyclist/motorcyclist [Inadequate process model]	- Following truck platoon controller requests insufficient braking while a cyclist/motor cyclist is present in-lane [H1]. - Following truck platoon controller requests braking too late while a cyclist/motor cyclist is present in-lane [H1]. - Following truck platoon controller stops braking request too soon while a cyclist/motor cyclist is present in-lane [H1].	- cyclists/motorcyclists driving on a curve - Low visibility due to bad weather or light conditions - temporarily overtaking other vehicles	- The following trucks shall be able to localize and track relevant cyclists/motorcyclists while driving on curved lanes including roundabouts and junctions. - The following trucks shall be able to localize and track relevant cyclists/ motorcyclists in all weather and light conditions within the ODD. - The following trucks shall be able to localize and track relevant cyclists/motorcyclists even when they are driving close to or overtaking other vehicles.
LS-29	System temporarily loses tracking of the vehicles in adjacent lane [Inadequate process model]	- Following truck platoon controller requests insufficient braking while giving right of way to other vehicles during a lane merger [H1]. - Following truck platoon controller requests braking too late to give right	- Vehicles driving on a curve - Low visibility due to bad weather or light conditions - Temporarily blocked by infrastructure like ramps, columns, etc.	- The following trucks shall be able to localize and track relevant vehicles in the adjacent lanes while driving on curved lanes including roundabouts and junctions. - The following trucks shall be able to

Loss Scenario	Loss Scenarios (Functional Insufficiency/Performance Limitation)	Unsafe Control Action	Causal Factor (Potential Triggering Conditions)	Requirements
		of way during a lane merger [H1]. - Following truck platoon controller stops braking request too soon to give right of way during a lane merger [H1]. - Following truck platoon controller requests steering towards traffic during a lane change [H1]. - Following truck platoon controller requests steering towards traffic during a lane merge [H1]. - Following truck platoon controller requests excessive steering while changing lanes [H1]. - Following truck platoon controller requests excessive steering during a lane merger [H1]. - Following truck platoon controller requests steering too early while changing lane [H1]. - Following truck platoon controller requests steering too early during a lane merger [H1].		localize and track relevant vehicles in the adjacent lane in all weather and light conditions within the ODD. - The following trucks shall be able to localize and track relevant vehicles in the adjacent lanes even when they are partially concealed due to ramps, columns and other view obstructions typically found on public roads.

4.6.5. Loss Category: Issues with lane detections

Table 24 - Loss scenarios: Issues with lane detections

Loss Scenario	Loss Scenarios (Functional Insufficiency/Performance Limitation)	Unsafe Control Action	Causal Factor (Potential Triggering Conditions)	Requirements
LS-30	System does not detect lanes lines correctly [Inadequate process model]	Following truck platoon controller does not request braking to give right of way during a lane merger [H1]. - Following truck platoon controller does not request steering to stay within the target lane (no lane keeping) [H1]. - Following truck platoon controller requests excessive steering while driving in the target lane [H1]. - Following truck platoon controller does not request steering while driving on a curved lane [H1]. - Following truck platoon controller requests excessive steering while driving in the target lane [H1]. - Following truck platoon controller requests insufficient steering while driving in the target lane [H1].	- Lanes lines are absent - Partially erased or murky lane markings - Lane markings under water (rain) - Lane markings under snow - Incorrect map data of the lanes - Glare facing the camera - Non-standard colours used for the lane lines - Low visibility due to bad weather or low light	- The following trucks shall be able to detect target lane even when the lanes are partially or fully unseen due to the following conditions within the ODD: - Absence of lane markings - Partially erased or murky lane lines - Lane lines under water or snow - Bad light or visibility conditions. - Special colour lanes used within the EU road regulations (e.g. yellow for road works) - If HD maps are used for driving by the following trucks, lane lines shall be mapped accurately to support localization and navigation.
LS-31	System does not detect lanes lines correctly during a lane merger [Inadequate process model]	- Following truck platoon controller requests excessive steering during a lane merger [H1]. - Following truck platoon controller requests steering towards traffic during a lane merge [H1].	- Unable to detect lanes merging	- The following trucks shall be able to independently (without depending on the leading truck/driver) detect lane merging situation in all weather and light conditions within the ODD. - If HD maps are used for driving by

Loss Scenario	Loss Scenarios (Functional Insufficiency/Performance Limitation)	Unsafe Control Action	Causal Factor (Potential Triggering Conditions)	Requirements
		- Following truck platoon controller does not request steering during a lane merger [H1]. - Following truck platoon controller requests insufficient steering during a lane merger [H1]. - Following truck platoon controller requests steering too early during a lane merger [H1]. - Following truck platoon controller requests steering too late during a lane merger [H1]. - Following truck platoon controller stops steering earlier than expected during a lane merger [H1]. - Following truck platoon controller stops steering later than expected during a lane merger [H1].		the following trucks, lane mergers shall be correctly mapped for navigation.
LS-32	System does not detect lanes lines correctly during a lane change [Inadequate process model]	- Following truck platoon controller requests excessive steering while changing lanes [H1]. - Following truck platoon controller requests steering towards traffic during a lane change [H1]. - Following truck platoon controller does not request steering during a lane change [H1]. - Following truck platoon controller requests insufficient steering while	- lane change situation not communicated to the following trucks - unable to detect adjacent lane lines due to bad weather or light conditions.	- Activation of turn indicators by the leading truck shall automatically communicate the intention and the direction of lane change to the following trucks. - The following trucks shall correctly identify the new target lane during a lane change situation in all weather and light conditions within the ODD. - If HD maps are used for driving by the following trucks, lane lines shall

Loss Scenario	Loss Scenarios (Functional Insufficiency/Performance Limitation)	Unsafe Control Action	Causal Factor (Potential Triggering Conditions)	Requirements
		changing lanes [H1]. - Following truck platoon controller requests steering too early while changing lane [H1]. - Following truck platoon controller requests steering too late while changing lane [H1]. - Following truck platoon controller stops steering earlier than expected while changing lane [H1]. - Following truck platoon controller stops steering later than expected while changing lane [H1].		be mapped accurately to support localization and navigation.
LS-33	System does not detect lanes lines correctly while passing through a roundabout [Inadequate process model]	- Following truck platoon controller requests excessive steering while passing through a roundabout [H1]. - Following truck platoon controller does not request steering while passing through a roundabout [H1]. - Following truck platoon controller requests insufficient steering while passing through a roundabout [H1].	- Unable to detect lane lines with high curvature - Low visibility due to bad weather or light conditions	- The following trucks shall correctly identify their target lane while passing through roundabouts in all weather and light conditions within the ODD. - 'If HD maps are used for driving by the following trucks, lane lines of roundabouts within the ODD shall be mapped accurately to support localization and navigation.
LS-34	System does not detect lanes lines correctly while passing through a junction [Inadequate process model]	- Following truck platoon controller requests excessive steering while passing through a junction [H1]. - Following truck platoon controller does not request steering while passing through a junction [H1]. - Following truck platoon controller	- Unable to detect lane lines with high curvature - Low visibility due to bad weather or light conditions	- The following trucks shall correctly identify their target lane while passing through junctions in all weather and light conditions within the ODD. - If HD maps are used for driving by the following trucks, lane lines of junctions within the ODD shall

Loss Scenario	Loss Scenarios (Functional Insufficiency/Performance Limitation)	Unsafe Control Action	Causal Factor (Potential Triggering Conditions)	Requirements
		requests insufficient steering while passing through a junction [H1].		mapped accurately to support localization and navigation.
LS-35	System does not detect lanes lines correctly while passing through road works [Inadequate process model]	- Following truck platoon controller requests excessive steering while passing through road works [H1]. - Following truck platoon controller requests insufficient steering while passing through a road works [H1].	- Unable to detect lane lines around road works related road furniture like cones, barriers, etc. - Low visibility due to bad weather or light conditions	- The following trucks shall correctly identify their target lane while passing through road works in all weather and light conditions within the ODD. - The following trucks shall be able to detect lanes around road works marked using special items like traffic cones, special lane (type and colour), special barriers, etc.. - If HD maps are used for driving by the following trucks, lane lines of road works within the ODD shall be correctly mapped for localization and navigation.
LS-36	System does not detect lanes lines correctly while passing through a tollgate [Inadequate process model]	- Following truck platoon controller requests excessive steering while passing through a toll gate [H1]. - Following truck platoon controller requests insufficient steering while passing through a toll gate [H1].	- Unable to detect lane lines when they merge with the toll gate barriers/infrastructure - Special criss-crossed lane lines and special coloured lanes.	- The following trucks shall correctly identify their target lane while passing through toll gates in all weather and light conditions within the ODD. - The following trucks shall be able to detect lanes around toll gates marked using special changed pattern and colour lanes. - The following trucks shall be able to identify their target lane while passing through toll gates even when the lane lines disappear/merge into the side walls of the toll gates.

Loss Scenario	Loss Scenarios (Functional Insufficiency/Performance Limitation)	Unsafe Control Action	Causal Factor (Potential Triggering Conditions)	Requirements
				- If HD maps are used for driving by the following trucks, lane lines around toll gates within the ODD shall be correctly mapped for localization and navigation.

4.6.6. Loss Category: Objects incorrectly ignored as “Does not pose collision danger”

Table 25 - Loss scenarios: Objects incorrectly ignored as “Does not pose collision danger”

Loss Scenario	Loss Scenarios (Functional Insufficiency/Performance Limitation)	Unsafe Control Action	Causal Factor (Potential Triggering Conditions)	Requirements
LS-37	System misclassifies the intruder as "does not pose collision danger" [Inadequate process model].	- Following truck platoon controller requests acceleration during a cut-in manoeuvre [H1]. - Following truck platoon controller does not request braking during a cut-in manoeuvre [H1]. - Following truck platoon controller does not request steering to avoid collision [H1].	- Intruder not part of the usual object classification categories.	The following vehicles shall be considered as intruders for cut-ins by the following trucks: - Cars - Vans - Emergency vehicles (ambulances, police vehicles, etc..) - Trucks - Motor cycles - Cyclists
LS-38	System misclassifies the obstacle as "does not pose collision danger" [Inadequate process model].	- Following truck platoon controller requests acceleration while an obstacle is present in the lane [H1]. - Following truck platoon controller does not request braking for an obstacle present in-lane [H1]. - Following truck platoon controller does not request steering to avoid collision [H1].	- Obstacle is too small but dangerous (e.g. dropped box from the forward vehicle, boulders, tire debris ..) - Material/colour difficult to detect (or can give low confidence in detection) - Wrong classification of animals (incomplete database/categories) - Multiple obstacles (together) difficult to classify	The following elements shall be considered as obstacles by the following trucks: - Debris that are large enough to cause accidents (e.g. blown out tyres, boxes from other vehicle, boulders, garbage bins, ...). - Animals that are large enough to cause accidents (e.g. elks, sheep, ...).
LS-39	System misclassifies the pedestrian as "does not pose collision danger"	- Following truck controller requests acceleration while a pedestrian is present in-lane [H1]. - Following truck platoon controller	- Pedestrian misclassified as safe due to size (e.g. child) - Pedestrian dressed in abnormal attire (e.g. Halloween	The following elements shall be considered as pedestrians by the following trucks: - People of all sizes (e.g. children) and

Loss Scenario	Loss Scenarios (Functional Insufficiency/Performance Limitation)	Unsafe Control Action	Causal Factor (Potential Triggering Conditions)	Requirements
	[Inadequate process model].	does not request braking while a pedestrian is present in-lane [H1]. - Following truck platoon controller does not request steering to avoid collision [H1].	costumes, …) - Pedestrian with umbrellas, pedestrian walking holding a bicycle, baby strollers, cargo trolley. - pedestrian not using zebra/pedestrian crossings	disabilities - People accompanied by objects like wheel chairs, canes, baby strollers, shopping trollies, umbrellas, e-scooter, walking holding bikes, etc. - People in abnormal attire (e.g. Halloween costumes, hot dog vendor costume, ..).
LS-40	System misclassifies the cyclist/motorcyclist as "does not pose collision danger" [Inadequate process model].	- Following truck controller requests acceleration while driving towards an in-lane cyclist/motorcyclist [H1]. - Following truck platoon controller does not request braking while a cyclist/motor cyclist is present in-lane [H1]. - Following truck platoon controller does not request steering to avoid collision [H1].	- Cyclist/motorcyclist misclassified as unknown due to abnormal shape (e.g. tandem cycle, delivery bikes, motorbike with sidecar) - Cyclist/motorcyclist with people dressed in abnormal attire (e.g. Halloween costumes, …) - Wheel chairs, e-scooters, ..	The following elements shall be considered as cyclists/motorcyclists by the following trucks: - Normal bicycles - Tandem cycles - Normal motorbikes - Moppets - Delivery bikes - Motorbikes with sidecar

4.6.7. Loss Category: Incorrect Time Gap/TTC estimations

Table 26 - Loss scenarios: Incorrect Time gap/TTC estimations

Loss Scenario	Loss Scenarios (Functional Insufficiency/Performance Limitation)	Unsafe Control Action	Causal Factor (Potential Triggering Conditions)	Requirements
LS-41	System incorrectly estimates the TG/TTC to the intruder [Inadequate process model]	- Following truck platoon controller requests acceleration during a cut-in manoeuvre [H1]. - Following truck platoon controller requests acceleration too early during a cut-out manoeuvre [H1]. - Following truck platooning controller does not request braking while the platoon is in a braking situation [H1]. - Following truck platoon controller requests insufficient braking while the platoon is in a braking situation [H1]. - Following truck platoon controller requests excessive braking while the platoon is in a braking situation [H1].	- Incorrect feedback from onboard perception sensors - Incorrect feedback from ego speed and acceleration sensors - Incorrect formula or method used to estimate TG/TTC	- The following trucks shall be able to estimate the time gap to the intruders with an accuracy of 0.1 seconds. **Note:** Error of 2.2 m in position at 80 km/h. - The following trucks shall be able to estimate the TTC to the intruders with an accuracy of +/- 0.1 seconds.

Loss Scenario	Loss Scenarios (Functional Insufficiency/Performance Limitation)	Unsafe Control Action	Causal Factor (Potential Triggering Conditions)	Requirements
		- Following truck platooning controller requests braking too late while the platoon is in a braking situation [H1]. - Following truck platooning controller stops braking request too soon while the platoon is in a braking situation [H1]. - Following truck platoon controller does not request steering to avoid collision [H1].		
LS-42	System estimates the TTC to the obstacle incorrectly [Inadequate process model]	- Following truck platoon controller requests acceleration while an obstacle is present in the lane [H1]. - Following truck platoon controller does not request braking during a cut-in manoeuvre [H1]. - Following truck platoon controller requests insufficient braking during a cut-in manoeuvre [H1].	- Incorrect feedback from onboard perception sensors - Incorrect feedback from ego speed and acceleration sensors - Incorrect formula or method used to estimate TTC	- The following trucks shall be able to estimate the TTC to the relevant obstacles with an accuracy of 0.1 seconds.

Loss Scenario	Loss Scenarios (Functional Insufficiency/Performance Limitation)	Unsafe Control Action	Causal Factor (Potential Triggering Conditions)	Requirements
		- Following truck platoon controller requests excessive braking during a cut-in manoeuvre [H1]. - Following truck platoon controller requests braking too late during a cut-in manoeuvre [H1]. - Following truck platoon controller stops braking request too soon during a cut-in manoeuvre [H1]. - Following truck platoon controller does not request steering to avoid collision [H1].		
LS-43	System estimates the TTC to the pedestrian incorrectly [Inadequate process model]	- Following truck controller requests acceleration while a pedestrian is present in-lane [H1]. - Following truck platoon controller does not request braking while a pedestrian is present in-lane [H1]. - Following truck platoon controller requests insufficient	- Incorrect feedback from onboard perception sensors - Incorrect feedback from ego speed and acceleration sensors - Incorrect formula or method used to estimate TTC	- The following trucks shall be able to estimate the TTC to the relevant pedestrians with an accuracy of 0.5 seconds.

Loss Scenario	Loss Scenarios (Functional Insufficiency/Performance Limitation)	Unsafe Control Action	Causal Factor (Potential Triggering Conditions)	Requirements
		braking while a pedestrian is present in-lane [H1]. - Following truck platoon controller requests excessive braking while a pedestrian is present in-lane [H1]. - Following truck platoon controller requests braking too late while a pedestrian is present in-lane [H1]. - Following truck platoon controller stops braking request too soon while a pedestrian is present in-lane [H1]. - Following truck platoon controller does not request steering to avoid collision [H1].		
LS-44	System estimates the TG/TTC to the cyclist/motorcyclist incorrectly [Inadequate process model]	- Following truck controller requests acceleration while driving towards an in-lane cyclist/motorcyclist [H1]. - Following truck platoon controller does not request	- Errors from onboard perception sensors - Errors of ego speed and acceleration sensors - Incorrect formula or	- The following trucks shall be able to estimate the time gap to cyclists/motorcyclists with an accuracy of 0.1 seconds. **Note:** Error of 2.2 m in position at 80 km/h.

Loss Scenario	Loss Scenarios (Functional Insufficiency/Performance Limitation)	Unsafe Control Action	Causal Factor (Potential Triggering Conditions)	Requirements
		braking while a cyclist/motor cyclist is present in-lane [H1]. - Following truck platoon controller requests insufficient braking while a cyclist/motor cyclist is present in-lane [H1]. - Following truck platoon controller requests excessive braking while a cyclist/motor cyclist is present in-lane [H1]. - Following truck platoon controller requests braking too late while a cyclist/motor cyclist is present in-lane [H1]. - Following truck platoon controller stops braking request too soon while a cyclist/motor cyclist is present in-lane [H1]. - Following truck platoon controller does not request steering to avoid collision [H1].	method used to estimate TG/TTC	- The following trucks shall be able to estimate the TTC to cyclists/motorcyclists with an accuracy of 0.5 seconds.
LS-45	System estimates the TG/TTC to the forward truck	- Following truck platoon controller requests excessive acceleration while following the	- Forward vehicle communicates incorrect position and speed data via	- The following trucks shall be able to estimate the time gap to the forward truck with an accuracy of

Loss Scenario	Loss Scenarios (Functional Insufficiency/Performance Limitation)	Unsafe Control Action	Causal Factor (Potential Triggering Conditions)	Requirements
	incorrectly [Inadequate process model]	forward truck [H1]. - Following truck platooning controller does not request braking while the platoon is in a braking situation [H1]. - Following truck platoon controller requests braking during a normal driving situation (not a braking situation) [H1]. - Following truck platoon controller requests insufficient braking while the platoon is in a braking situation [H1]. - Following truck platoon controller requests excessive braking while the platoon is in a braking situation [H1]. - Following truck platooning controller requests braking too late while the platoon is in a braking situation [H1]. - Following truck platooning controller stops braking request too soon while the platoon is in a	V2V - Incorrect feedback from onboard perception sensors - Incorrect feedback from ego speed and acceleration sensors - Incorrect formula or method used to estimate TG/TTC	0.1 seconds. **Note:** Error of 2.2 m in position at 80 km/h. - The following trucks shall be able to estimate the TTC to the forward truck with an accuracy of 0.5 seconds. - The following trucks shall independently validate the location information coming from the forward truck via V2V communication. - The following trucks shall independently validate the speed information coming from the forward truck via V2V communication.

Loss Scenario	Loss Scenarios (Functional Insufficiency/Performance Limitation)	Unsafe Control Action	Causal Factor (Potential Triggering Conditions)	Requirements
		braking situation [H1]. - Following truck platoon controller does not request steering to avoid collision [H1].		

4.6.8. Loss Category: Incorrect position estimations

Table 27 - Loss scenarios: Incorrect position estimations

Loss Scenario	Loss Scenarios (Functional Insufficiency/Performance Limitation)	Unsafe Control Action	Causal Factor (Potential Triggering Conditions)	Requirements
LS-46	System estimates the position of the intruder incorrectly [Inadequate process model]	- Following truck platoon controller requests acceleration during a cut-in manoeuvre [H1]. - Following truck platoon controller requests acceleration too early during a cut-out manoeuvre [H1]. - Following truck platoon controller does not request braking during a cut-in manoeuvre [H1]. - Following truck platoon controller requests insufficient braking during a cut-in manoeuvre [H1].	- Sensors mounted incorrectly, sensor focus or position compromised, sensor blocked, etc. - Processing of the environment model is compute intensive. Delays under high processing load (e.g. too many obstacles in close proximity). - Incorrect map data (Incorrectly assumes the vehicle is in the adjacent lane e.g. on a	- The following trucks shall detect perception sensor blockages, incorrect mounting and other perception related errors. - The following trucks' autonomous driving HW shall have enough processing power, memory and bus resources to track and update the relevant metadata of at least 20 of the closest vehicles/pedestrians/ obstacles in real-time. - If HD maps are used for driving by

Loss Scenario	Loss Scenarios (Functional Insufficiency/Performance Limitation)	Unsafe Control Action	Causal Factor (Potential Triggering Conditions)	Requirements
		- Following truck platoon controller requests excessive braking during a cut-in manoeuvre [H1]. - Following truck platoon controller requests braking too late during a cut-in manoeuvre [H1]. - Following truck platoon controller stops braking request too soon during a cut-in manoeuvre [H1]. - Following truck platoon controller does not request steering to avoid collision [H1].	curve) - Cut-in/out happening on a curve - Sensor feedback delayed and not received in time because the bus is busy, inadequate message priority or arbitration, EMI, etc. - Low visibility due to bad weather or light conditions within the ODD.	the following trucks, lane lines shall be mapped accurately to support localization and navigation. - The following trucks shall be able to estimate the position of intruders with an accuracy of +/- 2 meters. **Note:** Higher error will result in wrong classification of the lane. - The following trucks shall be able to localize intruders on curved lanes including roundabouts and junctions.
LS-47	System estimates the position of the obstacle incorrectly [Inadequate process model]	- Following truck platoon controller requests acceleration while an obstacle is present in the lane [H1]. - Following truck platoon controller does not request braking for an obstacle present in-lane [H1]. - Following truck platoon controller requests insufficient braking for an in-lane obstacle [H1]. - Following truck platoon controller requests excessive braking for an in-lane obstacle [H1]. - Following truck platoon controller requests braking too late for an obstacle present in-lane [H1]. - Following truck platoon controller	- Sensors mounted incorrectly, sensor focus or position compromised, sensor blocked, etc. - Processing of the environment model is compute intensive. Delays under high processing load (e.g. too many obstacles in close proximity). - Obstacle on a curved lane	- The following trucks shall detect perception sensor blockages, incorrect mounting and other related errors. - The following trucks' autonomous driving HW shall have enough processing power, memory and bus resources to track and update the relevant metadata of at least 20 of the closest vehicles/pedestrians/obstacles in real-time. - The following trucks shall be able to estimate the position of relevant obstacles with an accuracy of +/- 0.5 meters. **Note:** or else cannot clearly identify

Loss Scenario	Loss Scenarios (Functional Insufficiency/Performance Limitation)	Unsafe Control Action	Causal Factor (Potential Triggering Conditions)	Requirements
		does not request steering to avoid collision [H1].		the lane of the obstacle (e.g. garbage bin positioned just outside the lane lines. - The following trucks shall be able to localize relevant obstacles on curved lanes including roundabouts and junctions.
LS-48	System estimates the position of the pedestrian incorrectly [Inadequate process model]	- Following truck controller requests acceleration while a pedestrian is present in-lane [H1]. - Following truck platoon controller does not request braking while a pedestrian is present in-lane [H1]. - Following truck platoon controller requests insufficient braking while a pedestrian is present in-lane [H1]. - Following truck platoon controller requests excessive braking while a pedestrian is present in-lane [H1]. - Following truck platoon controller requests braking too late while a pedestrian is present in-lane [H1]. - Following truck platoon controller stops braking request too soon while a pedestrian is present in-lane [H1]. - Following truck platoon controller does not request steering to avoid collision [H1].	- Sensors mounted incorrectly, sensor focus or position compromised, sensor blocked, etc. - Processing of the environment model is compute intensive. Delays under high processing load (e.g. too many obstacles in close proximity). - Pedestrian on a curved lane	- The following trucks shall detect perception sensor blockages, incorrect mounting and other related errors. - The following trucks' autonomous driving HW shall have enough processing power, memory and bus resources to track and update the relevant metadata of at least 20 of the closest vehicles/pedestrians/obstacles in real-time. - The following trucks shall be able to estimate the position of relevant pedestrians with an accuracy of +/- 0.5 meters. **Note:** Or else cannot know if the pedestrian is in-lane or not (e.g. standing on the pavement). - The following trucks shall be able to localize pedestrians on curved lanes including roundabouts and junctions.

Loss Scenario	Loss Scenarios (Functional Insufficiency/Performance Limitation)	Unsafe Control Action	Causal Factor (Potential Triggering Conditions)	Requirements
LS-49	System estimates the position of the cyclist/motor cyclist incorrectly [Inadequate process model]	- Following truck controller requests acceleration while driving towards an in-lane cyclist/motorcyclist [H1]. - Following truck platoon controller does not request braking while a cyclist/motor cyclist is present in-lane [H1]. - Following truck platoon controller requests insufficient braking while a cyclist/motor cyclist is present in-lane [H1]. - Following truck platoon controller requests excessive braking while a cyclist/motor cyclist is present in-lane [H1]. - Following truck platoon controller requests braking too late while a cyclist/motor cyclist is present in-lane [H1]. - Following truck platoon controller stops braking request too soon while a cyclist/motor cyclist is present in-lane [H1].	- Sensors mounted incorrectly, sensor focus or position compromised, sensor blocked, etc. - Processing of the environment model is compute intensive. Delays under high processing load (e.g. too many obstacles in close proximity). - Cyclist/motorcyclist on a curved lane	- The following trucks shall detect perception sensor blockages, incorrect mounting and other related errors. - The following trucks' autonomous driving HW shall have enough processing power, memory and bus resources to track and update the relevant metadata of at least 20 of the closest vehicles/pedestrians/obstacles in real-time. - The following trucks shall be able to estimate the position of relevant cyclists/motorcyclists with an accuracy of +/- 1 meters. (or else cannot overtake cyclists). **Note:** Accuracy lower than 1 m will not permit overtaking cyclists. - The following trucks shall be able to localize relevant cyclists/motorcyclists on curved lanes including roundabouts and junctions.
LS-50	System estimates the position of the forward truck incorrectly [Inadequate process model]	- Following truck platoon controller requests excessive acceleration while following the forward truck [H1]. - Following truck controller requests excessive acceleration while passing through a junction [H1].	- Sensors mounted incorrectly, sensor focus or position compromised, sensor blocked, etc. - Sensor feedback delayed and not received in time because	- The following trucks shall detect perception sensor blockages, incorrect mounting and other related errors. - The following trucks' autonomous driving HW shall have enough

Loss Scenario	Loss Scenarios (Functional Insufficiency/Performance Limitation)	Unsafe Control Action	Causal Factor (Potential Triggering Conditions)	Requirements
		- Following truck controller requests excessive acceleration while passing through a roundabout [H1]. - Following truck platoon controller does not request braking to give right of way during a lane merger [H1]. - Following truck platoon controller requests braking during a normal driving situation (not a braking situation) [H1]. - Following truck platoon controller requests insufficient braking while giving right of way to other vehicles during a lane merger [H1]. - Following truck platoon controller requests excessive braking while giving way to other vehicles during a lane merger [H1]. - Following truck platoon controller requests braking too late to give right of way during a lane merger [H1]. - Following truck platoon controller stops braking request too soon to give right of way during a lane merger [H1]. - Following truck platoon controller does not request steering to avoid collision [H1].	the bus is busy, inadequate message priority or arbitration, EMI, etc. - Processing of the environment model is compute intensive. Delays under high processing load (e.g. too many obstacles in close proximity). - Incorrect dynamic parameters information received from the forward truck (V2V) - Forward truck on a curved lane.	processing power, memory and bus resources to track and update the relevant metadata of at least 20 of the closest vehicles/pedestrians/obstacles in real-time. - The following trucks shall be able to estimate the position of the forward truck with an accuracy of with an accuracy of +/- 2 meters. **Note:** At lower time gaps like 0.3s, there is a distance of less than 10 m between the trucks. - Each truck shall continuously transmit its current location to the following trucks. - The following trucks shall be able to estimate the location of the forward truck on curved lanes including roundabouts and junctions. - The following trucks shall independently validate the location information coming from the forward truck via V2V communication.

Loss Scenario	Loss Scenarios (Functional Insufficiency/Performance Limitation)	Unsafe Control Action	Causal Factor (Potential Triggering Conditions)	Requirements
LS-51	System estimates the position of the vehicles in adjacent lanes incorrectly [Inadequate process model]	- Following truck controller accelerates towards other vehicles during a lane change/merger [H1]. - Following truck platoon controller does not request braking to give right of way during a lane merger [H1]. - Following truck platoon controller requests braking during a normal driving situation (not a braking situation) [H1]. - Following truck platoon controller requests insufficient braking while giving right of way to other vehicles during a lane merger [H1]. - Following truck platoon controller requests excessive braking while giving way to other vehicles during a lane merger [H1]. - Following truck platoon controller requests braking too late to give right of way during a lane merger [H1]. - Following truck platoon controller stops braking request too soon to give right of way during a lane merger [H1]. - Following truck platoon controller does not request steering during a lane change [H1]. - Following truck platoon controller	- Sensors mounted incorrectly, sensor focus or position compromised, sensor blocked, etc. - Sensor feedback delayed and not received in time because the bus is busy, inadequate message priority or arbitration, EMI, etc. - Processing of the environment model is compute intensive. Delays under high processing load (e.g. too many obstacles in close proximity). - Merging on a curved road - Incorrect feedback from onboard perception sensors - Conflicting information from different sensors [Inadequate process Model]	- The following trucks shall be able to detect perception sensor blockages, incorrect mounting and other perception related errors. - The following trucks shall be able to estimate the position of relevant vehicles in the adjacent lanes with an accuracy of 1 meter. **Note:** Or else cannot confirm the lane. - The following trucks shall be able to localize relevant vehicles (e.g. even in high speed situations like autobahns) in the adjacent lanes in all weather and light conditions within the ODD. - The following trucks shall be able to localize and track relevant vehicles in the adjacent lanes even when they are partially concealed due to ramps, pillars and other view obstructions typically found on public roads. - If HD maps are used for driving by the following trucks, lane lines shall be mapped accurately to support localization and navigation. - The following trucks' autonomous driving HW shall have enough processing power, memory and bus resources to track and update the relevant metadata of at least 20 of

Loss Scenario	Loss Scenarios (Functional Insufficiency/Performance Limitation)	Unsafe Control Action	Causal Factor (Potential Triggering Conditions)	Requirements
		does not request steering during a lane merger [H1]. - Following truck platoon controller does not request steering while passing through a roundabout [H1]. - Following truck platoon controller does not request steering while passing through a junction [H1]. - Following truck platoon controller does not request steering while driving on a curved lane [H1]. - Following truck platoon controller does not request steering while driving through road works [H1]. - Following truck platoon controller requests steering towards traffic during a lane change [H1]. - Following truck platoon controller requests steering towards traffic during a lane merge [H1]. - Following truck platoon controller requests insufficient steering while changing lanes [H1]. - Following truck platoon controller requests insufficient steering during a lane merger [H1]. - Following truck platoon controller requests steering too early while changing lane [H1]. - Following truck platoon controller		the closest vehicles/pedestrians/ obstacles in real-time.

Loss Scenario	Loss Scenarios (Functional Insufficiency/Performance Limitation)	Unsafe Control Action	Causal Factor (Potential Triggering Conditions)	Requirements
		requests steering too late while changing lane [H1]. - Following truck platoon controller requests steering too early during a lane merger [H1]. - Following truck platoon controller requests steering too late during a lane merger [H1]. - Following truck platoon controller stops steering later than expected while changing lane [H1]. - Following truck platoon controller stops steering later than expected during a lane merger [H1].		
LS-52	System estimates the lane of the vehicles in adjacent lane incorrectly (incorrectly assumed not in the adjacent lane) [Inadequate process model]	- Following truck controller accelerates towards other vehicles during a lane change/merger [H1]. - Following truck platoon controller does not request braking to give right of way during a lane merger [H1]. - Following truck platoon controller requests braking during a normal driving situation (not a braking situation) [H1]. - Following truck platoon controller requests excessive braking while giving way to other vehicles during a lane merger [H1]. - Following truck platoon controller	- Sensors mounted incorrectly, sensor focus or position compromised, sensor blocked, etc. - Sensor feedback delayed and not received in time because the bus is busy, inadequate message priority or arbitration, EMI, etc. - Processing of the environment model is compute intensive. Delays under high processing load (e.g. too many obstacles in close proximity). - Merging on a curved road	- The following trucks shall be able to detect perception sensor blockages, incorrect mounting and other perception related errors. - The following trucks shall correctly estimate the lane of the relevant vehicles in their vicinity including on curved lanes of roundabouts and junctions. - If HD maps are used for driving by the following trucks, lane lines shall be mapped accurately to support localization and navigation. - The following trucks' autonomous driving HW shall have enough

Loss Scenario	Loss Scenarios (Functional Insufficiency/Performance Limitation)	Unsafe Control Action	Causal Factor (Potential Triggering Conditions)	Requirements
		requests braking too late to give right of way during a lane merger [H1]. - Following truck platoon controller stops braking request too soon to give right of way during a lane merger [H1]. - Following truck platoon controller does not request steering during a lane change [H1]. - Following truck platoon controller does not request steering during a lane merger [H1]. - Following truck platoon controller does not request steering while passing through a roundabout [H1]. - Following truck platoon controller does not request steering while passing through a junction [H1]. - Following truck platoon controller requests steering towards traffic during a lane change [H1]. - Following truck platoon controller requests steering towards traffic during a lane merge [H1]. - Following truck platoon controller requests excessive steering while changing lanes [H1]. - Following truck platoon controller requests excessive steering during a lane merger [H1].	- Incorrect map data of the lanes (e.g. Incorrect number of lanes in the map) - Calibration errors of the onboard perception sensors	processing power, memory and bus resources to track and update the relevant metadata of at least 20 of the closest vehicles/pedestrians/ obstacles in real-time.

Loss Scenario	Loss Scenarios (Functional Insufficiency/Performance Limitation)	Unsafe Control Action	Causal Factor (Potential Triggering Conditions)	Requirements
		- Following truck platoon controller requests insufficient steering while passing through a roundabout [H1]. - Following truck platoon controller requests insufficient steering while passing through a junction [H1]. - Following truck platoon controller requests insufficient steering while changing lanes [H1]. - Following truck platoon controller requests insufficient steering during a lane merger [H1]. - Following truck platoon controller requests steering too early while changing lane [H1]. - Following truck platoon controller requests steering too late while changing lane [H1]. - Following truck platoon controller requests steering too early during a lane merger [H1]. - Following truck platoon controller requests steering too late during a lane merger [H1].		

4.6.9. Loss Category: Incorrect speed estimations

Table 28 - Loss scenarios: Incorrect speed estimations

Loss Scenario	Loss Scenarios (Functional Insufficiency/Performance Limitation)	Unsafe Control Action	Causal Factor (Potential Triggering Conditions)	Requirements
LS-53	System estimates the speed of the forward truck incorrectly [Inadequate process model]	- Following truck platoon controller requests excessive acceleration while following the forward truck [H1]. - Following truck platooning controller does not request braking while the platoon is in a braking situation [H1]. - Following truck platoon controller requests braking during a normal driving situation (not a braking situation) [H1]. - Following truck platoon controller requests insufficient braking while the platoon is in a braking situation [H1]. - Following truck platoon controller requests excessive braking while the platoon is in a braking situation [H1]. - Following truck platooning	- Sensors mounted incorrectly, sensor focus or position compromised, sensor blocked, etc. - Sensor feedback delayed and not received in time because the bus is busy, inadequate message priority or arbitration, EMI, etc. - Processing of the environment model is compute intensive. Delays under high processing load (e.g. too many obstacles in close proximity). - Incorrect feedback from onboard perception sensors - Conflicting information	- The following trucks shall be able to detect perception sensor blockages, incorrect mounting and other perception related errors. - The following trucks' autonomous driving HW shall have enough processing power, memory and bus resources to track and update the relevant metadata of at least 20 of the closest vehicles/pedestrians/obstacles in real-time. - Each truck shall continuously transmit its current speed to the following trucks. - The following trucks shall be able to estimate the speed of the forward truck an accuracy of +/- 1 m/s. **Note:** Error of +/- 3.6 km/h enough to detect slow moving traffic.

Loss Scenario	Loss Scenarios (Functional Insufficiency/Performance Limitation)	Unsafe Control Action	Causal Factor (Potential Triggering Conditions)	Requirements
		controller requests braking too late while the platoon is in a braking situation [H1]. - Following truck platooning controller stops braking request too soon while the platoon is in a braking situation [H1].	from different sensors [Inadequate process Model]	- The following trucks shall independently validate the speed information coming from the forward truck via V2V communication.
LS-54	System estimates the speed of vehicles in adjacent lanes incorrectly [Inadequate process model]	- Following truck controller accelerates towards other vehicles during a lane change/merger [H1]. - Following truck platoon controller does not request braking to give right of way during a lane merger [H1]. - Following truck platoon controller requests insufficient braking while giving right of way to other vehicles during a lane merger [H1]. - Following truck platoon controller requests excessive braking while giving way to other	- Sensors mounted incorrectly, sensor focus or position compromised, sensor blocked, etc. - Sensor feedback delayed and not received in time because the bus is busy, inadequate message priority or arbitration, EMI, etc. - Processing of the environment model is compute intensive. Delays under high processing load (e.g. too many obstacles in close proximity).	- The following trucks shall be able to detect perception sensor blockages, incorrect mounting and other perception related errors. - The following trucks' autonomous driving HW shall have enough processing power, memory and bus resources to track and update the relevant metadata of at least 20 of the closest vehicles/pedestrians/ obstacles in real-time. - The following trucks shall be able to estimate the speed of relevant vehicles in the adjacent lanes with an accuracy of +/- 1 m/s.

Loss Scenario	Loss Scenarios (Functional Insufficiency/Performance Limitation)	Unsafe Control Action	Causal Factor (Potential Triggering Conditions)	Requirements
		vehicles during a lane merger [H1]. - Following truck platoon controller requests braking too late to give right of way during a lane merger [H1]. - Following truck platoon controller stops braking request too soon to give right of way during a lane merger [H1]. - Following truck platoon controller does not request steering during a lane change [H1]. - Following truck platoon controller does not request steering during a lane merger [H1]. - Following truck platoon controller requests steering towards traffic during a lane change [H1]. - Following truck platoon controller requests steering towards traffic during a lane	- Incorrect feedback from onboard perception sensors - Conflicting information from different sensors [Inadequate process Model]	**Note:** Error of +/- 3.6 km/h enough to detect slow moving traffic.

Loss Scenario	Loss Scenarios (Functional Insufficiency/Performance Limitation)	Unsafe Control Action	Causal Factor (Potential Triggering Conditions)	Requirements
		merge [H1]. - Following truck platoon controller requests excessive steering while changing lanes [H1]. - Following truck platoon controller requests excessive steering during a lane merger [H1]. - Following truck platoon controller requests insufficient steering while changing lanes [H1]. - Following truck platoon controller requests insufficient steering during a lane merger [H1]. - Following truck platoon controller requests steering too early while changing lane [H1]. - Following truck platoon controller requests steering too late while changing lane [H1]. - Following truck platoon		

Loss Scenario	Loss Scenarios (Functional Insufficiency/Performance Limitation)	Unsafe Control Action	Causal Factor (Potential Triggering Conditions)	Requirements
		controller requests steering too early during a lane merger [H1]. - Following truck platoon controller requests steering too late during a lane merger [H1]. - Following truck platoon controller stops steering later than expected while changing lane [H1]. - Following truck platoon controller stops steering later than expected during a lane merger [H1].		
LS-55	System estimates the speed of intruder incorrectly [Inadequate process model]	- Following truck platoon controller requests insufficient braking during a cut-in manoeuvre [H1]. - Following truck platoon controller requests excessive braking during a cut-in manoeuvre [H1]. - Following truck platoon controller requests braking too late during a cut-in manoeuvre	- Sensors mounted incorrectly, sensor focus or position compromised, sensor blocked, etc. - Sensor feedback delayed and not received in time because the bus is busy, inadequate message priority or arbitration, EMI, etc. - Processing of the	- The following trucks shall be able to detect perception sensor blockages, incorrect mounting and other perception related errors. - The following trucks' autonomous driving HW shall have enough processing power, memory and bus resources to track and update the relevant metadata of at least 20 of the closest vehicles/pedestrians/obstacles in

Loss Scenario	Loss Scenarios (Functional Insufficiency/Performance Limitation)	Unsafe Control Action	Causal Factor (Potential Triggering Conditions)	Requirements
		[H1]. - Following truck platoon controller stops braking request too soon during a cut-in manoeuvre [H1].	environment model is compute intensive. Delays under high processing load (e.g. too many obstacles in close proximity). - Incorrect feedback from onboard perception sensors - Conflicting information from different sensors [Inadequate process Model]	real-time. - The following trucks shall be able to estimate the speed of the intruders with an accuracy of +/- 1 m/s. **Note:** Error of +/- 3.6 km/h enough to detect slow moving traffic.
LS-56	System estimates the speed of the pedestrian incorrectly [Inadequate process model]	- Following truck platoon controller requests insufficient braking during a cut-in manoeuvre [H1]. - Following truck platoon controller requests excessive braking while a pedestrian is present in-lane [H1]. - Following truck platoon controller requests braking too late while a pedestrian is present in-lane [H1]. - Following truck platoon	- Sensors mounted incorrectly, sensor focus or position compromised, sensor blocked, etc. - Sensor feedback delayed and not received in time because the bus is busy, inadequate message priority or arbitration, EMI, etc. - Processing of the environment model is compute intensive. Delays	- The following trucks shall be able to detect perception sensor blockages, incorrect mounting and other perception related errors. - The following trucks' autonomous driving HW shall have enough processing power, memory and bus resources to track and update the relevant metadata of at least 20 of the closest vehicles/pedestrians/obstacles in real-time. - The following trucks shall be able

Loss Scenario	Loss Scenarios (Functional Insufficiency/Performance Limitation)	Unsafe Control Action	Causal Factor (Potential Triggering Conditions)	Requirements
		controller stops braking request too soon while a pedestrian is present in-lane [H1].	under high processing load (e.g. too many obstacles in close proximity). - Incorrect feedback from onboard perception sensors - Conflicting information from different sensors [Inadequate process Model]	to estimate the speed of relevant pedestrians with an accuracy of +/- 1 m/s. **Note:** Average walking speed is 1.5 m/s. This accuracy is required to differential a stationary pedestrian from a moving one.
LS-57	System estimates the speed of the cyclist/motorcyclist incorrectly [Inadequate process model]	- Following truck platoon controller requests insufficient braking while a cyclist/motor cyclist is present in-lane [H1]. - Following truck platoon controller requests excessive braking while a cyclist/motor cyclist is present in-lane [H1]. - Following truck platoon controller requests braking too late while a cyclist/motor cyclist is present in-lane [H1]. - Following truck platoon controller stops braking request	- Sensors mounted incorrectly, sensor focus or position compromised, sensor blocked, etc. - Sensor feedback delayed and not received in time because the bus is busy, inadequate message priority or arbitration, EMI, etc. - Processing of the environment model is compute intensive. Delays under high processing load (e.g. too many obstacles in close proximity).	- The following trucks shall be able to detect perception sensor blockages, incorrect mounting and other perception related errors. - The following trucks' autonomous driving HW shall have enough processing power, memory and bus resources to track and update the relevant metadata of at least 20 of the closest vehicles/pedestrians/ obstacles in real-time. - The following trucks shall be able to estimate the speed of relevant cyclists/motorcyclists with an accuracy of +/- 1 m/s.

Loss Scenario	Loss Scenarios (Functional Insufficiency/Performance Limitation)	Unsafe Control Action	Causal Factor (Potential Triggering Conditions)	Requirements
		too soon while a cyclist/motor cyclist is present in-lane [H1].	- Incorrect feedback from onboard perception sensors - Conflicting information from different sensors [Inadequate process Model]	**Note**: Error of +/- 3.6 km/h enough to detect slow moving traffic.

4.6.10. Loss Category: Incorrect acceleration estimations

Table 29 - Loss scenarios: Incorrect acceleration estimations

Loss Scenario	Loss Scenarios (Functional Insufficiency/Performance Limitation)	Unsafe Control Action	Causal Factor (Potential Triggering Conditions)	Requirements
LS-58	System estimates the acceleration of the forward truck incorrectly [Inadequate process model]	- Following truck platooning controller does not request braking while the platoon is in a braking situation [H1]. - Following truck platoon controller requests braking during a normal driving situation	- Conflicting dynamics information between the V2V information and the measurements from the onboard sensors: - Calibration error of onboard perception sensors	- Each truck shall estimate its current acceleration with an accuracy of +/- 0.5 m/s² and continuously transmit it to the following trucks. - The following trucks shall be able to estimate the acceleration of the

		(not a braking situation) [H1]. - Following truck platoon controller requests insufficient braking while the platoon is in a braking situation [H1]. - Following truck platoon controller requests excessive braking while the platoon is in a braking situation [H1]. - Following truck platooning controller requests braking too late while the platoon is in a braking situation [H1]. - Following truck platooning controller stops braking request too soon while the platoon is in a braking situation [H1]. - Following truck platoon controller does not request steering to avoid collision [H1].	(SOTIF) - Incorrect information received from forward truck (V2V) - Functional safety - Incorrect formula used to estimate the acceleration of the forward truck	forward truck with an accuracy of +/- 1 m/s^2. **Note:** To maintain safe time gap when driving at lower time gaps. - The following trucks shall independently validate the acceleration data coming from the forward truck via V2V communication.
LS-59	System estimates the acceleration of the intruder incorrectly [Inadequate control algorithm or Inadequate process model]	- Following truck platoon controller does not request braking during a cut-in manoeuvre [H1]. - Following truck platoon controller requests insufficient braking during a cut-in manoeuvre [H1]. - Following truck platoon	- Incorrect information received from the onboard sensors - Incorrect formula used to estimate the acceleration of the forward truck	- The following trucks shall be able to estimate the acceleration of the intruder with an accuracy of +/- 1 m/s^2.

		controller requests excessive braking during a cut-in manoeuvre [H1]. - Following truck platoon controller requests braking too late during a cut-in manoeuvre [H1]. - Following truck platoon controller stops braking request too soon during a cut-in manoeuvre [H1]. - Following truck platoon controller does not request steering to avoid collision [H1].		
LS-60	System estimates the acceleration of the cyclist/motorcyclist incorrectly [Inadequate control algorithm or Inadequate process model]	- Following truck platoon controller does not request braking while a cyclist/motor cyclist is present in-lane [H1]. - Following truck platoon controller requests insufficient braking while a cyclist/motor cyclist is present in-lane [H1]. - Following truck platoon controller requests excessive braking while a cyclist/motor cyclist is present in-lane [H1]. - Following truck platoon controller requests braking too	- Incorrect information received from the onboard sensors - Incorrect formula used to estimate the acceleration of the forward truck	- The following trucks shall be able to estimate the acceleration of the cyclist/motorcyclist with an accuracy of +/- 1 m/s².

		late while a cyclist/motor cyclist is present in-lane [H1]. - Following truck platoon controller stops braking request too soon while a cyclist/motor cyclist is present in-lane [H1]. - Following truck platoon controller does not request steering to avoid collision [H1].		
LS-61	System estimates the acceleration of the vehicles in adjacent lanes incorrectly [Inadequate control algorithm or Inadequate process model]	- Following truck platoon controller requests insufficient braking while giving right of way to other vehicles during a lane merger [H1]. - Following truck platoon controller requests excessive braking while giving way to other vehicles during a lane merger [H1]. - Following truck platoon controller requests braking too late to give right of way during a lane merger [H1]. - Following truck platoon controller stops braking request too soon to give right of way during a lane merger [H1]. - Following truck platoon controller does not request	- Incorrect information received from the onboard sensors - Incorrect formula used to estimate the acceleration of the forward truck	- The following trucks shall be able to estimate the acceleration of the vehicles in adjacent lanes with an accuracy of +/- 1 m/s^2. **Note:** To detect if the vehicle is giving way for lane change/merger.

		steering during a lane change [H1]. - Following truck platoon controller does not request steering during a lane merger [H1]. - Following truck platoon controller requests steering towards traffic during a lane change [H1]. - Following truck platoon controller requests steering towards traffic during a lane merge [H1]. - Following truck platoon controller requests excessive steering while changing lanes [H1]. - Following truck platoon controller requests excessive steering during a lane merger [H1]. - Following truck platoon controller requests insufficient steering while changing lanes [H1]. - Following truck platoon controller requests insufficient steering during a lane merger		

		[H1]. - Following truck platoon controller requests steering too early while changing lane [H1]. - Following truck platoon controller requests steering too late while changing lane [H1]. - Following truck platoon controller requests steering too early during a lane merger [H1]. - Following truck platoon controller requests steering too late during a lane merger [H1]. - Following truck platoon controller stops steering later than expected while changing lane [H1]. - Following truck platoon controller stops steering later than expected during a lane merger [H1].		

4.6.11. Loss Category: Incorrect behaviour prediction

Table 30 - Loss scenarios: Incorrect behaviour prediction

Loss Scenario	Loss Scenarios (Functional Insufficiency/Performance Limitation)	Unsafe Control Action	Causal Factor (Potential Triggering Conditions)	Requirements
LS-62	System predicts the behaviour/trajectory of the forward truck incorrectly [Inadequate process model]	- Following truck platoon controller requests excessive acceleration while following the forward truck [H1]. - Following truck controller requests excessive acceleration while passing through a junction [H1]. - Following truck controller requests excessive acceleration while passing through a roundabout [H1]. - Following truck platooning controller does not request braking while the platoon is in a braking situation [H1]. - Following truck platoon controller requests braking during a normal driving situation (not a braking situation) [H1].	- Conflicting speed information between the V2V information and the measurements from the onboard sensors: - Incorrect feedback from onboard perception sensors - Incorrect path data received from forward truck (V2V) - Functional safety	- Each truck shall transmit its current path with an accuracy of +/- 20 cm to the following trucks. **Note:** Required for the following trucks to correctly estimate the lane of the forward truck. - The following trucks shall be able to predict the behaviour/trajectory of the forward truck including on curved lanes of roundabouts and junctions with an accuracy of +/- 1 meter. **Note:** To correctly identify the target lane. - The following trucks shall independently validate the path information coming from the forward truck via V2V communication.

Loss Scenario	Loss Scenarios (Functional Insufficiency/Performance Limitation)	Unsafe Control Action	Causal Factor (Potential Triggering Conditions)	Requirements
		- Following truck platoon controller requests insufficient braking while the platoon is in a braking situation [H1]. - Following truck platoon controller requests excessive braking while the platoon is in a braking situation [H1]. - Following truck platooning controller requests braking too late while the platoon is in a braking situation [H1]. - Following truck platooning controller stops braking request too soon while the platoon is in a braking situation [H1]. - Following truck platoon controller does not request steering to avoid collision [H1].		
LS-63	System estimates the behaviour/trajectory of the intruder incorrectly [Unsafe	- Following truck platoon controller requests acceleration during a cut-in manoeuvre [H1]. - Following truck platoon controller does not request	- Indicators turned ON incorrectly by the vehicle - Cyclist uses hand gestures to indicate movement	- The following trucks truck shall be able to predict the behaviour/trajectory of intruders including on curved lanes of roundabouts and junctions with an

Loss Scenario	Loss Scenarios (Functional Insufficiency/Performance Limitation)	Unsafe Control Action	Causal Factor (Potential Triggering Conditions)	Requirements
	sensor input or Inadequate environment model]	braking during a cut-in manoeuvre [H1]. - Following truck platoon controller requests insufficient braking during a cut-in manoeuvre [H1]. - Following truck platoon controller requests excessive braking during a cut-in manoeuvre [H1]. - Following truck platoon controller requests braking too late during a cut-in manoeuvre [H1]. - Following truck platoon controller stops braking request too soon during a cut-in manoeuvre [H1]. - Following truck platoon controller does not request steering to avoid collision [H1].		accuracy of +/- 1 meter. **Note:** Enough accuracy to know the target lane correctly. - The following trucks shall be able to predict the behaviour of cyclists using hand gestures to indicate their manoeuvre.

Loss Scenario	Loss Scenarios (Functional Insufficiency/Performance Limitation)	Unsafe Control Action	Causal Factor (Potential Triggering Conditions)	Requirements
LS-64	System predicts the behaviour/trajectory of the obstacle incorrectly [Inadequate environment model]	- Following truck platoon controller requests acceleration while an obstacle is present in the lane [H1]. - Following truck platoon controller does not request braking for an obstacle present in-lane [H1]. - Following truck platoon controller requests insufficient braking for an in-lane obstacle [H1]. - Following truck platoon controller requests excessive braking for an in-lane obstacle [H1]. - Following truck platoon controller requests braking too late for an obstacle present in-lane [H1]. - Following truck platooning controller stops braking request too soon while the platoon is in a braking situation [H1]. - Following truck platoon	- Moving obstacle with unpredictable behaviour (falling cargo box, rocks, ...)	- The following trucks shall be able to predict the behaviour/trajectory of moving obstacles (falling boxes, debris, etc..) including on curved lanes with an accuracy of +/- 0.5 meters. **Note:** Or else cannot accurately know if the obstacle will enter the target lane or not.

Loss Scenario	Loss Scenarios (Functional Insufficiency/Performance Limitation)	Unsafe Control Action	Causal Factor (Potential Triggering Conditions)	Requirements
		controller does not request steering to avoid collision [H1].		
LS-65	System predicts the behaviour/trajectory of the pedestrian incorrectly [Inadequate process model]	- Following truck controller requests acceleration while a pedestrian is present in-lane [H1]. - Following truck platoon controller does not request braking while a pedestrian is present in-lane [H1]. - Following truck platoon controller requests insufficient braking while a pedestrian is present in-lane [H1]. - Following truck platoon controller requests excessive braking while a pedestrian is present in-lane [H1]. - Following truck platoon controller requests braking too late while a pedestrian is present in-lane [H1]. - Following truck platoon controller stops braking request	- Pedestrian using skateboard, scooter, roller skates, etc..	- The following trucks shall be able to predict the behaviour/trajectory of relevant pedestrians including on curved lanes with an accuracy of +/- 0.5 meters. **Note:** Or else cannot know if the pedestrian going to enter the target lane or not. - The following trucks shall be able to predict the behaviour/trajectory of pedestrians even when they are using alternate modes of transportation like skateboards, roller skates, e-scooters, etc..).

Loss Scenario	Loss Scenarios (Functional Insufficiency/Performance Limitation)	Unsafe Control Action	Causal Factor (Potential Triggering Conditions)	Requirements
		too soon while a pedestrian is present in-lane [H1]. - Following truck platoon controller does not request steering to avoid collision [H1].		
LS-66	System predicts the behaviour/trajectory of the cyclist/motor cyclist incorrectly [Inadequate process model]	- Following truck controller requests acceleration while driving towards an in-lane cyclist/motorcyclist [H1]. - Following truck platoon controller does not request braking while a cyclist/motor cyclist is present in-lane [H1]. - Following truck platoon controller requests insufficient braking while a cyclist/motor cyclist is present in-lane [H1]. - Following truck platoon controller requests excessive braking while a cyclist/motor cyclist is present in-lane [H1]. - Following truck platoon controller requests braking too late while a cyclist/motor cyclist is	- Movement of the cyclist difficult to predict (e.g. e-scooter, …) - System does not recognise hand signals for lane change	- The following trucks shall be able to predict the behaviour/trajectory of relevant cyclists/motorcyclist including on curved lanes with an accuracy of +/- 1 meters. **Note:** To correctly predict intention of entering the target lane.

Loss Scenario	Loss Scenarios (Functional Insufficiency/Performance Limitation)	Unsafe Control Action	Causal Factor (Potential Triggering Conditions)	Requirements
		present in-lane [H1]. - Following truck platoon controller stops braking request too soon while a cyclist/motor cyclist is present in-lane [H1]. - Following truck platoon controller does not request steering to avoid collision [H1].		
LS-67	System predicts the behaviour/trajectory of the vehicles in adjacent lanes incorrectly [Inadequate process model]	- Following truck controller accelerates towards other vehicles during a lane change/merger [H1]. - Following truck platoon controller does not request braking to give right of way during a lane merger [H1]. - Following truck platoon controller requests braking during a normal driving situation (not a braking situation) [H1]. - Following truck platoon controller requests insufficient braking while giving right of way	- Unable to detect turn indicators from the side - Unable to detected driver cues to go first through hand or face gestures - Heavy traffic with almost stationary vehicles - Late reaction by the ego vehicle makes the other driver change his mind to give way - Presence of cyclist or motor cyclists in the lane (difficult to detect?)	- The following trucks shall be able to predict the behaviour/trajectory of the vehicles in adjacent lanes including on curved lanes with an accuracy of +/- 1 meters. **Note:** Or else cannot accurately know if the vehicle will enter the target lane or not. - The following trucks shall be able to predict the behaviour/trajectory of slow moving traffic in adjacent lanes (e.g. traffic jams) by considering driver cues like turn indicators.

Loss Scenario	Loss Scenarios (Functional Insufficiency/Performance Limitation)	Unsafe Control Action	Causal Factor (Potential Triggering Conditions)	Requirements
		to other vehicles during a lane merger [H1]. - Following truck platoon controller requests braking too late to give right of way during a lane merger [H1]. - Following truck platoon controller stops braking request too soon to give right of way during a lane merger [H1]. - Following truck platoon controller does not request steering during a lane change [H1]. - Following truck platoon controller does not request steering during a lane merger [H1]. - Following truck platoon controller does not request steering while passing through a roundabout [H1]. - Following truck platoon controller does not request steering while passing through a	- Unable to track vehicles on roundabouts, junctions, etc..	

Loss Scenario	Loss Scenarios (Functional Insufficiency/Performance Limitation)	Unsafe Control Action	Causal Factor (Potential Triggering Conditions)	Requirements
		roundabout [H1]. - Following truck platoon controller does not request steering while passing through a junction [H1]. - Following truck platoon controller does not request steering while driving through road works [H1]. - Following truck platoon controller requests steering towards traffic during a lane change [H1]. - Following truck platoon controller requests steering towards traffic during a lane merge [H1]. - Following truck platoon controller requests excessive steering while changing lanes [H1]. - Following truck platoon controller requests excessive steering during a lane merger		

Loss Scenario	Loss Scenarios (Functional Insufficiency/Performance Limitation)	Unsafe Control Action	Causal Factor (Potential Triggering Conditions)	Requirements
		[H1]. - Following truck platoon controller requests insufficient steering while changing lanes [H1]. - Following truck platoon controller requests insufficient steering during a lane merger [H1]. - Following truck platoon controller requests steering too early while changing lane [H1]. - Following truck platoon controller requests steering too late while changing lane [H1]. - Following truck platoon controller requests steering too early during a lane merger [H1]. - Following truck platoon controller requests steering too late during a lane merger [H1]. - Following truck platoon controller stops steering later than expected while changing lane [H1].		

Loss Scenario	Loss Scenarios (Functional Insufficiency/Performance Limitation)	Unsafe Control Action	Causal Factor (Potential Triggering Conditions)	Requirements
		- Following truck platoon controller stops steering later than expected during a lane merger [H1]. - Following truck platoon controller does not request steering to avoid collision [H1].		
LS-68	System estimates the space to merge in the adjacent lane incorrectly [Inadequate process model]	- Following truck controller accelerates towards other vehicles during a lane change/merger [H1]. - Following truck platoon controller does not request braking to give right of way during a lane merger [H1]. - Following truck platoon controller requests insufficient braking while giving right of way to other vehicles during a lane merger [H1]. - Following truck platoon controller requests excessive braking while giving way to other	- Low visibility due to bad weather or low light - Incorrect estimation of the position and speed of other vehicle - Conflicting information from different sensors - Incorrect method used to calculate the space	- The following trucks shall be able to estimate the space available to change/merge into adjacent lanes with an accuracy of +/- 2 meters in all weather and light conditions within the ODD. **Note:** Since lane change/merge will not go ahead when the gap is lower than 5 m, an error of 2 m is acceptable.

Loss Scenario	Loss Scenarios (Functional Insufficiency/Performance Limitation)	Unsafe Control Action	Causal Factor (Potential Triggering Conditions)	Requirements
		vehicles during a lane merger [H1]. - Following truck platoon controller requests braking too late to give right of way during a lane merger [H1]. - Following truck platoon controller stops braking request too soon to give right of way during a lane merger [H1]. - Following truck platoon controller does not request steering during a lane change [H1]. - Following truck platoon controller does not request steering during a lane merger [H1]. - Following truck platoon controller requests steering towards traffic during a lane change [H1]. - Following truck platoon controller requests steering towards traffic during a lane		

Loss Scenario	Loss Scenarios (Functional Insufficiency/Performance Limitation)	Unsafe Control Action	Causal Factor (Potential Triggering Conditions)	Requirements
		merge [H1]. - Following truck platoon controller requests excessive steering while changing lanes [H1]. - Following truck platoon controller requests excessive steering during a lane merger [H1]. - Following truck platoon controller requests insufficient steering while changing lanes [H1]. - Following truck platoon controller requests insufficient steering during a lane merger [H1]. - Following truck platoon controller requests steering too early while changing lane [H1]. - Following truck platoon controller requests steering too late while changing lane [H1]. - Following truck platoon		

Loss Scenario	Loss Scenarios (Functional Insufficiency/Performance Limitation)	Unsafe Control Action	Causal Factor (Potential Triggering Conditions)	Requirements
		controller requests steering too early during a lane merger [H1]. - Following truck platoon controller requests steering too late during a lane merger [H1]. - Following truck platoon controller does not request steering to avoid collision [H1].		

4.6.12. Loss Category: Speed limits

Table 31 - Loss scenarios: Speed limits

Loss Scenario	Loss Scenarios (Functional Insufficiency/Performance Limitation)	Unsafe Control Action	Causal Factor (Potential Triggering Conditions)	Requirements
LS-69	System does not have a speed limit for passing through junctions [Inadequate control algorithm]	- Following truck controller requests excessive acceleration while passing through a junction [H1]. - Following truck platoon controller requests insufficient braking while the platoon is passing through a junction [H1].	- Presence of a junction not communicated by the lead vehicle - Platoon leader does not set a speed limit while passing through the junction - No predefined speed limits for driving through junctions	- The leading truck shall communicate the presence of preceding junction to the following trucks (not the responsibility of the driver). - While driving through junctions, the following trucks shall maintain speeds within legal limits.

Loss Scenario	Loss Scenarios (Functional Insufficiency/Performance Limitation)	Unsafe Control Action	Causal Factor (Potential Triggering Conditions)	Requirements
LS-70	System does not have a speed limit for passing through roundabouts [Inadequate control algorithm]	- Following truck controller requests excessive acceleration while passing through a roundabout [H1]. - Following truck platoon controller requests insufficient braking while the platoon is passing through a roundabout [H1].	- Presence of a roundabout not communicated by the lead vehicle - Platoon leader does not set a speed limit while passing through the roundabouts - No predefined speed limits for driving through roundabouts	- The leading truck shall communicate the presence of preceding roundabout to the following trucks (not the responsibility of the driver). - While driving through roundabouts, the following trucks shall maintain speeds within legal limits.
LS-71	System does not have a speed limit for passing through tollgates [Inadequate control algorithm]	- Following truck controller requests excessive acceleration while passing through a toll gate [H1]. - Following truck platoon controller requests insufficient braking while the platoon is passing through a tollgate [H1].	- Presence of a toll gate not communicated by the lead vehicle - Platoon leader does not set/follow the speed limits while passing through toll gates - No predefined speed limits for driving through toll gates	- The leading truck shall communicate the presence of preceding toll gate to the following trucks (not the responsibility of the driver). - While driving through toll gates, the following trucks shall maintain speeds within legal limits.
LS-72	System does not have a speed limit while driving at the hubs [Inadequate control algorithm]	- Following truck controller requests excessive acceleration while driving at the hub [H1]. - Following truck platoon controller requests insufficient braking while the platoon is passing through a hub [H1].	- Presence of a hub not communicated by the lead vehicle - Platoon leader does not set/follow the speed limits driving through hubs - No predefined speed limits for driving through hubs	- The leading truck shall communicate the presence of preceding hub to the following trucks (not the responsibility of the driver). - While driving through hubs, the following trucks shall maintain speeds within legal limits.
LS-73	System does not have a speed limit for passing through road works [Inadequate control algorithm]	- Following truck controller requests excessive acceleration while driving through road works [H1]. - Following truck platoon controller requests insufficient braking while	- Presence of road works not communicated by the lead vehicle - Platoon leader does not set/follow the speed limits	- The leading truck shall communicate the presence of preceding road works to the following trucks (not the responsibility of the driver). - While driving through road works,

Loss Scenario	Loss Scenarios (Functional Insufficiency/Performance Limitation)	Unsafe Control Action	Causal Factor (Potential Triggering Conditions)	Requirements
		the platoon is passing through roadworks [H1].	driving through road works - No predefined speed limits for driving through road works	the following trucks shall maintain speeds within legal limits.

4.6.13. Loss Category: Ego estimations

Table 32 - Loss scenarios: Ego estimations

Loss Scenario	Loss Scenarios (Functional Insufficiency/Performance Limitation)	Unsafe Control Action	Causal Factor (Potential Triggering Conditions)	Requirements
LS-74	System estimates its current position incorrectly [Inadequate process model]	All the UCAs that can result in hazard H1.	- Loss of GNSS signal (inside tunnels/urban canyons) - Incorrect map data - Incorrect feedback from onboard perception sensors - Incorrect feedback from ego speed and acceleration sensors	- The following trucks shall be able to localize themselves with an accuracy of 10 cm. **Note:** This level of accuracy is required to localize in the correct lane.. - The following trucks shall be able to localize themselves even under the loss of GNSS signal. - If HD maps are used for localization, landmarks shall be correctly mapped for accurate localization and navigation.
LS-75	System evaluates its current speed incorrectly	All the UCAs that can result in hazard H1.	- Incorrect feedback from ego speed sensors	- Each truck shall estimate its current speed with an accuracy of +/- 0.5 m/s.

Loss Scenario	Loss Scenarios (Functional Insufficiency/Performance Limitation)	Unsafe Control Action	Causal Factor (Potential Triggering Conditions)	Requirements
	[Inadequate process model]			**Note:** Accurate estimations required to follow the target path.
LS-76	System evaluates its current acceleration incorrectly [Inadequate process model]	All the UCAs that can result in hazard H1.	- Incorrect feedback from the acceleration sensors	- Each truck shall estimate its current acceleration with an accuracy of +/- 0.5 m/s^2 and continuously transmit it to the following trucks.
LS-77	System estimates its cargo load incorrectly [unsafe sensor input or inadequate process model]	- Following truck platoon controller requests excessive acceleration while following the forward truck [H1]. - Following truck controller requests excessive acceleration while passing through a junction [H1]. - Following truck controller requests excessive acceleration while passing through a roundabout [H1]. - Following truck controller requests excessive acceleration while passing through a toll gate [H1]. - Following truck controller requests excessive acceleration while driving at the hub [H1]. - Following truck controller requests excessive acceleration while driving through road works [H1]. - Following truck platoon controller requests insufficient braking while the platoon is in a braking situation [H1]. - Following truck platoon controller	- Calibration errors or incorrect placement of load sensors - Incorrect feedback from ego speed and acceleration sensors	- Each truck shall estimate its cargo load with an accuracy of +/- 50 kgs. **Note**: Enough to correctly estimate the brake performance.

Loss Scenario	Loss Scenarios (Functional Insufficiency/Performance Limitation)	Unsafe Control Action	Causal Factor (Potential Triggering Conditions)	Requirements
		requests insufficient braking during a cut-in manoeuvre [H1]. - Following truck platoon controller requests insufficient braking while a pedestrian is present in-lane [H1]. - Following truck platoon controller requests insufficient braking while a cyclist/motor cyclist is present in-lane [H1]. - Following truck platoon controller requests insufficient braking while giving right of way to other vehicles during a lane merger [H1]. - Following truck platoon controller requests insufficient braking for an in-lane obstacle [H1]. - Following truck platoon controller requests insufficient braking while the platoon is passing through a junction [H1]. - Following truck platoon controller requests insufficient braking while the platoon is passing through a roundabout [H1]. - Following truck platoon controller requests insufficient braking while the platoon is passing through a tollgate [H1]. - Following truck platoon controller requests insufficient braking while		

Loss Scenario	Loss Scenarios (Functional Insufficiency/Performance Limitation)	Unsafe Control Action	Causal Factor (Potential Triggering Conditions)	Requirements
		the platoon is passing through a hub [H1]. - Following truck platoon controller requests insufficient braking while the platoon is passing through roadworks [H1]. - Following truck platoon controller requests excessive braking while the platoon is in a braking situation [H1]. - Following truck platoon controller requests excessive braking during a cut-in manoeuvre [H1]. - Following truck platoon controller requests excessive braking while a pedestrian is present in-lane [H1]. - Following truck platoon controller requests excessive braking while a cyclist/motor cyclist is present in-lane [H1]. - Following truck platoon controller requests excessive braking while giving way to other vehicles during a lane merger [H1]. - Following truck platoon controller requests excessive braking for an in-lane obstacle [H1].		
LS-78	System estimates its brake performance incorrectly [unsafe sensor input or	- Following truck platoon controller requests insufficient braking while the platoon is in a braking situation	Does not consider the following factors for brake performance estimation:	- The following trucks shall estimate their brake performance with an accuracy of +/- 1.5 m/s².

Loss Scenario	Loss Scenarios (Functional Insufficiency/Performance Limitation)	Unsafe Control Action	Causal Factor (Potential Triggering Conditions)	Requirements
	inadequate process model]	[H1]. - Following truck platoon controller requests insufficient braking during a cut-in manoeuvre [H1]. - Following truck platoon controller requests insufficient braking while a pedestrian is present in lane [H1]. - Following truck platoon controller requests insufficient braking while a cyclist/motor cyclist is present in lane [H1]. - Following truck platoon controller requests insufficient braking while giving way to other vehicles during a lane merger [H1]. - Following truck platoon controller requests insufficient braking for an in-lane obstacle [H1]. - Platooning controller provides lower than actual brake performance value to the following truck [H1].	- Road inclination and surface conditions (low mu conditions, etc..) - Vehicle load conditions - Current condition of the braking system (pressure gradient, pads wear, temperature, ...) - Tyre conditions (type, wear conditions, air pressure, ...) - Distribution of brake force between the axles	**Note:** Acceptable error to maintain safe distance. The following factors shall be considered for the brake force estimation: - Road inclination and surface conditions (low mu conditions, etc..) - Vehicle load conditions - Current condition of the braking system (pressure gradient, pads wear, temperature, ...) - Tyre conditions (type, wear conditions, air pressure, ...) - Distribution of brake force between the axles - If no brake performance is communicated by the forward truck, the following trucks shall assume maximum performance by the forward truck.

4.6.14. Loss Category: Calculation of target path to follow

Table 33 - Loss scenarios: Calculation of target path to follow

Loss Scenario	Loss Scenarios (Functional Insufficiency/Performance Limitation)	Unsafe Control Action	Causal Factor (Potential Triggering Conditions)	Requirements
LS-79	System calculates the path to follow during a cut-in incorrectly [Inadequate control algorithm]	- Following truck platoon controller requests acceleration during a cut-in manoeuvre [H1]. - Following truck platoon controller does not request braking during a cut-in manoeuvre [H1]. - Following truck platoon controller does not request braking during a cut-in manoeuvre [H1]. - Following truck platoon controller does not request steering to avoid collision [H1].	- System does not take the intruder into consideration for the target path calculations	The following trucks shall generate the desired trajectories considering the behaviour of the following elements: - forward truck - Intruders (Other vehicles (including emergency vehicles), cyclists/motor-cyclists) - Pedestrians (including on skate boarders, roller skaters, scooters, etc..) - Other obstacles (cargo boxes, boulders, road debris, etc..)
LS-80	System calculates the path to follow around obstacles incorrectly [Inadequate control algorithm]	- Following truck platoon controller requests acceleration while an obstacle is present in the lane [H1]. - Following truck platoon controller does not request braking for an obstacle present in-lane [H1]. - Following truck platoon controller does not request braking for an obstacle present in-lane [H1]. - Following truck platoon controller does not request braking for an obstacle present in-lane [H1].	- System does not take the obstacle into consideration for the target path calculations '- Unclassified obstacles not considered for target path calculations	

Loss Scenario	Loss Scenarios (Functional Insufficiency/Performance Limitation)	Unsafe Control Action	Causal Factor (Potential Triggering Conditions)	Requirements
		- Following truck platoon controller does not request steering to avoid collision [H1]. - Following truck platoon controller does not request steering to avoid collision [H1].		
LS-81	System calculates the path to follow around pedestrians incorrectly [Inadequate control algorithm]	- Following truck controller requests acceleration while a pedestrian is present in-lane [H1]. - Following truck platoon controller does not request braking while a pedestrian is present in-lane [H1]. - Following truck platoon controller does not request braking while a pedestrian is present in-lane [H1]. - Following truck platoon controller does not request steering to avoid collision [H1].	- System does not take the pedestrian into consideration for the target path calculations	
LS-82	System calculates the path to follow around cyclists/motor cyclists incorrectly [Inadequate control algorithm]	- Following truck controller requests acceleration while driving towards an in-lane cyclist/motorcyclist [H1]. - Following truck platoon controller does not request braking while a cyclist/motor cyclist is present in-lane [H1]. - Following truck platoon controller does not request steering to avoid collision [H1].	- System does not take the cyclist/motor cyclist into consideration for the target path calculations	

Loss Scenario	Loss Scenarios (Functional Insufficiency/Performance Limitation)	Unsafe Control Action	Causal Factor (Potential Triggering Conditions)	Requirements
LS-83	System calculates the path to follow during lane keeping incorrectly [Inadequate control algorithm]	- Following truck platoon controller does not request steering to stay within the target lane (no lane keeping) [H1]. - Following truck platoon controller does not request steering while driving on a curved lane [H1]. - Following truck platoon controller requests excessive steering while driving in the target lane [H1]. - Following truck platoon controller requests insufficient steering while driving in the target lane [H1].	- Incorrect map data of the lanes - Incorrect path data received from the forward truck (Functional safety) - Incorrect interpretation of the path data from the forward truck - Incorrect activation of lane following mode (LFM)	- Unless a lane change manoeuvre is indicated by the forward truck, the path to follow calculated by the following trucks shall maintain the ego vehicles within the target lane even while driving on curved roads. - Unless Lane following mode (LFM) is requested by the forward truck, the path to follow calculated by the following trucks shall maintain the ego vehicles within the target lanes. - If HD maps are used for driving by the following trucks, lane lines shall be mapped accurately to support localization and navigation.
LS-84	System calculates the path to follow during a lane change incorrectly [Inadequate control algorithm]	- Following truck platoon controller does not request steering during a lane change [H1]. - Following truck platoon controller requests steering towards traffic during a lane change [H1]. - Following truck platoon controller requests steering in the opposite direction while changing lanes [H1]. - Following truck platoon controller requests excessive steering while changing lanes [H1]. - Following truck platoon controller requests insufficient steering while	- Lane change not indicated by the leading truck - Incorrect path data from the forward truck - Does not consider traffic in the new target lane - Incorrect map data on the lanes	- Lead driver shall always activate the turn indicators before a lane change manoeuvre. - Activation of turn indicators by the leading truck shall automatically communicate the intention and the direction of lane change/merger to the following trucks. - If lane change active status is communicated by the forward vehicle, the following trucks shall plan their trajectories to change the target lane to the one indicated by the forward truck.

Loss Scenario	Loss Scenarios (Functional Insufficiency/Performance Limitation)	Unsafe Control Action	Causal Factor (Potential Triggering Conditions)	Requirements
		changing lanes [H1]. - Following truck platoon controller requests steering too early while changing lane [H1]. - Following truck platoon controller requests steering too late while changing lane [H1]. - Following truck platoon controller stops steering earlier than expected while changing lane [H1]. - Following truck platoon controller stops steering later than expected while changing lane [H1]. - Following truck platoon controller does not request steering to avoid collision [H1].		- During a lane change manoeuvre, the path planned by the following trucks shall always maintain a safe distance to the vehicle in the adjacent lanes. - The lane change manoeuvre shall not complete until the following trucks are completely within the new target lane and the lane keeping function is active. - If HD maps are used for driving by the following trucks, lane lines shall be mapped accurately to support localization and navigation.
LS-85	System calculates the path to follow during a lane merger incorrectly [Inadequate control algorithm]	- Following truck platoon controller does not request steering during a lane merger [H1]. - Following truck platoon controller requests steering towards traffic during a lane merge [H1]. - Following truck platoon controller requests excessive steering during a lane merger [H1]. - Following truck platoon controller requests insufficient steering during a lane merger [H1]. - Following truck platoon controller	- Lane merger not indicated by the leading truck - Incorrect path data from the forward truck - Does not consider traffic in the new target lane - Incorrect map data on the lanes	- Lead driver shall always activate the turn indicators before a lane merger manoeuvre. - Activation of turn indicators by the leading truck shall automatically communicate the intention and the direction of lane change/merger to the following trucks. - The following vehicles shall autonomously detect the lane merger situation from the lane lines. - During a lane merger manoeuvre, the path planned by the following

Loss Scenario	Loss Scenarios (Functional Insufficiency/Performance Limitation)	Unsafe Control Action	Causal Factor (Potential Triggering Conditions)	Requirements
		requests steering too early during a lane merger [H1]. - Following truck platoon controller requests steering too late during a lane merger [H1]. - Following truck platoon controller stops steering earlier than expected during a lane merger [H1]. - Following truck platoon controller stops steering later than expected during a lane merger [H1]. - Following truck platoon controller does not request steering to avoid collision [H1].		trucks shall always maintain a safe distance to the vehicle in the adjacent lanes. - The lane merger manoeuvre shall not complete until the following trucks are completely within the new target lane and the lane keeping function is active. - If HD maps are used for driving by the following trucks, lane lines shall be mapped accurately to support localization and navigation.
LS-86	System calculates the path to follow while passing through a roundabout incorrectly [Inadequate control algorithm]	- Following truck platoon controller does not request steering while passing through a roundabout [H1]. - Following truck platoon controller requests excessive steering while passing through a roundabout [H1]. - Following truck platoon controller requests insufficient steering while passing through a roundabout [H1].	- Incorrect map data on the lanes - Exit not correctly indicated by the lead driver	- The leading truck shall communicate its planned route to the following trucks (so that roundabout exits can be known in advance). - The lead driver shall always activate the turn indicators before exiting the roundabout. - If conflicting information is received between the communicated route and the path followed from the leading truck, the path information shall take precedence over the route data. (Priority given to follow the lead driver). - The following trucks shall plan their

Loss Scenario	Loss Scenarios (Functional Insufficiency/Performance Limitation)	Unsafe Control Action	Causal Factor (Potential Triggering Conditions)	Requirements
				trajectories such that they remain in their target lane while driving through roundabouts. - If HD maps are used for driving by the following trucks, lane lines of roundabouts within the ODD shall be mapped accurately to support localization and navigation.
LS-87	System calculates the path to follow while passing through a junction incorrectly [Inadequate control algorithm]	- Following truck platoon controller does not request steering while passing through a junction [H1]. - Following truck platoon controller requests excessive steering while passing through a junction [H1]. - Following truck platoon controller requests insufficient steering while passing through a junction [H1].	- Incorrect map data on the lanes - Exit not correctly indicated by the lead driver	- The leading truck shall communicate its planned route to the following trucks (so that junction exits can be known in advance). - The lead driver shall always activate the turn indicators to signal the exit before entering a junction. - If conflicting information is received between the communicated route and the path followed from the leading truck, the path information shall take precedence over the route data. (Priority given to follow the lead driver). - The following trucks shall plan their trajectories such that they remain in their target lane while passing through junctions. - If HD maps are used for driving by the following trucks, lane lines of junctions within the ODD shall

Loss Scenario	Loss Scenarios (Functional Insufficiency/Performance Limitation)	Unsafe Control Action	Causal Factor (Potential Triggering Conditions)	Requirements
				mapped accurately to support localization and navigation.
LS-88	System calculates the path to follow while driving through road works incorrectly [Inadequate control algorithm]	- Following truck platoon controller does not request steering while driving through road works [H1]. - Following truck platoon controller requests excessive steering while passing through road works [H1]. - Following truck platoon controller requests insufficient steering while passing through road works [H1].	- Incorrect map data - Unable to recognize manual gestures of the traffic warden.	- The lead driver shall activate the Lane Following Mode (LFM) before entering road works. - Each truck shall communicate its current path to the following trucks. - The following trucks shall plan their trajectories such that they remain in their target lane while passing through road works. - If HD maps are used for driving by the following trucks, lane lines of roadworks within the ODD shall be correctly mapped for localization and navigation.
LS-89	System calculates the path to follow while driving through a tollgate incorrectly [Inadequate control algorithm]	- Following truck platoon controller does not request steering while driving through a tollgate [H1]. - Following truck platoon controller requests excessive steering while passing through a toll gate [H1]. - Following truck platoon controller requests insufficient steering while passing through a toll gate [H1].	- Incorrect map data - Unable to plan route through narrow lanes of a toll gate	- Each truck shall communicate its current path to the following trucks. - The following trucks shall plan their trajectories such that they remain in their target lane while passing through toll gates. - If HD maps are used for driving by the following trucks, lane lines of roadworks within the ODD shall be correctly mapped for localization and navigation.

4.6.15. Loss Category: Others

Table 34 - Loss scenarios: Others

Loss Scenario	Loss Scenarios (Functional Insufficiency/Performance Limitation)	Unsafe Control Action	Causal Factor (Potential Triggering Conditions)	Requirements
LS-90	Leading truck driver does not deactivate the platooning function at the end of the journey [Inadequate control algorithm]	- Following truck controller requests acceleration while stationary at the hub [H1]	- Inadequate information or training given to the driver on when to engage/disengage the platoon. - Door open status not communicated to the lead driver.	- Platooning shall not be allowed when any of the doors (including cargo door) are open. - The following trucks shall communicate their "ready for platooning" status to the leading truck. - The lead driver shall be reminded to disengage the platoon at the end of the journey.
LS-91	System incorrectly receives acceleration request from the leading truck at a traffic light [unsafe controller input]	- Following truck controller requests acceleration while stationary at a red light [H1].	- Platoon leader does not communicate the stop status to the ego vehicle - Incorrect accelerate request (e.g. via path data) received from the forward vehicle (Functional safety malfunction). - Incorrect signal status	- The ITS systems shall communicate the location and the status of the traffic lights to the platoon. - The leading truck shall communicate the status of the traffic light to the following trucks. - As long as the communication with the leading truck is active and the traffic light status

Loss Scenario	Loss Scenarios (Functional Insufficiency/Performance Limitation)	Unsafe Control Action	Causal Factor (Potential Triggering Conditions)	Requirements
			received from the ITS system	communicated via V2V is green, the following trucks shall follow the path requested by the forward truck. - While passing through roundabouts/junctions, each truck can communicate with the infrastructure to know the status of the signal, but shall not negotiate with it unless the platoon leader informs loss of communication with the infrastructure to the following trucks.

4.6.16. Loss Category: Data misinterpretation

Table 35 - Loss scenarios: Data misinterpretation

Loss Scenario	Loss Scenarios (Functional Insufficiency/Performance Limitation)	Unsafe Control Action	Causal Factor (Potential Triggering Conditions)	Requirements
LS-92	System incorrectly assumes that platooning is enabled when the forward truck moves at the hub [Inadequate process model or Inadequate control algorithm]	- Following truck controller requests acceleration while stationary at the hub [H1]	- Incorrect “platoon engage/disengage” status transmitted by the leading truck [inadequate process model] - Incorrect interpretation of the engage/disengage status received from the forward truck (Functional safety)	- The lead driver shall be reminded to disengage the platoon at the end of the journey. - Each truck shall interpret and transmit the engage/disengage status to the following trucks. - Platooning shall not be allowed when any of the doors (including cargo door) are open. - The following trucks shall communicate their "ready for platooning" status to the leading truck.
LS-93	System incorrectly believes that the platoon leader is accelerating [inadequate process model]	- Following truck controller requests acceleration while stationary at a red light [H1]. - Following truck controller requests acceleration while stationary at the hub [H1]	- Incorrect path data communicated by the forward truck via V2V - Incorrect processing of the V2V path data by the ego truck (Functional safety) - Incorrect feedback from onboard perception sensors	- Each truck shall transmit its current path with an accuracy of +/- 20 cm to the following trucks. **Note:** Required for the following trucks to correctly estimate the lane of the forward truck. - While platooning, the following trucks shall follow the path transmitted by the forward truck. - The following trucks shall independently validate the path information coming from the forward

Loss Scenario	Loss Scenarios (Functional Insufficiency/Performance Limitation)	Unsafe Control Action	Causal Factor (Potential Triggering Conditions)	Requirements
				truck via V2V communication. - Each truck shall estimate its current acceleration with an accuracy of +/- 0.5 m/s² and continuously transmit it to the following trucks. - The following trucks shall be able to estimate the acceleration of the forward truck with an accuracy of +/- 1 m/s². **Note:** To maintain safe time gap when driving at lower time gaps. - The following trucks shall independently validate the acceleration data coming from the forward truck via V2V communication.
LS-94	System requests incorrect drive direction request to the powertrain [Inadequate control algorithm]	- Following truck controller accelerates in the reverse direction while at a traffic light [H1]. - Following truck controller accelerates in the reverse direction while starting at a hub [H1].	- No requirement to limit only driver in the forward direction	- Platooning shall only be allowed in the forward direction.

4.6.17. Loss Category: Vehicle control

Table 36 - Loss scenarios: Vehicle control

Loss Scenario	Loss Scenarios (Functional Insufficiency/Performance Limitation)	Unsafe Control Action	Causal Factor (Potential Triggering Conditions)	Requirements
LS-95	System calculates the required throttle response incorrectly [Inadequate control algorithm]	All the acceleration UCAs that can result in hazard H1.	- Powertrain calibration errors - Incorrect feedback from ego speed and acceleration sensors - System does not consider slippery road conditions (snow/ice, wet…) - Incorrect formula used for throttle response calculation	- Each truck shall transmit its current path with an accuracy of +/- 20 cm to the following trucks. **Note:** Required for the following trucks to correctly estimate the lane of the forward truck. - The target path generated by the following trucks shall be achievable by the current acceleration capabilities of the ego vehicle. - The following trucks shall generate the throttle request to meet the target trajectory with an accuracy of +/- 50 cm in the longitudinal axis. **Note:** Enough to maintain safe distance to other vehicles. - The following trucks shall maintain traction on all road conditions within the ODD.
LS-96	System calculates the required deceleration response incorrectly [Inadequate control algorithm]	All the deceleration UCAs that can result in hazard H1.	- Incorrect brake performance estimation by the ego vehicle - System receives incorrect feedback that sufficient braking is already being applied - Forward truck incorrectly	- Each truck shall transmit its current path with an accuracy of +/- 20 cm to the following trucks. **Note:** Required for the following trucks to correctly estimate the lane of the forward truck.

Loss Scenario	Loss Scenarios (Functional Insufficiency/Performance Limitation)	Unsafe Control Action	Causal Factor (Potential Triggering Conditions)	Requirements
			requests deceleration - System incorrectly interprets the deceleration information from the forward truck	- The following trucks shall estimate their brake performance with an accuracy of +/- 1.5 m/s^2. **Note:** Acceptable error to maintain safe distance.. - The target path generated by the following trucks shall be achievable by the current deceleration capabilities of the ego vehicle. - Each truck shall estimate its current acceleration with an accuracy of +/- 0.5 m/s^2 and continuously transmit it to the following trucks. - The deceleration requested by the following trucks shall maintain the ego vehicle on the target trajectory with an accuracy of +/- 50 cm in the longitudinal axis. **Note:** Enough to maintain safe distance to other vehicles. - Each truck shall consider the following factors for its brake force estimation: - Road inclination and surface conditions (low mu conditions, etc..) - Vehicle load conditions - Current condition of the braking system (pressure gradient, pads wear, temperature, ...)

Loss Scenario	Loss Scenarios (Functional Insufficiency/Performance Limitation)	Unsafe Control Action	Causal Factor (Potential Triggering Conditions)	Requirements
				- Tyre conditions (type, wear conditions, air pressure, ...) - Distribution of brake force between the axles
LS-97	System calculates the required steering response incorrectly [Inadequate control algorithm]	All the steering function UCAs that can result in hazard H1.	- System receives incorrect feedback that steering is already being applied - Conflict between multiple systems asking for steering control - Incorrect algorithm/formula used to calculate the steering response - Requested steering is outside the limits of the truck (roundabouts, junctions)	- Each truck shall transmit its current path with an accuracy of +/- 20 cm to the following trucks. **Note:** Required for the following trucks to correctly estimate the lane of the forward truck. - The target path generated by the following trucks shall be achievable considering the physical limits of the steering geometry of the ego vehicle and the safety of the occupants. - The steering requested by the following trucks shall maintain the ego vehicle on the target trajectory with an +/- 15 cm in the lateral axis. **Note:** Required to keep the lane.

4.6.18. Loss Category: Communications

Table 37 - Loss scenarios: Communications

Loss Scenario	Loss Scenarios (Functional Insufficiency/Performance Limitation)	Unsafe Control Action	Causal Factor (Potential Triggering Conditions)	Requirements
LS-98	System is unable to send V2V messages	- Platooning controller does not provide its dynamic data to the following truck [H1].	- Loss of V2V communication due to Functional safety malfunctions. - Loss of V2V communication when entering tunnels.	- Each truck shall maintain V2V communication with the platoon even under the loss of GNSS signal (e.g. inside tunnels).
LS-99	System is unable to send V2I messages	- Leading truck platooning controller does not negotiate with the infrastructure before crossing it [H1, H4, H5].	- Loss of V2I communication due to Functional safety malfunctions in the leading truck. - No V2I communication received from the infrastructure	- ITS systems shall be able to communicate the location and status of the infrastructure to a range of at least 100 meters from the infrastructure. - The platoon leader shall inform the loss of communication with the infrastructure to the following trucks. - While passing through roundabouts/junctions, each truck can communicate with the infrastructure to know the status of the signal, but shall not negotiate with it unless the platoon leader informs loss of communication with the infrastructure to the following trucks.

4.7. SOTIF Safety Concept

This section catalogues the functional requirements (FRs) derived from the step 4 of STPA: Identifying loss scenarios into various categories for better comprehension.

The current set of requirements constitute the first version of functional requirements derived from the initial set of assumptions and requirements defined for the Platooning Autonomous Function in the deliverable D2.3 (Willemsen, 2022) and D2.5 (Mascalchi E., 2022).

Note: Since the platooning autonomous function is only a vision for the future of platooning and no implementation is available to validate the assumptions, the values provided for ranges, accuracies, tolerances, etc in the requirements are only indicative and based on engineering judgement. Further research is required to validate these values.

Similarly, assumptions have been made on the requirements which might not apply to all the trucks due to different implementations used by each OEM to meet the same functional requirements. For example, requirements on HD maps do not apply if the trucks depend on simultaneous localization and mapping (SLAM) for navigation instead of HD maps.

Linked loss scenario IDs are provided for each requirement as a reference to the loss scenarios (section **Error! Reference source not found.**) from which they were derived.

4.7.1. Requirements Category: Intruders

Table 38 - Requirements Category: Intruders

Req. No	Requirements	Linked Loss Scenarios
FR-1	The following vehicles shall be classified as intruders for cut-ins by the following trucks: - Cars - Vans - Emergency vehicles (ambulances, police vehicles, etc..) - Trucks - Motor cycles - Cyclists	LS-37
FR-2	The following trucks shall be able to localize and track intruders in all weather and light conditions within the ODD.	LS-1, LS-11, LS-26
FR-3	The following trucks shall be able to localize and track intruders while driving on curved lanes including roundabouts and junctions.	LS-11, LS-26, LS-46
FR-4	The following trucks shall be able to localize vehicles with unusual livery (e.g. road or people or animals painted on them).	LS-1
FR-5	The following trucks shall be able to estimate the position of intruders with an accuracy of +/- 2 meters. **Note:** Higher error will result in wrong classification of the lane.	LS-46
FR-6	The following trucks shall be able to estimate the speed of the intruders with an accuracy of +/- 1 m/s. **Note:** Error of +/- 3.6 km/h enough to detect slow moving traffic.	LS-55
FR-7	The following trucks shall be able to estimate the acceleration of the intruder with an accuracy of +/- 1 m/s^2.	LS-59
FR-8	The following trucks shall be able to estimate the time gap to the intruders with an accuracy of 0.1 seconds. **Note:** Error of 2.2 m in position at 80 km/h.	LS-41
FR-9	The following trucks shall be able to estimate the TTC to the intruders with an accuracy of +/- 0.5 seconds.	LS-41
FR-10	The following trucks truck shall be able to predict the behaviour/trajectory of intruders including on curved lanes of roundabouts and junctions with an accuracy of +/- 1 meter. **Note:** Enough accuracy to know the target lane correctly.	LS-63

4.7.2. Requirements Category: Cyclists/Motorcyclists

Table 39 - Requirements Category: Cyclist/motorcyclists

Req. No	Requirements	Linked Loss Scenarios
FR-11	The following elements shall be classified as cyclists/motorcyclists by the following trucks: - Normal bicycles - Tandem cycles - Normal motorbikes - Moppets - Delivery bikes - Motorbikes with sidecar - Tricycles	LS-40
FR-12	The following trucks shall be able to localize and track relevant motorcycles and cyclists in all weather and light conditions within the ODD.	LS-1, LS-4, LS-14, LS-28
FR-13	The following trucks shall localize and track motorcyclists and cyclist around high glare and reflective road surfaces.	LS-4
FR-14	The following trucks shall be able to localize and track cycles and motorcycles even when they are being driven close to/adjacent to other vehicles.	LS-4, LS-28
FR-15	The following trucks shall be able to localize and track relevant cyclists/motorcyclists while driving on curved lanes including roundabouts and junctions.	LS-14, LS-28, LS-49
FR-16	The following trucks shall be able to estimate the position of relevant cyclists/motorcyclists with an accuracy of +/- 1 meters. (or else cannot overtake cyclists). **Note:** Accuracy lower than 1 m will not permit overtaking the cyclists.	LS-49
FR-17	The following trucks shall be able to estimate the speed of relevant cyclists/motorcyclists with an accuracy of +/- 1 m/s. **Note:** Error of +/- 3.6 km/h enough to detect slow moving traffic.	LS-57
FR-18	The following trucks shall be able to estimate the acceleration of the cyclist/motorcyclist with an accuracy of +/- 1 m/s^2.	LS-60
FR-19	The following trucks shall be able to estimate the time gap to cyclists/motorcyclists with an accuracy of 0.1 seconds. **Note:** Error of 2.2 m in position at 80 km/h.	LS-44
FR-20	The following trucks shall be able to estimate the TTC to cyclists/motorcyclists with an accuracy of 0.5 seconds.	LS-44
FR-21	The following trucks shall be able to predict the behaviour/trajectory of relevant cyclists/motorcyclist including on curved lanes with an accuracy of +/- 1 meters. **Note:** To correctly predict intention of entering the target lane.	LS-66
FR-22	The following trucks shall be able to predict the behaviour/trajectory of cyclists using hand gestures to indicate their manoeuvre.	LS-63

4.7.3. Requirements Category: Pedestrians

Table 40 - Requirements Category: Pedestrians

Req. No	Requirements	Linked Loss Scenarios
FR-23	The following elements shall be classified as pedestrians by the following trucks: - People of all sizes (e.g. children) and disabilities - People accompanied by objects like wheel chairs, canes, baby strollers, shopping trollies, umbrellas, e-scooter, walking holding bikes, etc. - People in abnormal attire (e.g. Halloween costumes, hot dog vendor costume, ...). - People wearing Long skirts where legs do not move	LS-39
FR-24	The following trucks shall be able to localize and track relevant pedestrians in all weather and light conditions within the ODD.	LS-3, LS-13, LS-27
FR-25	The following trucks shall localize and track relevant pedestrians even if they are walking behind road furniture/object (trash bins, lamp posts, ...)/parked vehicles.	LS-3
FR-26	The following trucks shall be able to localize and track pedestrians in abnormal attire (e.g. Halloween costumes, hot dog vendor costume, ...).	LS-3
FR-27	The following trucks shall localize and track pedestrians around high glare and reflective road surfaces.	LS-3
FR-28	The following trucks shall be able to localize and track relevant pedestrians while driving on curved lanes including roundabouts and junctions.	LS-13, LS-27, LS-48
FR-29	The following trucks shall be able to estimate the position of relevant pedestrians with an accuracy of +/- 0.5 meters. **Note:** Or else cannot know if the pedestrian is in-lane or not (e.g. standing on the pavement).	LS-48
FR-30	The following trucks shall be able to estimate the speed of relevant pedestrians with an accuracy of +/- 1 m/s. **Note:** Average walking speed is 1.5 m/s. This accuracy is required to differential a stationary pedestrian from a moving one.	LS-56
FR-31	The following trucks shall be able to estimate the TTC to the relevant pedestrians with an accuracy of 0.5 seconds.	LS-43
FR-32	The following trucks shall be able to predict the behaviour/trajectory of relevant pedestrians including on curved lanes with an accuracy of +/- 0.5 meters. **Note:** Or else cannot know if the pedestrian going to enter the target lane or not.	LS-65
FR-33	The following trucks shall be able to predict the behaviour/trajectory of pedestrians even when they are using alternate modes of transportation like skateboards, roller skates, e-scooters, etc..).	LS-65

4.7.4. Requirements Category: Obstacles

Table 41 - Requirements Category: Obstacles

Req. No	Requirements	Linked Loss Scenarios
FR-34	The following elements shall be classified as obstacles by the following trucks: - Debris that are large enough to cause accidents (e.g. blown out tyres, boxes from other vehicle, boulders, garbage bins, ...). - Animals that are large enough to cause accidents (e.g. elks, sheep, ...).	LS-38
FR-35	The following trucks shall be able to localize obstacles in all weather and light conditions within the ODD.	LS-2, LS-12
FR-36	The following trucks shall be able to detect and track relevant obstacles on curved lanes including roundabouts and junctions.	LS-12, LS-47
FR-37	The following trucks shall be able to localize and track relevant obstacles/debris that are large enough to cause accidents (e.g. blown out tyres, boxes from other vehicle, ..) in all weather and light conditions within the ODD.	LS-2
FR-38	The following trucks shall be able to localize and track relevant animals large enough to cause accidents (e.g. elks, cattle, sheep, etc..) in all weather and light conditions within the ODD.	LS-2
FR-39	The following trucks shall be able to estimate the TTC to the relevant obstacles with an accuracy of 0.5 seconds.	LS-42
FR-40	The following trucks shall be able to estimate the position of relevant obstacles with an accuracy of +/- 0.5 meters. **Note:** Or else cannot clearly identify the lane of the obstacle (e.g. garbage bin positioned just outside the lane lines.	LS-47
FR-41	The following trucks shall be able to predict the behaviour/trajectory of moving obstacles (falling boxes, debris, etc..) including on curved lanes with an accuracy of +/- 0.5 meters. **Note:** Or else cannot accurately know if the obstacle will enter the target lane or not.	LS-64

4.7.5. Requirements Category: Vehicles in adjacent lanes

Table 42 - Requirements: Vehicles in adjacent lanes

Req. No	Requirements	Linked Loss Scenarios
FR-42	The following trucks shall be able to localize and track relevant vehicles (e.g. even in high speed situations like autobahns) in the adjacent lanes in all weather and light conditions within the ODD.	LS-10, LS-15, LS-29, LS-51
FR-43	The following trucks shall be able to localize and track relevant vehicles in the adjacent lanes while driving on curved lanes including roundabouts and junctions.	LS-10, LS-15, LS-29, LS-51
FR-44	The following trucks shall be able to detect and track relevant vehicles in the adjacent lanes even when they are partially concealed due to ramps, pillars and other view obstructions typically found on public roads.	LS-10, LS-15, LS-29, LS-51
FR-45	The following trucks shall be able to estimate the position of relevant vehicles in the adjacent lanes with an accuracy of +/- 1 meter. **Note:** Or else cannot confirm the lane.	LS-51
FR-46	The following trucks shall be able to estimate the speed of relevant vehicles in the adjacent lanes with an accuracy of +/- 1 m/s. **Note:** Error of +/- 3.6 km/h enough to detect slow moving traffic.	LS-54
FR-47	The following trucks shall be able to estimate the acceleration of the vehicles in adjacent lanes with an accuracy of +/- 1 m/s^2. **Note:** To detect if the vehicle is giving way for lane change/merger.	LS-61
FR-48	The following trucks shall be able to estimate the space available to change/merge into adjacent lanes with an accuracy of +/- 2 meters in all weather and light conditions within the ODD. **Note:** Since lane change/merge will not go ahead when the gap is lower than 5 m, an error of 2 m is acceptable.	LS-68
FR-49	The following trucks shall be able to predict the behaviour/trajectory of the vehicles in adjacent lanes including on curved lanes with an accuracy of +/- 1 meters. **Note:** Or else cannot accurately know if the vehicle will enter the target lane or not.	LS-22, LS-67
FR-50	The following trucks shall be able to predict the behaviour/trajectory of slow-moving traffic in adjacent lanes (e.g. traffic jams) by considering driver cues like turn indicators.	LS-67

4.7.6. Requirements Category: Forward truck

Table 43 - Requirements: Forward truck

Req. No	Requirements	Linked Loss Scenarios
FR-51	The following trucks shall be able to localize the forward truck in all weather and light conditions within the ODD.	LS-25
FR-52	The following trucks shall be able to localize and track the forward truck while driving on curved lanes including roundabouts and junctions.	LS-25
FR-53	The following trucks shall be able to estimate the position of the forward truck with an accuracy of with an accuracy of +/- 2 meters. **Note:** At lower time gaps like 0.3s, there is a distance of less than 10 m between the trucks.	LS-50
FR-54	The following trucks shall independently validate the location information coming from the forward truck via V2V communication.	LS-45, LS-50
FR-55	The following trucks shall be able to estimate the speed of the forward truck an accuracy of +/- 1 m/s. **Note:** Error of +/- 3.6 km/h enough to detect slow moving traffic.	LS-53
FR-56	The following trucks shall independently validate the speed information coming from the forward truck via V2V communication	LS-45, LS-53
FR-57	The following trucks shall be able to estimate the acceleration of the forward truck with an accuracy of +/- 1 m/s^2. Note: To maintain safe time gap when driving at lower time gaps.	LS-58, LS-93
FR-58	The following trucks shall independently validate the acceleration data coming from the forward truck via V2V communication.	LS-58, LS-93
FR-59	The following trucks shall be able to estimate the time gap to the forward truck with an accuracy of 0.1 seconds. **Note:** Error of 2.2 m in position at 80 km/h.	LS-45
FR-60	The following trucks shall be able to estimate the TTC to the forward truck with an accuracy of 0.5 seconds.	LS-45
FR-61	The following trucks shall be able to predict the behaviour/trajectory of the forward truck including on curved lanes of roundabouts and junctions with an accuracy of +/- 1 meter. **Note:** To correctly identify the target lane.	LS-62

4.7.7. Requirements Category: Roundabouts

Table 44 - Requirements: Roundabouts

Req. No	Requirements	Linked Loss Scenarios
FR-62	ITS systems shall communicate the location and status of roundabouts to the platoon.	LS-6
FR-63	ITS systems shall be able to communicate the location and status of the roundabouts to a range of at least 100 meters from the roundabout.	LS-17
FR-64	The leading truck shall automatically detect roundabouts' related road signs and communicate them to the following vehicles (not the responsibility of the lead driver).	LS-6
FR-65	The leading truck shall negotiate with the infrastructure for the entire platoon to pass through roundabouts.	LS-6
FR-66	The leading truck shall communicate the presence of preceding roundabout to the following trucks (not the responsibility of the driver).	LS-70
FR-67	The leading truck shall be able to detect and communicate the presence of a roundabout to the platoon before entering the roundabout.	LS-17
FR-68	The leading truck shall communicate its planned route to the following trucks (so that roundabout exits can be known in advance).	LS-86
FR-69	The lead driver shall always activate the turn indicators before exiting the roundabout.	LS-86
FR-70	If HD maps are used for driving by the following trucks, roundabouts shall be mapped accurately to support localization and navigation.	LS-6
FR-71	While driving through roundabouts, the following trucks shall maintain speeds within legal limits.	LS-70
FR-72	The following trucks shall plan their trajectories such that they remain in their target lane while driving through roundabouts.	LS-86
FR-73	While passing through roundabouts/junctions, each truck can communicate with the infrastructure to know the status of the signal, but shall not negotiate with it unless the platoon leader informs loss of communication with the infrastructure to the following trucks.	LS-91, LS-99

4.7.8. Requirements Category: Junctions

Table 45 - Requirements: Junctions

Req. No	Requirements	Linked Loss Scenarios
FR-74	ITS systems shall communicate the location and status of junctions to the platoon.	LS-5
FR-75	ITS systems shall be able to communicate the location and status of the junctions to a range of at least 100 meters from the junction.	LS-16
FR-76	The leading truck shall automatically detect junctions' related road signs and communicate them to the following vehicles (not the responsibility of the lead driver).	LS-5
FR-77	The leading truck shall communicate the presence of preceding junction to the following trucks (not the responsibility of the driver).	LS-69
FR-78	The leading truck shall be able to detect and communicate the presence of a junction to the platoon before entering the junction.	LS-16
FR-79	The leading truck shall negotiate with the infrastructure for the entire platoon to pass through junctions.	LS-5
FR-80	The leading truck shall communicate its planned route to the following trucks (so that junction exits can be known in advance).	LS-87
FR-81	The lead driver shall always activate the turn indicators to signal the exit before entering a junction.	LS-87
FR-82	If HD maps are used for driving by the following trucks, junctions shall be mapped accurately to support localization and navigation.	LS-5
FR-83	While driving through junctions, the following trucks shall maintain speeds within legal limits.	LS-69
FR-84	The following trucks shall plan their trajectories such that they remain in their target lane while passing through junctions.	LS-87
FR-85	While passing through roundabouts/junctions, each truck can communicate with the infrastructure to know the status of the signal, but shall not negotiate with it unless the platoon leader informs loss of communication with the infrastructure to the following trucks.	LS-91, LS-99

4.7.9. Requirements Category: Toll gates

Table 46 - Requirements Category: Toll gates

Req. No	Requirements	Linked Loss Scenarios
FR-86	ITS systems shall communicate the location and status of toll gates to the platoon.	LS-7
FR-87	ITS systems shall be able to communicate the location and status of the toll gates to a range of at least 200 meters from the toll gate.	LS-18
FR-88	The leading truck shall automatically detect toll gates' related road signs and communicate them to the following vehicles (not the responsibility of the lead driver).	LS-7
FR-89	The leading truck shall communicate the presence of preceding toll gate to the following trucks (not the responsibility of the driver).	LS-71
FR-90	The leading truck shall negotiate with the infrastructure for the entire platoon to pass through toll gates.	LS-7
FR-91	The leading truck shall be able to detect and communicate the presence of a toll gate to the platoon before entering the toll gate.	LS-18
FR-92	If HD maps are used for driving by the following trucks, toll gates shall be mapped accurately to support localization and navigation.	LS-7
FR-93	While driving through toll gates, the following trucks shall maintain speeds within legal limits.	LS-71
FR-94	The following trucks shall be able to detect boom barriers at the tollgates.	LS-7
FR-95	The following trucks shall plan their trajectories such that they remain in their target lane while passing through toll gates.	LS-89

4.7.10. Requirements Category: Road works

Table 47 - Requirements: Road works

Req. No	Requirements	Linked Loss Scenarios
FR-96	ITS systems shall communicate the location and status of the road works to the platoon.	LS-9
FR-97	ITS systems shall be able to communicate the location and status of the road works to a range of at least 200 meters from the road works.	LS-20
FR-98	Leading truck shall automatically detect road works related signs and communicate them to the following vehicles (not the responsibility of the lead driver).	LS-9
FR-99	The leading truck shall be able to detect and communicate the presence of a road works to the platoon before entering the road works.	LS-20
FR-100	The leading truck shall communicate the presence of preceding road works to the following trucks (not the responsibility of the driver).	LS-73
FR-101	The leading truck shall negotiate with the infrastructure for the entire platoon to pass through road works.	LS-9
FR-102	The lead driver shall activate the Lane Following Mode (LFM) before entering road works.	LS-88
FR-103	If HD maps are used for driving by the following trucks, road works shall be mapped accurately to support localization and navigation.	LS-9
FR-104	While driving through road works, the following trucks shall maintain speeds within legal limits.	LS-73
FR-105	The following trucks shall plan their trajectories such that they remain in their target lane while passing through road works.	LS-88

4.7.11. Requirements Category: Hubs

Table 48 - Requirements: Hubs

Req. No	Requirements	Linked Loss Scenarios
FR-106	ITS systems shall communicate the location and status of hubs to the platoon.	LS-8
FR-107	ITS systems shall be able to communicate the location and status of the hubs to a range of at least 100 meters from the hub.	LS-19
FR-108	The leading truck shall communicate the presence of preceding hub to the following trucks (not the responsibility of the driver).	LS-72
FR-109	The leading truck shall be able to detect and communicate the presence of a hub to the platoon before entering the hub.	LS-19
FR-110	While driving at hubs, the following trucks shall maintain speeds within legal limits.	LS-8
FR-111	The leading truck shall automatically detect hubs' related road signs and communicate them to the following vehicles (not the responsibility of the lead driver).	LS-8
FR-112	If HD maps are used for driving by the following trucks, hubs shall be mapped accurately to support localization and navigation.	LS-8
FR-113	While driving through hubs, the following trucks shall maintain speeds within legal limits.	LS-72

4.7.12. Requirements Category: Lanes in general

Table 49 - Requirements: Lanes in general

Req. No	Requirements	Linked Loss Scenarios
FR-114	The following elements shall not be classified as in-lane obstacles/pedestrians/vehicles by the following trucks: - Overpass above the current lane - Reflections from the metallic overhead boards or manhole covers - Curved road with metal railings - Parked vehicles next to the lane - Pedestrians on the pavements on curved roads - Metallic posts that narrow the vehicle's path - Bridges with ramps facing overhead metallic sign boards - Big but non-hazardous items (plastic bags, etc..) - Confusing sculptures at the centre of the roundabout (statues, ..) - Metallic guardrails at the junction/roundabout - Construction related vehicles (dumpers, excavators,..) being used in close proximity to atypical target lanes around road works. - Toll booth infrastructure constructed close to/on the lane lines while passing through toll gates - Open boom barriers	LS-21, LS-22, LS-23, LS-24

Req. No	Requirements	Linked Loss Scenarios
FR-115	The following trucks shall be able to detect target lane even when the lanes are partially or fully unseen due to the following conditions within the ODD: - Absence of lane markings - Partially erased or murky lane lines - Lane lines under water or snow - Bad light or visibility conditions. - Special colour lanes used within the EU road regulations (e.g. yellow for road works)	LS-30
FR-116	If HD maps are used for driving by the following trucks, lane lines shall be mapped accurately to support localization and navigation.	LS-30, LS-32, LS-46, LS-51, LS-52, LS-83, LS-84, LS-85
FR-117	If HD maps are used for driving by the following trucks, lane lines of roundabouts within the ODD shall be mapped accurately to support localization and navigation.	LS-33, LS-86
FR-118	The following trucks shall correctly identify their target lane while passing through roundabouts in all weather and light conditions within the ODD.	LS-33
FR-119	If HD maps are used for driving by the following trucks, lane lines of junctions within the ODD shall mapped accurately to support localization and navigation.	LS-34, LS-87
FR-120	The following trucks shall correctly estimate the lane of the relevant vehicles in their vicinity including on curved lanes of roundabouts and junctions.	LS-52
FR-121	The following trucks shall correctly identify their target lane while passing through junctions in all weather and light conditions within the ODD.	LS-34
FR-122	If HD maps are used for driving by the following trucks, lane lines of road works within the ODD shall be mapped accurately to support localization and navigation.	LS-35, LS-88
FR-123	The following trucks shall be able to detect lanes around road works marked using special items like traffic cones, special lane (type and colour), special barriers, etc.	LS-9, LS-35
FR-124	The following trucks shall correctly identify their target lane while passing through road works in all weather and light conditions within the ODD.	LS-35
FR-125	The following trucks shall be able to identify their target lane while passing through toll gates even when the lane lines disappear/merge into the side walls of the toll gates.	LS-36
FR-126	If HD maps are used for driving by the following trucks, lane lines around toll gates within the ODD shall be correctly mapped for localization and navigation.	LS-36
FR-127	The following trucks shall correctly identify their target lane while passing through toll gates in all weather and light conditions within the ODD.	LS-36
FR-128	The following trucks shall be able to detect lanes around toll gates marked using special changed pattern and colour lanes.	LS-36

4.7.13. Requirements Category: Lane changes

Table 50 - Requirements: Lane changes

Req. No	Requirements	Linked Loss Scenarios
FR-129	Lead driver shall always activate the turn indicators before a lane change manoeuvre.	LS-84
FR-130	Activation of turn indicators by the leading truck shall automatically communicate the intention and the direction of lane change/merger to the following trucks.	LS-31, LS-32, LS-84, LS-85
FR-131	The following trucks shall correctly identify the new target lane during a lane change situation in all weather and light conditions within the ODD.	LS-32
FR-132	Unless a lane change manoeuvre is indicated by the forward truck, the path to follow calculated by the following trucks shall maintain the ego vehicles within the target lane even while driving on curved roads.	LS-83
FR-133	If lane change active status is communicated by the forward vehicle, the following trucks shall plan their trajectories to change the target lane to the one indicated by the forward truck.	LS-84
FR-134	During a lane change manoeuvre, the path planned by the following trucks shall always maintain a safe distance to the vehicle in the adjacent lanes.	LS-84
FR-135	The lane change manoeuvre shall not complete until the following trucks are completely within the new target lane and the lane keeping function is active.	LS-84

4.7.14. Requirements Category: Lane merges

Table 51 - Requirements: Lane mergers

Req. No	Requirements	Linked Loss Scenarios
FR-136	Lead driver shall always activate the turn indicators before a lane merger manoeuvre.	LS-85
FR-137	The following vehicles shall autonomously detect the lane merger situation from the lane lines.	LS-85
FR-138	The following trucks shall be able to independently (without depending on the leading truck/driver) detect lane merging situation in all weather and light conditions within the ODD.	LS-31
FR-139	If HD maps are used for driving by the following trucks, lane mergers shall be mapped accurately to support localization and navigation.	LS-31
FR-140	During a lane merger manoeuvre, the path planned by the following trucks shall always maintain a safe distance to the vehicle in the adjacent lanes.	LS-85
FR-141	The lane merger manoeuvre shall not complete until the following trucks are completely within the new target lane and the lane keeping function is active.	LS-85

4.7.15. Requirements Category: Generic path following

Table 52 - Requirements: Generic path following

Req. No	Requirements	Linked Loss Scenarios
FR-142	While platooning, the following trucks shall follow the path transmitted by the forward truck.	LS-93
FR-143	The following trucks shall independently validate the path information coming from the forward truck via V2V communication.	LS-62, LS-93
FR-144	Unless Lane following mode (LFM) is requested by the forward truck, the path to follow calculated by the following trucks shall maintain the ego vehicles within the target lanes.	LS-83
FR-145	As long as the communication with the leading truck is active and the traffic light status communicated via V2V is green, the following trucks shall follow the path requested by the forward truck.	LS-91
FR-146	The following trucks shall independently confirm co-operative perception data before dynamically reacting to an obstacle/pedestrian/vehicle.	LS-21

4.7.16. Requirements Category: Ego estimations

Table 53 - Requirements: Ego estimations

Req. No	Requirements	Linked Loss Scenarios
FR-147	The following trucks shall be able to localize themselves with an accuracy of +/- 10 cm. **Note:** This level of accuracy is required to localize in the correct lane.	LS-74
FR-148	Each truck shall continuously transmit its current location to the following trucks.	LS-25, LS-50
FR-149	If HD maps are used for localization, landmarks shall be correctly mapped for accurate localization and navigation.	LS-74
FR-150	Each truck shall estimate its current speed with an accuracy of +/- 0.5 m/s. **Note:** Accurate estimations required to follow the target path.	LS-75
FR-151	Each truck shall continuously transmit its current speed to the following trucks.	LS-53
FR-152	Each truck shall estimate its current acceleration with an accuracy of +/- 0.5 m/s^2 and continuously transmit it to the following trucks.	LS-58, LS-76, LS-93, LS-96
FR-153	Each truck shall transmit its current path with an accuracy of +/- 20 cm to the following trucks. **Note:** Required for the following trucks to correctly estimate the lane of the forward truck.	LS-62, LS-93, LS-95, LS-96, LS-97
FR-154	Each truck shall continuously communicate its current path to the following trucks.	LS-88, LS-89
FR-155	The following trucks shall be able to localize themselves even under the loss of GNSS signal.	LS-74

Req. No	Requirements	Linked Loss Scenarios
FR-156	Each truck shall estimate its cargo load with an accuracy of +/- 50 kgs. **Note:** Enough to correctly estimate the brake performance.	LS-77
FR-157	The following trucks shall estimate their brake performance with an accuracy of +/- 1.5 m/s². **Note:** Acceptable error to maintain safe distance.	LS-78, LS-96
FR-158	The following factors shall be considered for the brake force estimation: - Road inclination and surface conditions (low mu conditions, etc..) - Vehicle load conditions - Current condition of the braking system (pressure gradient, pads wear, temperature, ...) - Tyre conditions (type, wear conditions, air pressure, ...) - Distribution of brake force between the axles	LS-78
FR-159	The following trucks shall generate the desired trajectories considering the behaviour of the following elements: - forward truck - Intruders (Other vehicles (including emergency vehicles), cyclists/motor-cyclists) - Pedestrians (including on skate boarders, roller skaters, scooters, etc..) - Other obstacles (cargo boxes, boulders, road debris, etc..)	LS-79, LS-80, LS-81, LS-82

4.7.17. Requirements Category: Ego status

Table 54 - Requirements: Ego status

Req. No	Requirements	Linked Loss Scenarios
FR-160	Each truck shall interpret and transmit the engage/disengage status to the following trucks.	LS-92
FR-161	Platooning shall not be allowed when any of the doors (including cargo door) are open.	LS-90, LS-92
FR-162	The following trucks shall communicate their "ready for platooning" status to the leading truck.	LS-90, LS-92
FR-163	The lead driver shall be reminded to disengage the platoon at the end of the journey.	LS-90, LS-92

Req. No	Requirements	Linked Loss Scenarios
FR-164	The leading truck shall communicate the status of the traffic lights to the following trucks.	LS-91

4.7.18. Requirements Category: ITS generic

Table 55 - Requirements: ITS generic

Req. No	Requirements	Linked Loss Scenarios
FR-165	The ITS systems shall communicate the location and the status of the traffic lights to the platoon.	LS-91
FR-166	The ITS systems shall be able to communicate the location and status of the infrastructure to a range of at least 100 meters from the infrastructure.	LS-99

4.7.19. Requirements Category: Throttle control

Table 56 - Requirements: Throttle control

Req. No	Requirements	Linked Loss Scenarios
FR-167	Platooning shall only be allowed in the forward direction.	LS-94
FR-168	The target path generated by the following trucks shall be achievable by the current acceleration capabilities of the ego vehicle.	LS-95
FR-169	The following trucks shall maintain traction on all road conditions within the ODD.	LS-95
FR-170	The following trucks shall generate the throttle request to meet the target trajectory with an accuracy of +/- 50 cm in the longitudinal axis. **Note:** Enough to maintain safe distance to other vehicles.	LS-95

4.7.20. Requirements Category: Brake control

Table 57 - Requirements: Brake control

Req. No	Requirements	Linked Loss Scenarios
FR-171	The target path generated by the following trucks shall be achievable by the current deceleration capabilities of the ego vehicle.	LS-96
FR-172	The deceleration requested by the following trucks shall maintain the ego vehicle on the target trajectory with an accuracy of +/- 50 cm in the longitudinal axis. **Note:** Enough to maintain safe distance to other vehicles.	LS-96
FR-173	If no brake performance is communicated by the forward truck, the following trucks shall assume maximum performance by the forward truck.	LS-78

4.7.21. Requirements Category: Steering control

Table 58 - Requirements: Steering control

Req. No	Requirements	Linked Loss Scenarios
FR-174	'The target path generated by the following trucks shall be achievable considering the physical limits of the steering geometry of the ego vehicle and the safety of the occupants.	LS-97
FR-175	The steering requested by the following trucks shall maintain the ego vehicle on the target trajectory with an +/- 15 cm in the lateral axis. **Note:** Required to keep the lane.	LS-97

4.7.22. Requirements Category: Self diagnosis

Table 59 - Requirements: Self diagnosis

Req. No	Requirements	Linked Loss Scenarios
FR-176	The following trucks shall be able to detect perception sensor blockages, incorrect mounting, and other perception related errors.	LS-1, LS-3, LS-4, LS-10, LS-46, LS-47, LS-48, LS-49, LS-50, LS-53, LS-54, LS-55, LS-56, LS-57
FR-177	The following trucks' autonomous driving HW shall have enough processing power, memory, and bus resources to track and update the relevant metadata of at least 20 of the closest vehicles/pedestrians/obstacles in real-time.	LS-11, LS-12, LS-13, LS-14, LS-15, LS-46, LS-47, LS-48, LS-49, LS-50, LS-51, LS-52, LS-53, LS-54, LS-55, LS-56, LS-57.
FR-178	If conflicting information is received between the communicated route and the path followed from the leading truck, the path information shall take precedence over the route data. **Note:** Priority given to follow the lead driver.	LS-86, LS-87
FR-179	Each truck shall maintain V2V communication with the platoon even under the loss of GNSS signal Note: e.g. inside tunnels, urban canyons, ...	LS-98
FR-180	The platoon leader shall inform the loss of communication with the infrastructure to the following trucks.	LS-99

5. SUMMARY AND CONCLUSION

This deliverable evaluates the Platooning Autonomous Function (PAF) to derive requirements that avoid or mitigate safety critical hazards arising due to performance limitations or functional insufficiencies of the PAF.

For this, system theoretic process analysis (STPA) method was applied to firstly identify safety critical losses and vehicle level hazards and then, to define a control structure diagram for the PAF to facilitate identification of the unsafe control actions (UCAs) arising from each of the controllers. Once the safety critical UCAs were identified, around 100 different loss scenarios were defined to identify the causal factors (triggering conditions and the functional insufficiencies) that can lead to the safety critical UCAs. Finally, 180 different functional requirements were defined to avoid or mitigate the safety risk arising from the PAF.

The inclusion of the routes between the hubs and the highways within the ODD hugely increases the complexity of the PAF and the number of unsafe triggering conditions that can be encountered while driving. These include triggering conditions related to infrastructure due to the requirement on the following trucks to autonomously pass-through junctions, roundabouts, etc as well as the inclusion of multiple type of objects like pedestrians, cyclists, garbage cans, etc that are usually not encountered on the highways. Various categories of requirements have been defined to clearly identify requirements based on the type of unsafe scenarios.

Since the platooning autonomous function is only a vision for the future of autonomous platooning and no system design or implementation details are available, assumptions made on the requirements and values of ranges and accuracies defined for the requirements are only indicative and are based on engineering judgement. Further research is required to validate the requirements.

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7. APPENDIX A - GLOSSARY

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 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,

Term	Definition
	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).

7.1.1. 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