Ref. Ares(2019)3289432 - 20/05/2019

Deliverable **D4.1**

Description and Taxonomy of Automated Driving Functions

Version: 2.0

Dissemination level: PU

Lead contractor: Groupe PSA

Due date: 31.12.2017

Version date: 30.04.2019

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 723051.

Document information

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Project funding

Horizon 2020
ART-02-2016 – Automation pilots for passenger cars
Contract number 723051
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Executive Summary

The methodology adopted by L3Pilot includes an important initial phase focused on the preparation of the tests to be performed on the fleet of cars with automated driving functions. This phase covers the design of experiments, the specification of use cases, and the definition of research questions as well as the set of data to be acquired.

In the frame of this task, subproject SP4 “Pilot Preparation and Support” has worked out a detailed description of the automated driving functions that will be tested, including a taxonomy of these functions, which identifies the common basic concepts and thus simplifies the final evaluation.

The present deliverable describes the work performed on these topics, providing an accurate description of the functions and discussing the concepts of the taxonomy, along the following lines.

First, the overall objectives and the applied methodologies are outlined. In particular, the description of functions was organized using a questionnaire filled out by each vehicle owner providing a test car. For this aim, the following topics were selected: narrative; context; function; take-over request; video and HMI; and vehicles.

In the second part, the report gives a visual presentation of each function, using icons and graphics. Starting from the consideration that partners will test a great number of different functions, this section of the deliverable allows a quick comparison among several kinds of automated functions, tested by different partners.

The last section of the deliverable explains how the taxonomy was developed, based on the aforementioned general descriptions. Taxonomy is the practice and science of classification of things or concepts, including the principles that underlie such classification. In our case, it supported the grouping of AD functions into consistent classes. We have proposed two kinds of taxonomy: the first one gives a generic understanding; the second one is more detailed and directed at the technical applications. In line with the main use cases on the road, functions are grouped into Highway functions, Traffic Jam functions, Parking functions, and Urban functions.

Due to the present dynamic situation regarding the development of AD functions and the establishment of testing procedures, changes in their characteristics might be expected in the time frame leading to the pilot tests. Nevertheless, the functions described in this document reflect the situation existing as of March 2019, and should closely approximate the functions eventually tested in L3Pilot until the end of 2021.

1 Introduction

1.1 Motivation for the L3Pilot Project

Over the years, numerous projects have paved the way for automated driving (AD). Significant progress has been made, but AD is not yet ready for market introduction. Nonetheless, the technology is rapidly advancing and is currently at a stage that justifies automated driving tests in large-scale pilot programmes.

L3Pilot is taking the final steps before the introduction of automated cars in everyday traffic. Drivers are familiar with Advanced Driver Assistance Systems (ADAS), and numerous vehicles are equipped with ADAS.

The issues of automation will not be resolved simply by integrating more and better technology. This topic needs above all a focus on user behaviour with automated driving systems. The key to the success of AD on the market will depend on user acceptance as well as on an understanding of the legal restrictions, which first need to be discussed and resolved on a broad level.

The idea of a vehicle controlling itself by a computer creates fears among the global population, not unlike those in the 1800s when the motor vehicle was first introduced. This lack of acceptance may hinder the introduction of driver assistance systems with automation despite their obvious benefits for safety and efficiency. In order to overcome public concerns, automated vehicles (AV) need to be designed according to user needs, otherwise they will not be accepted.

L3Pilot differs from earlier and ongoing EU-funded projects, in that AD systems will influence societies and peoples' lives far more greatly than all previous automotive innovations since the introduction of the mass-produced automobile more than one hundred years ago.

1.2 L3Pilot Objectives

The overall objective of the L3Pilot project is to test and study the viability of automated driving as a safe and efficient means of transportation and to explore and promote new service concepts to provide inclusive mobility.

AD technology has matured to a level that calls for a final phase of road tests to answer the key questions before market introduction. These newly-attained levels of maturity will ensure an appropriate assessment of the impact of AD, the processes both inside and outside the vehicles, the means of ensuring vehicle security, the evaluation of societal impacts, and the emerging business models.

Recent work indicates that driver assistance systems and AD functions can best be validated by means of extensive road tests, with a sufficiently long operation time, to allow extensive interaction with the driver and testable functions. The project will use large-scale testing and piloting of AD with developed SAE Level 3 (L3) functions (Figure 1.1) exposed to different users and mixed traffic environments, including conventional vehicles and vulnerable road users (VRUs), along different road networks. Some Level 4 (L4) functions and connected automation will also be assessed.

The data collected in these pilot programmes will support the main aims of the project to:

- Lay the foundation for the design of future, user-accepted, L3 and L4 systems, to ensure their commercial success. This will be achieved by assessing user reactions to, experiences of, and preferences for the AD systems' functionalities.
- Enable non-automotive stakeholders, such as authorities and certification bodies, to prepare measures that will support the uptake of AD, including updated regulations for the certification of vehicle functions with a higher degree of automation, as well as incentives for the user.
- Create unified de-facto standardized methods to ensure further development of AD applications (Code of Practice).
- Create a large databank to enable simulation studies of the performance of AD over time that cannot be investigated in road tests, due to the time and effort required. The data will be one product of the pilots.

SAE level	Name	Narrative Definition	Execution of Steering and Acceleration/ Deceleration	*Monitoring* of Driving Environment	Fallback Performance of *Dynamic Driving Task*	System Capability *(Driving Modes)*
Human driver **monitors the driving environment**						
0	No Automation	the full-time performance by the *human driver* of all aspects of the *dynamic driving task*, even when enhanced by warning or intervention systems	Human driver	Human driver	Human driver	n/a
1	Driver Assistance	the *driving mode*-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	Human driver and system	Human driver	Human driver	Some driving modes
2	Partial Automation	the *driving mode*-specific execution by one or more driver assistance systems of both steering and acceleration/ deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	**System**	Human driver	Human driver	Some driving modes
Automated driving system **("system") monitors the driving environment**						
3	Conditional Automation	the *driving mode*-specific performance by an *automated driving system* of all aspects of the dynamic driving task with the expectation that the *human driver* will respond appropriately to a *request to intervene*	System	**System**	Human driver	Some driving modes
4	High Automation	the *driving mode*-specific performance by an automated driving system of all aspects of the *dynamic driving task*, even if a *human driver* does not respond appropriately to a *request to intervene*	System	System	**System**	Some driving modes
5	Full Automation	the full-time performance by an *automated driving system* of all aspects of the *dynamic driving task* under all roadway and environmental conditions that can be managed by a *human driver*	System	System	System	**All driving modes**

Figure 1.1: SAE Levels of Driving Automation.

The consortium addresses the four major technical and scientific objectives listed below:

1. Create a standardized Europe-wide piloting environment for automated driving.
2. Coordinate activities across the piloting community to acquire the required data.
3. Pilot, test, and evaluate automated driving functions and connected automation.
4. Innovate and promote AD for wider awareness and market introduction.

1.3 Approach and Scope

The L3Pilot project will focus on large-scale piloting of Automated Driving functions (AD Functions), primarily L3 functions, with an additional assessment of some L4 functions. The key in testing is to ensure that the functionality of the systems used is exposed to variable conditions and that performance is consistent, reliable, and predictable. This will enhance a successful experience for the users (Figure 1.2). A good experience of using AD will accelerate acceptance and adoption of the technology and improve the business case to deploy AD.

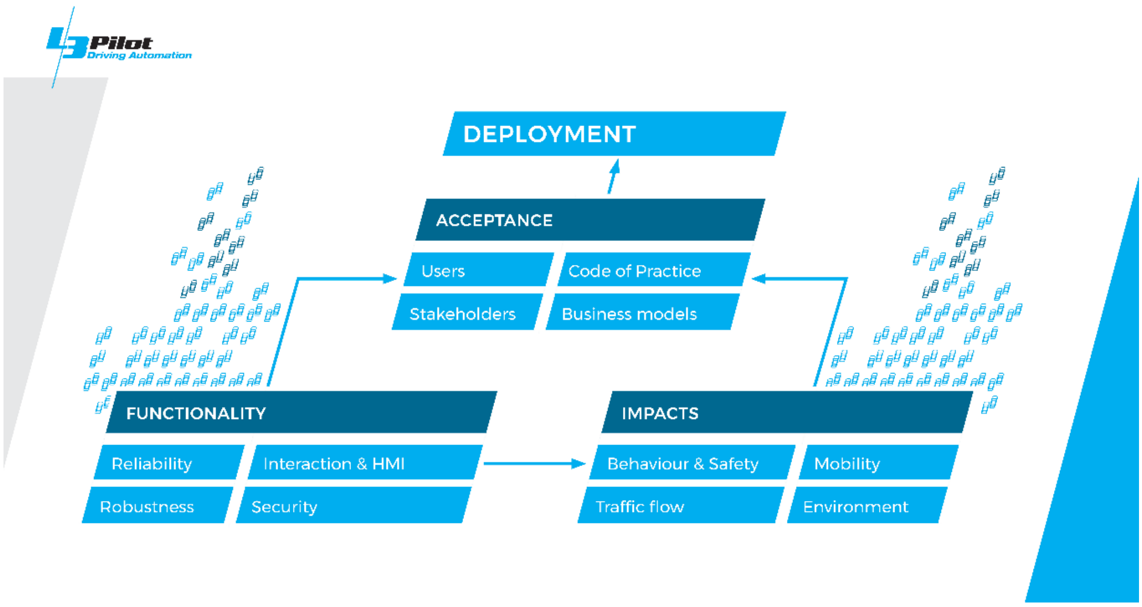


Figure 1.2: L3Pilot approach and the mechanism for deployment.

The L3Pilot consortium brings together stakeholders from the entire value chain, including: OEMs, suppliers, academic institutes, research institutes, infrastructure operators, governmental agencies, the insurance sector, and user groups. More than 1,000 users will test approximately 100 vehicles across Europe with bases in 10 European countries, including: Austria, Belgium, Finland, France, Germany, Italy, Luxembourg, the Netherlands, Sweden, and the United Kingdom, as shown in Figure 1.3. The project will last for 48 months and includes 18 months of road tests.

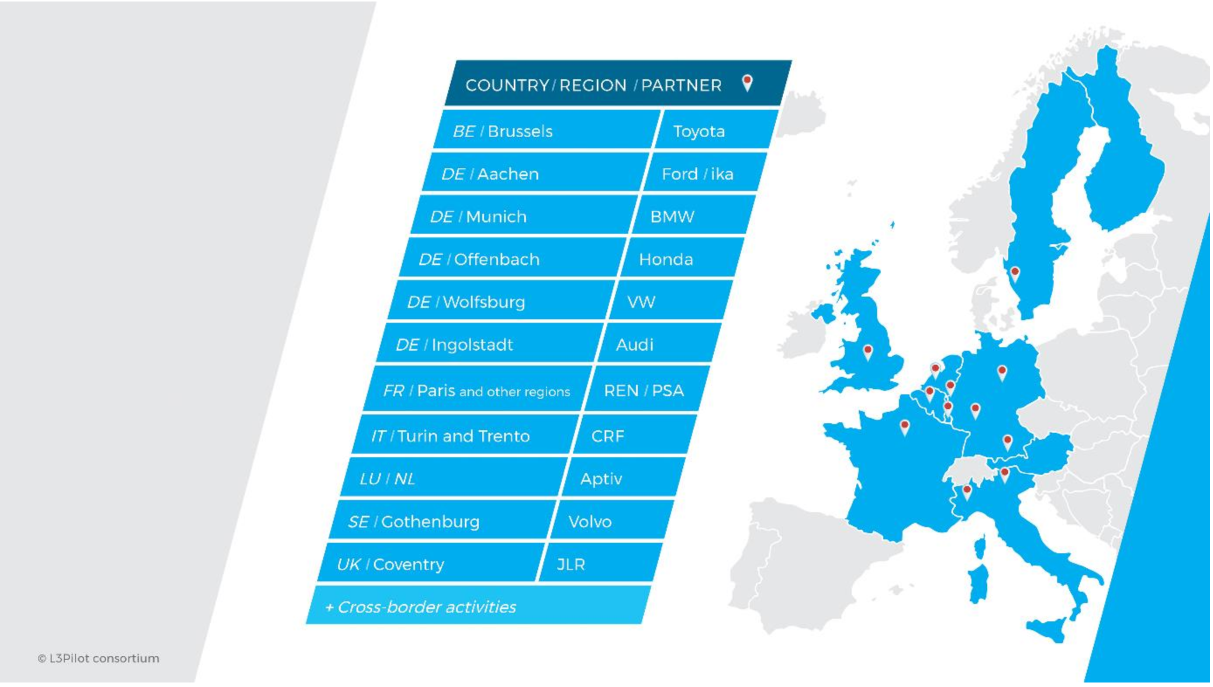


Figure 1.3: L3Pilot testing areas.

Since the development of AD functions, especially at SAE L3, is fairly far advanced, the aim is not only to pilot the functions, but also to study user preferences, reactions, and willingness to use vehicles equipped with AD applications. This information has led the consortium to create plans for the market introduction of AD. The L3Pilot concept can be split into the following two parallel, but intertwined, major activities:

(i) *Development of test and evaluation methodologies*, and actual testing and evaluation of functions, to answer the open questions. In this scientific part, a variety of controlled experiments will be carried out.

(ii) *Promotion of the project work for maximum impact.* This includes dissemination of the project results and communication to the public, through showcases, to accelerate deployment of AD. The planned showcases are:

- Showcase 1: Dynamic pit stop – Software Defined Vehicles (SDV).
- Showcase 2: L4V2X – connected automated vehicles.
- Showcase 3: Urban driving + automated parking.
- Showcase 4: Cross-border driving – highway automation.

1.4 Methodology and Evaluation

The project follows the FESTA V process methodology, adapted to suit L3Pilot needs, of setting up and implementing tests with the four main pillars, as follows: (i) Prepare, (ii) Drive, (iii) Evaluate, and (iv) Address legal and cyber-security aspects. FESTA was originally created as an ADAS testing methodology to be used in FOTs. L3Pilot will adapt it, however, to the piloting of AD functions.

When functions and use cases have been determined, research questions (RQs) and hypotheses (HYPs) will be formulated. The piloting will mainly focus on RQs and HYPs in four impact areas: (i) safety (ii) mobility (iii) efficiency, and (iv) environment. Additional evaluation areas will be carried out separately to address issues such as legal aspects and cyber security, as well as user evaluation and acceptance.

In the evaluation stage, a holistic approach will be used by analysing different aspects of AD based on real-world driving data. As such, the approach will follow FESTA evaluation domains: technical, user acceptance, driving and travel behaviour, impact on traffic, and societal impacts (Figure 1.4).

However, in addition to different evaluation aspects, a third dimension is needed. For instance, the analysis of driving situations is locally limited to the surrounding traffic. Hence, this is an analysis on single vehicle and fleet levels, whereas a European level is required, using aggregated data. The holistic evaluation approach of L3Pilot will consider aspects in all three dimensions. Investigating different fleets will allow L3Pilot to analyse intercultural differences in the interaction with AD applications. The evaluation will also take into account that the test vehicles are not market-ready products.

Technical analysis will focus on the situations in which AD functions operate outside their specifications, as well as their misuse and operational limits due to environmental conditions. The transition of control from the vehicle to the driver will focus on timing and the causes of the transition.

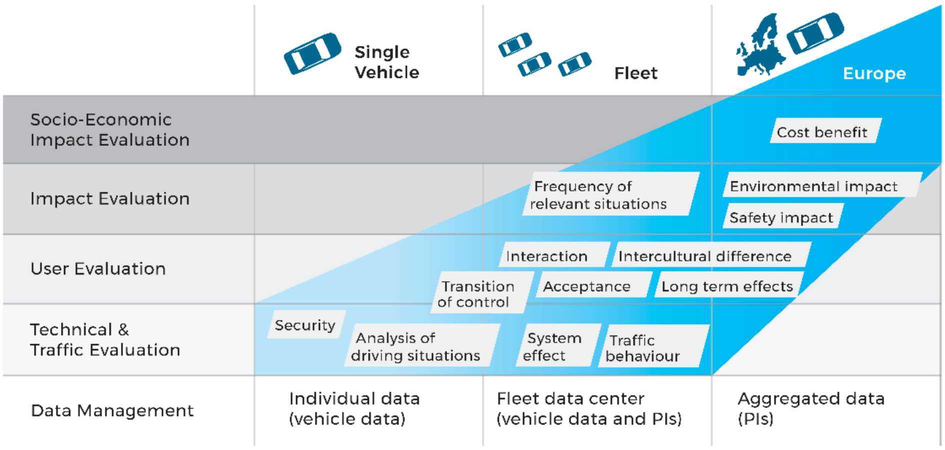


Figure 1.4: Considered evaluation aspects depending on the level of traffic and evaluation domain.

1.5 Objectives of Subproject SP4 “Pilot Preparation & Support”

L3Pilot has defined the following main objectives for subproject SP4:

- The selection of the cars to be used in the experiments by each OEM and supplier participating in the Pilot phase. These cars will constitute the so-called “experimental fleet”.
- The detailed description of the automated functions to be investigated and a comprehensive taxonomy providing their classification.
- The implementation of the functions in the experimental fleet, including sensors, algorithms, hardware and software, recording devices, etc.
- The technical pre-tests of a single car from each sub-fleet and then the technical pre-tests of each car in all the sub-fleets.
- The submission of “dossiers” to public authorities to obtain the licence for driving AD cars in the different EU countries (Sweden, Germany, France, the UK, Italy, etc.)
- The technical support for the teams involved in the pilot phase.
- The strategies of cyber security of the AD functions implemented in the car fleet.

In sum, the final target of subproject SP4 is the readiness of all the cars, so that they can be driven on public roads during the piloting phase of the project.

1.6 Objectives of the Description and Taxonomy of AD Functions

The objectives of the specific work on AD Functions are illustrated in the present section.

Concerning the description of functions:

This work is based on the original concepts defined in the work description of L3Pilot, as reported here:

“12 OEM’s and 2 suppliers are participating in the L3Pilot project with different cars and various AD functions, working with various use cases, with different technical limitations and different HMI. These functions need to be described in detail before the impact assessment can be done with regard to capabilities of these functions, the role of the driver, and driver-vehicle interaction.

A first task will consist of describing these functions one by one, with the help of a criteria list that structures the descriptions in a comprehensive and understandable manner.”

On this basis, the SP4 team decided to create a structured template in order to collect all the relevant data using the same approach for all the car owners.

The aims for using this template were essentially:

- To create an exhaustive description of all AD functions and all the vehicles, taking care that the focus was on the functions to be tested and not on the piloting conditions.

- To gain a comprehensive idea of the use cases of each AD function, as well as the piloting context and environment.
- To lay the groundwork for a classification of all the AD functions within the project.

Concerning the taxonomy:

A second task of the work was the specification of a taxonomy of the functions under test, with attention to highlighting similarities and discrepancies in order to facilitate the assessment. The rationale for this work was that the functions cannot be evaluated one by one. Therefore, criteria for taxonomy should be developed for making it simpler to group similar functions, with each group being as different as possible from other groups.

The idea was to emphasize the Operational Design Domain (ODD) (motorway, highway, rural road, cities), the exact functionalities (car following, lane change, maximum speed), and the role of the driver (monitoring of the environment, take-over request,). Moreover, the reconstruction of the external scenario should be taken into account, including e.g. the sensor capabilities (radar, cameras, ultrasonic, LiDAR, etc.), the type of obstacles (fixed, moving, markings, and vertical signs), and the possibility of adverse environmental conditions (rain, fog, snow, night, etc.).

It must be noted here that the proposed taxonomy is not related to any other classification of automated systems, such as the SAE classification. The L3Pilot taxonomy classifies the specific functions tested in the project for a clear understanding of how, when, and where the functions work.

1.7 Definition of Terms to Describe Status of the Driver

- **Hands-On**: the driver must keep his/her hands on the steering wheel during AD mode, even though the AD system ensures lateral and longitudinal control.
- **Hands-Off**: the driver does not have to keep his/her hands on the steering wheel during AD mode.
- **Eyes-On**: the driver has to be attentive and monitor the driving scene. In reference to SAE terms, the driver is in charge of the OEDR (Object and Event Detection and Response).
- **Eyes-Off**: the driver does not have to be attentive to driving all the time. He/she can engage in certain side activities (but not all). **“Eyes-Off” should not be used alone**. “Mind-on” or “Mind-off” must be added to fully understand what the driver must do and can do.
- **Eyes-Off – Mind-On**: the driver does not have to be attentive to driving all the time. However, he/she must be perceptive to take-over requests and to obvious dangers.
- **Eyes-Off – Mind-Off**: the driver need not be attentive nor perceptive to take-over requests. If there is a take-over request and the driver does not respond, the vehicle switches to a minimal risk manoeuvre in order to reach a minimal risk condition.

SAE standard J3016 never refers to these terms. They have been proposed afterwards for the sake of quick understanding but must be used appropriately. For example, a SAE level 2 can be hands-on or hands-off but is always eyes-on and mind-on. A SAE level 3 system is eyes-off, mind-on. A SAE level 4 system is eyes-off, mind-off in the sense of the above definitions.

2 Description of AD Functions

2.1 Introduction

The description of AD functions was obtained by means of detailed questionnaires, filled out by each partner responsible for the experiments.

For this task, a two-stage approach was adopted. In the first stage, the focus was on a short description of the function in order to identify the interest of the partners and to shape the direction of the investigation. The results of stage one were analysed and fed into stage two. Here a detailed questionnaire was generated with a list of questions organized according to the following items: narrative; context; function; take-over request; video and HMI; vehicles.

The use of a template as an Excel spreadsheet allowed the multiplicity of answers to be easily compared and evaluated. In a later step, difficult or sensitive questions were rephrased and refined in a series of personal interviews.

The topics covered by the questionnaire are described in the Sections 2.3–2.6 below, and the template with the questionnaire administered to the partners is presented in Annex 1.

2.2 Methodology

The following principles were applied to guide the partners providing piloting vehicles in the process of filling out the template.

Principles for the description of the AD functions:

- The AD functions are pre-production, not those that are being targeted to be sold.
- The AD functions are described mainly at a high level, providing a comprehensive viewpoint focused on their operational requirements.
- The description must be self-sufficient and clear.
- The description must be oriented towards the needs of the evaluation phase for an impact assessment.
- The taxonomy of AD functions is established ex-post, once they have been described. The description is the sole basis for the taxonomy.

The ideas for this template were mainly derived from the AdaptIVe project deliverables [1] and from the SAE classification of automated driving levels (Figure 1.1).

When filling out the template, the partners follow a logical sequence, as shown in Figure 2.1.

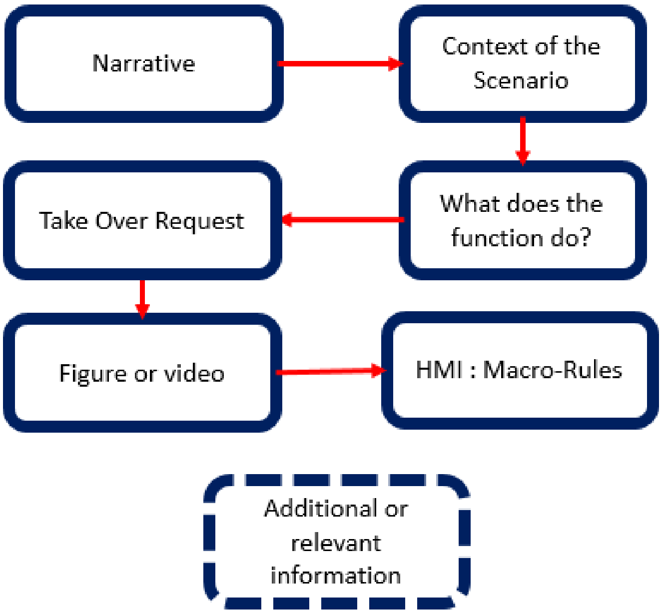


Figure 2.1: Sequence of AD function description.

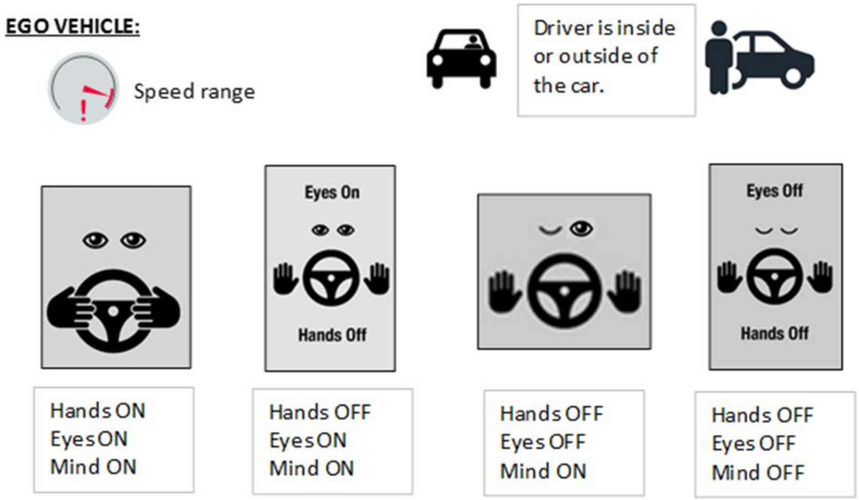
In this process, some questions require a free text, while others allow both free text and a list of options. An additional spreadsheet in the template is used to describe the vehicles of the fleet that implement the functions.

The components of the sequence are described in the following sections.

2.3 Narrative

2.3.1 AD function description and automation target

In this first part of the template, the partner gives a general description. The target of automation that the function is intended to deliver follows the SAE level of automation and includes the status of the driver as in “mind-on/mind-off”; “eyes-on/eyes-off”; and “hands-on/hands-off”.



2.3.2 Pilot site

The template also asks the partner to specify the main location for piloting and any optional additional locations. This is relevant to enable the project to provide tests on a comprehensive set of locations with different traffic conditions, weather circumstances, kinds of roads, etc.

2.4 Context

2.4.1 ODD – Function boundaries

To describe the context in which the function will be tested, and additionally to determine the boundaries of the functions, the description is divided into three parts: road, traffic, and visibility.

In order to capture the exact context, the partner is asked to indicate for each column in the template what is “required for an AD function” and what is “compatible with an AD function”.

2.4.2 Environment – Road

To describe the road, the partner indicates the road type (motorway, urban road, parking area, etc.) and its characteristics, such as surface condition (good, bumpy, etc.) and geometry (straight, curved, inclined, etc.).

The next type of question regards the characteristics of the road, to obtain information about the existing infrastructure, such as lane dividers, guard rails, or limitations such as bicycle lanes and intersections.

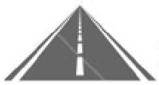
Other questions refer to the accessibility of the test sites (private or public area) and the level of mapping required.

INFRASTRUCTURE:


Steep road

Private site or parking area


Motorway


Straight road


Curved road

2.4.3 Environment – Traffic

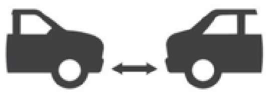
To describe the situation, the partner indicates planned traffic conditions (flow, mixed traffic, or automation only).

TRAFFIC ENVIRONMENT:


Possible slow or stationary traffic


Working zone


Non motorized road users


Ego vehicle needs a front vehicle

2.4.4 Environment – Visibility

Visibility is mainly a consequence of weather conditions (sun, fog, rain, snow, etc.) but also of lighting conditions and of possible obstacles such as vehicles and infrastructure.

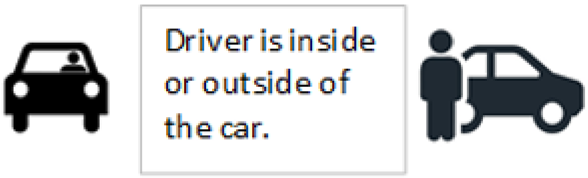
2.5 Function

2.5.1 Driver

The information on the driver is an essential part of the overall description of the tested function. Therefore, before determining the “Service provided by the AD function” and its scope, the questionnaire poses queries about the driver.

Depending on the SAE automation level, but also on the function, partners indicate the driver position (inside or outside of the vehicle, remote operation) and the need for monitoring. If the driver is allowed to perform alternative tasks, a question requires the partner to specify if the driver can be drowsy or sleeping.

There is also a query about the target population of drivers (professional or non-professional) and their condition. A last question is about parameter settings by the driver, such as inter-vehicle distance, maximum speed, and other choices directly indicated during the driving process.



2.5.2 Service provided by the AD function

In this section, we collect information about the activation of the AD function, for instance in terms of duration, speed range, and type of manoeuvres (lane following, lane change, reversing, etc.). The section also describes boundaries such as longitudinal and lateral control forces, lower and upper speed limit, etc.

Finally, the questionnaire refers to the connectivity with other vehicles, in particular with two questions about “coordination V2X” and “following distances”.

Coordination V2X

2.6 Give-back Sequence

In this part of the questionnaire, the partner describes an expected and unexpected “give-back” sequence in a timeline. Details are given on the give-back process (initiated by the AD) and the take-over process (initiated by the driver) if available. The template also describes the position of hands and the detection of inattention by the driver monitoring system.

Give Back

The AD function has a possible Give Back in X sec.

2.7 Video and HMI

In this part, the partner pictorially describes the AD function, using a video or figures.

The template also illustrates the HMI of the dashboard or of the phone for those functions that use this device. The aim is to have a general view of the interface. If the partners have macro rules for HMI, they can be included in this section.

2.8 Vehicles

For each function, a short description of the piloting vehicles is added in this last section.

The partners firstly describe the number of cars (prototype or serial) and the model for the given function. Then, they describe the actuators (steering, throttle, braking system, etc.) and all the sensors (cameras, LiDAR, GPS, radar, etc.) used for the AD function.

Finally, the template asks for communication protocols and data logging. It also requests that the hardware providing the HMI and the main features of the communication channel be specified.

3 AD Function Description

The full scope of all L3Pilot functions, as obtained by the questionnaires, is presented in Table 3.1. The project will cover four types of road scenarios and three levels of automation according to the SAE classification – with a distinct focus on Level 3, as shown in Table 3.2.

Table 3.1: L3Pilot functions by SAE automated driving level (ID=Identity Document)

			Parking	Motorway	Traffic Jam	Urban
ID	1			Level 3		
ID	2				Level 3	
ID	3			Level 4		
ID	4			Level 3		
ID	5		Level 4			
ID	6			Level 3		
ID	7				Level 3	
ID	8		Level 4			
ID	9				Level 3	
ID	10			Level 3		
ID	11					Level 3
ID	12			Level 3		
ID	13				Level 3	
ID	14		Level 2			
ID	15			Level 3		
ID	16					Level 3
ID	17			Level 3		
ID	18				Level 3	
ID	19		Level 4			
ID	20			Level 3		

Note: in the taxonomy part, ID19 can be split into two: ID19 in Level 4 and ID 21 in Level 2. This describes different possibilities for parking.

Table 3.2: Information on the focus on distribution by SAE AD level and function

	Number of partners
Function Level 2	1
Function Level 3	15
Function Level 4	4

	Number of partners
Parking	4
Highway	9
Traffic	5
Urban	2

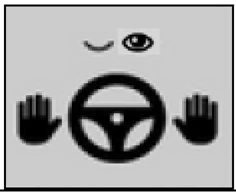
The next pictorial description represents the functions under development, for a total of 20 applications. This representation covers the main topics of the questionnaire and delivers a general and visual approach that illustrates the parallels and differences at a glance. The function name and SAE level are given in the upper box, followed by symbols indicating the key characteristics and by a sketch of the topics as they were described by the partners. One partner can have multiple IDs because the partner is testing multiple AD functions.

"Motorway Chauffeur"

ID 1.

SAE LEVEL 4 ☐
SAE LEVEL 3 ☑
SAE LEVEL 2 ☐
SAE LEVEL 1 ☐

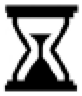
Ego vehicle



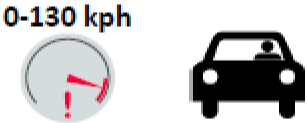
Eyes off
Hands off
Mind on

Manoeuvre:
- Lane following
- Change lane
- Emergency braking
- Obstacle avoidance

15 sec.



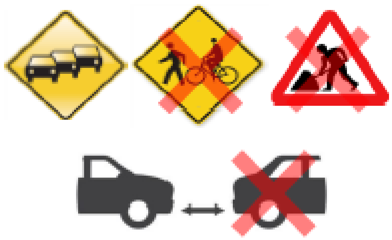
0-130 kph



Infrastructure

Road environment

Traffic environment



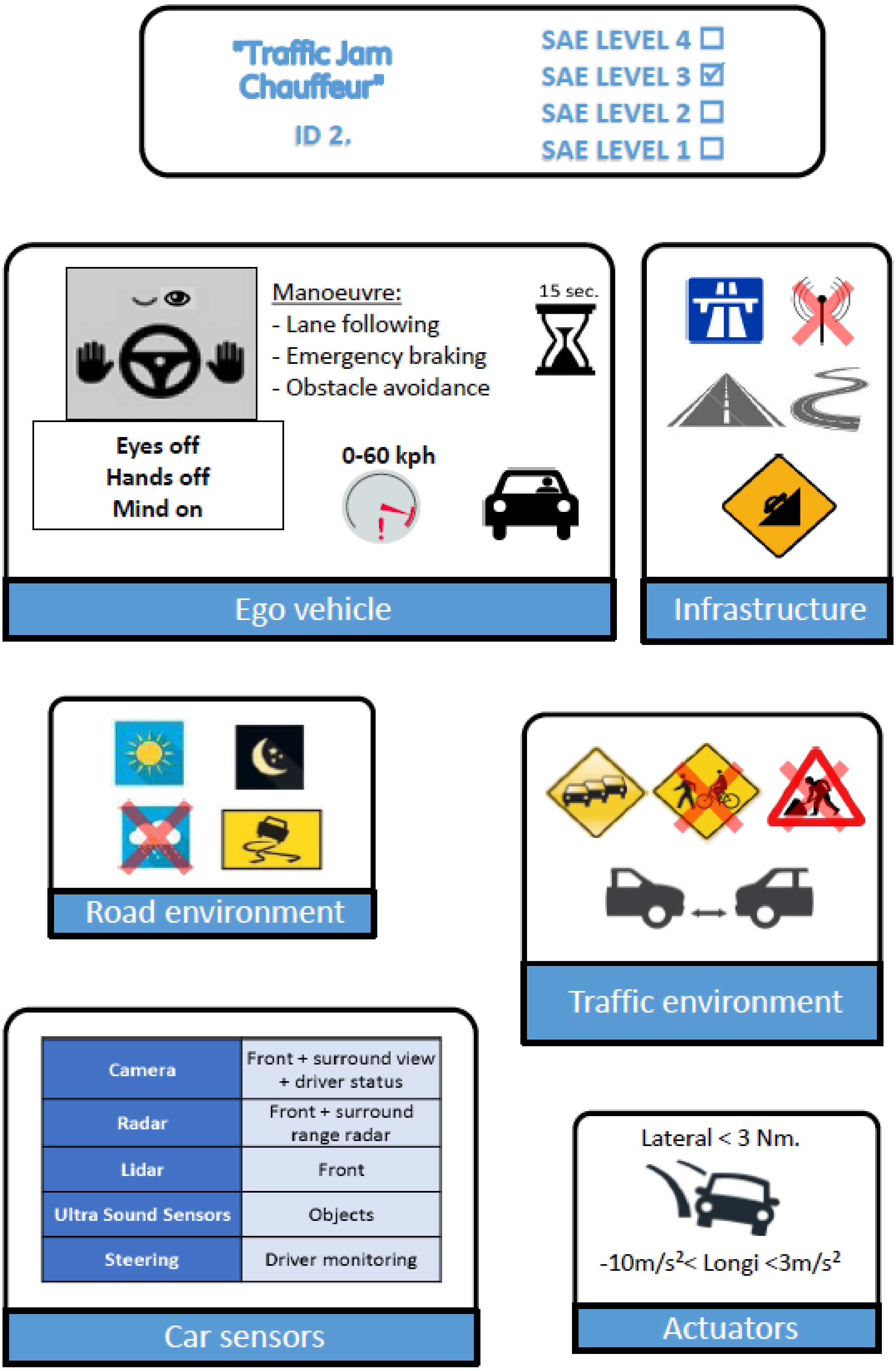
Car sensors

Camera	Front + surround view + driver status
Radar	Front + surround range radar
Lidar	Front
Ultra Sound Sensors	Objects
Steering	Driver monitoring

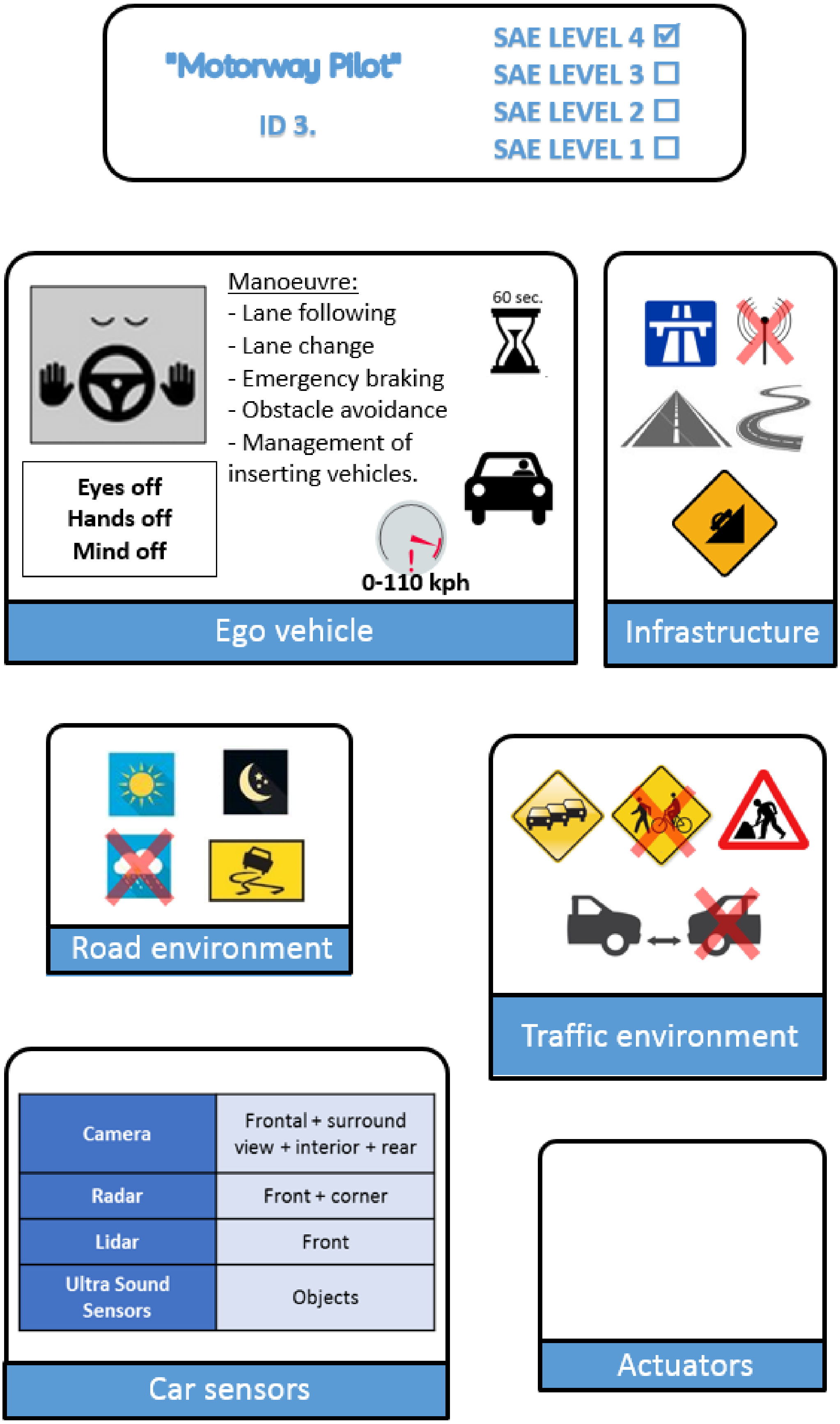
Actuators

Lateral < 3 Nm.

$-10 m/s^2 <$ Longi $< 3 m/s^2$



Camera	Front + surround view + driver status
Radar	Front + surround range radar
Lidar	Front
Ultra Sound Sensors	Objects
Steering	Driver monitoring



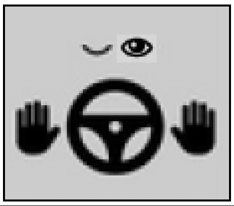
Camera	Frontal + surround view + interior + rear
Radar	Front + corner
Lidar	Front
Ultra Sound Sensors	Objects

"Motorway Chauffeur"

ID 4.

SAE LEVEL 4 ☐
SAE LEVEL 3 ☑
SAE LEVEL 2 ☐
SAE LEVEL 1 ☐

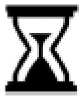
Ego vehicle



Eyes off
Hands off
Mind on

Manoeuvre:
- Lane following
- Lane change
- Emergency braking
- Obstacle avoidance

15 sec.

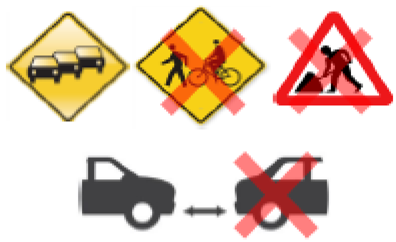


0-100 kph

Infrastructure

Road environment

Traffic environment



Car sensors

Camera	Front + surround view + driver status
Radar	Front + surround range radar
Lidar	Front
Ultra Sound Sensors	Objects
Steering	Driver monitoring

Actuators

Lateral < 10 Nm.

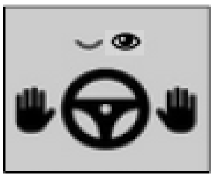
$-10m/s^2 <$ Longi $< 3m/s^2$

"Parking Chauffeur"

ID 5.

SAE LEVEL 4 ☑
SAE LEVEL 3 ☐
SAE LEVEL 2 ☐
SAE LEVEL 1 ☐

Ego vehicle

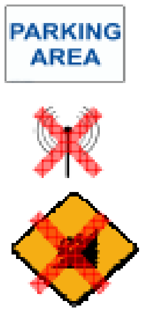


Manoeuvre:
- Reversing
- Emergency braking
- Obstacle avoidance

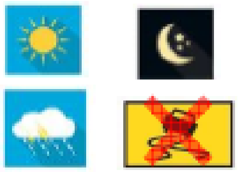
Eyes off
Hands off
Mind on

0-10 kph

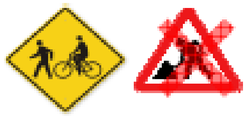
Infrastructure



Road environment



Traffic environment

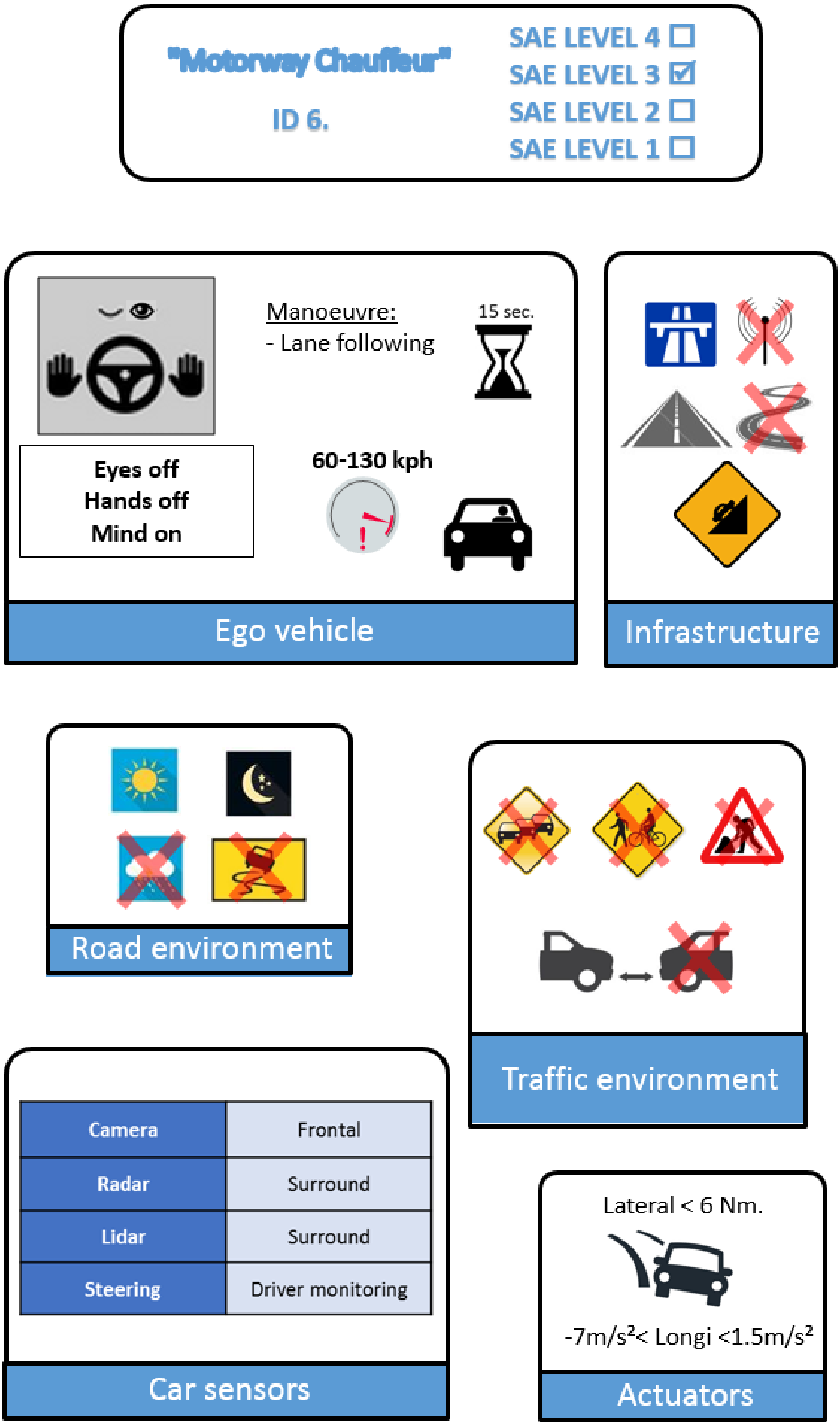


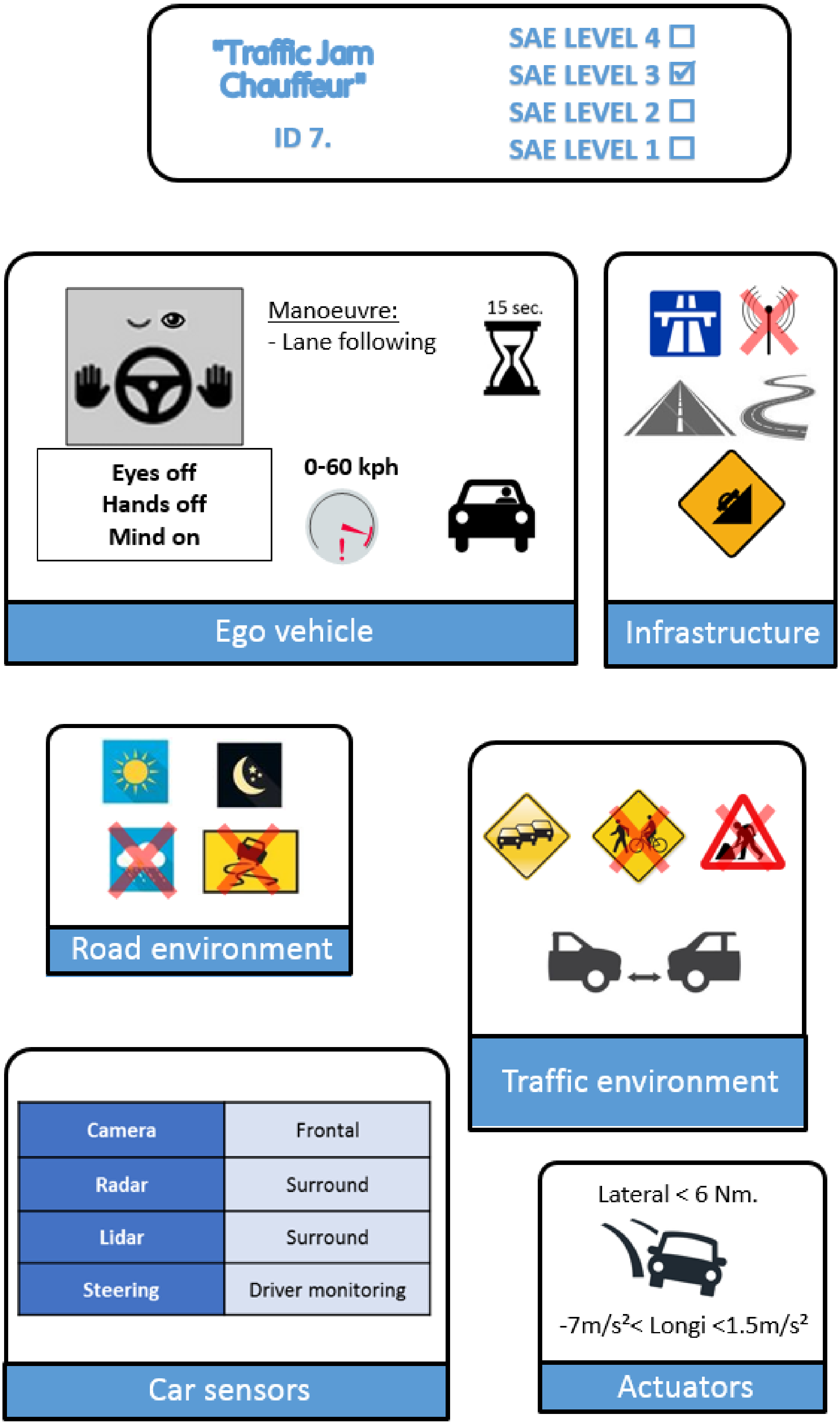
Car sensors

Camera	Frontal + surround view.
Radar	Surround
Lidar	Front
Ultra Sound Sensors	Objects

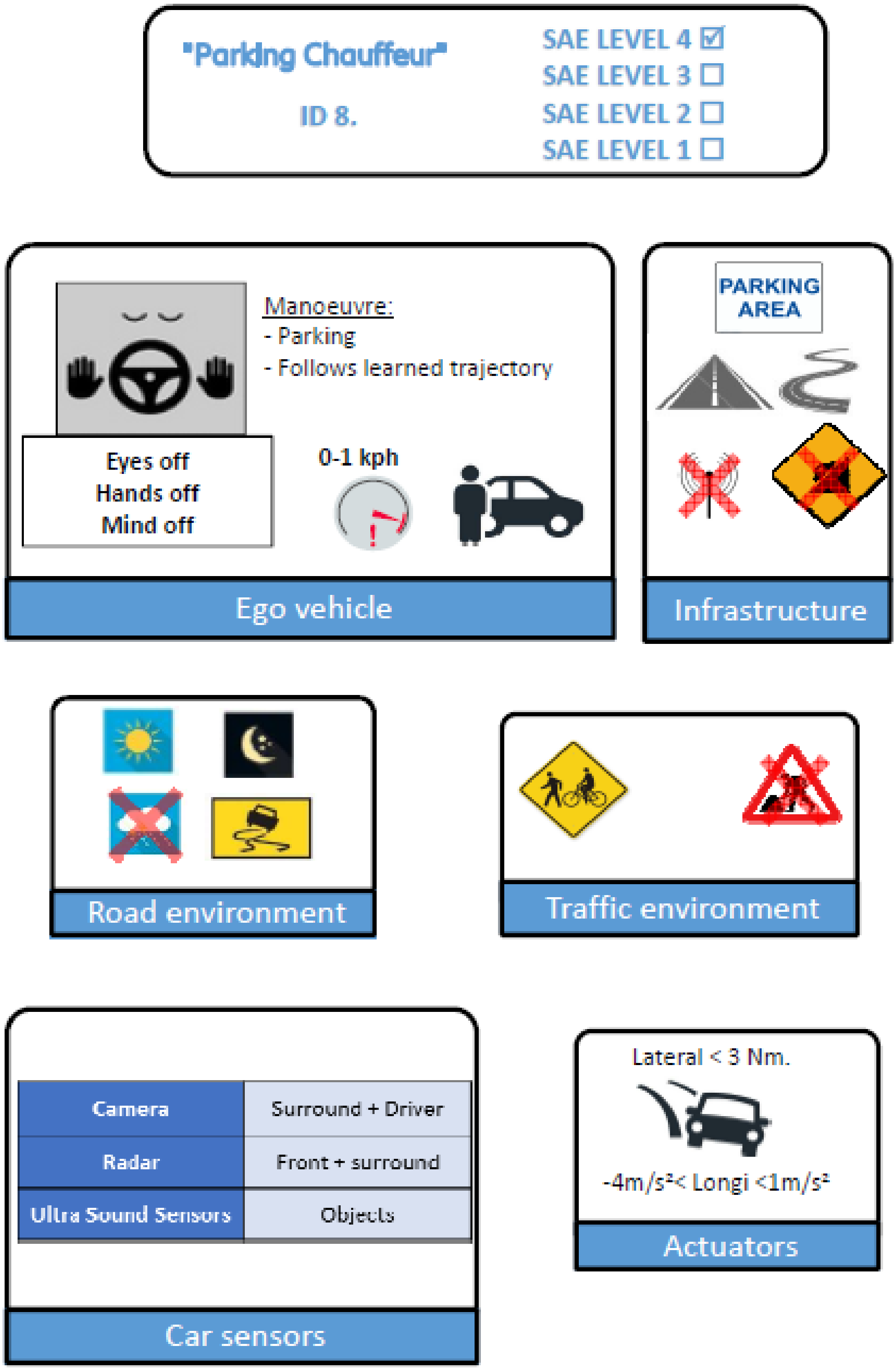
Actuators

-4m/s²< Longi <1m/s²


"Motorway Chauffeur"
ID 6.
SAE LEVEL 4
SAE LEVEL 3
SAE LEVEL 2
SAE LEVEL 1
Eyes off
Hands off
Mind on
Manoeuvre:
- Lane following
15 sec.
60-130 kph
Ego vehicle
Infrastructure
Road environment
Traffic environment
Camera
Frontal
Radar
Surround
Lidar
Surround
Steering
Driver monitoring
Car sensors
Lateral < 6 Nm.
-7m/s²< Longi <1.5m/s²
Actuators



Camera	Frontal
Radar	Surround
Lidar	Surround
Steering	Driver monitoring



"Parking Chauffeur"
ID 8.
SAE LEVEL 4 ☑
SAE LEVEL 3 ☐
SAE LEVEL 2 ☐
SAE LEVEL 1 ☐
Manoeuvre:
- Parking
- Follows learned trajectory
Eyes off
Hands off
Mind off
0-1 kph
Ego vehicle
PARKING AREA
Infrastructure
Road environment
Traffic environment
Camera
Surround + Driver
Radar
Front + surround
Ultra Sound Sensors
Objects
Car sensors
Lateral < 3 Nm.
-4m/s²< Longi <1m/s²
Actuators

"Traffic Jam Chauffeur"

ID 9.

SAE LEVEL 4 ☐
SAE LEVEL 3 ☑
SAE LEVEL 2 ☐
SAE LEVEL 1 ☐

Ego vehicle

Manoeuvre:
- Lane following
- Emergency braking

15 sec.

Eyes off
Hands off
Mind on

0-60 kph

Infrastructure

Road environment

Traffic environment

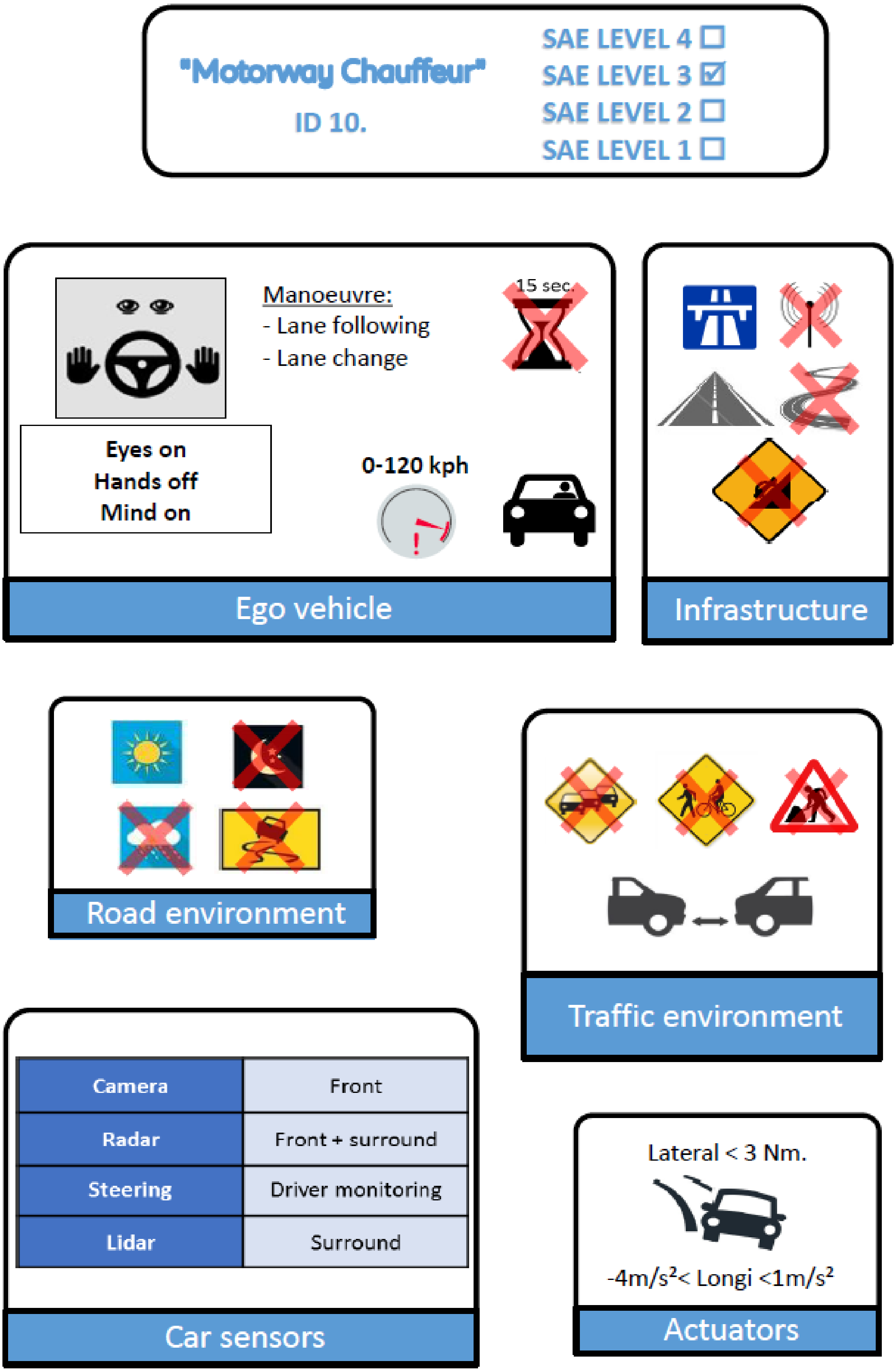
Car sensors

Camera	Front + surround view + driver status
Radar	Front + surround range radar
Ultra Sound Sensors	Objects
Steering	Driver monitoring

Actuators

Lateral < 6 Nm.

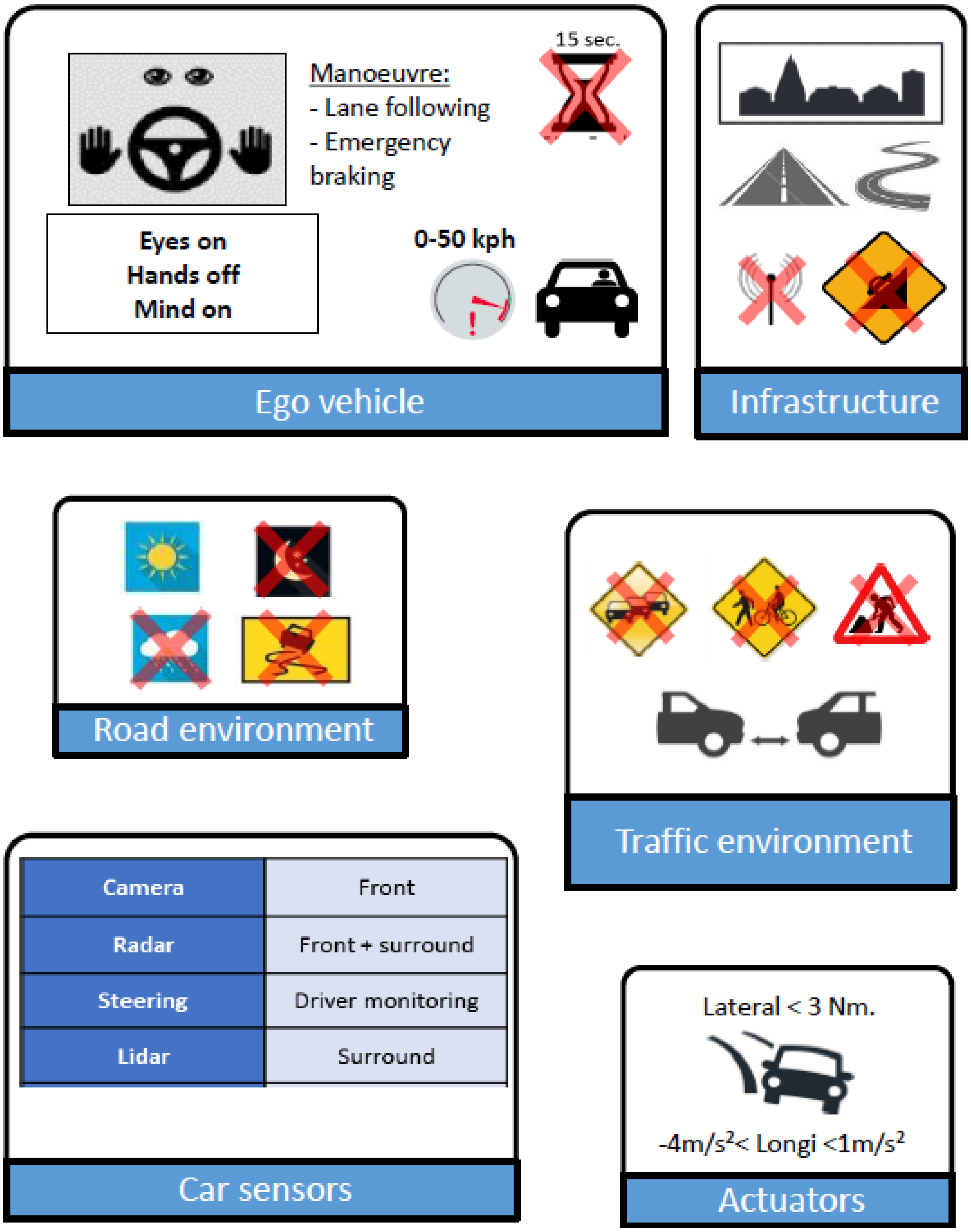
$-7 m/s^2 <$ Longi $< 1.5 m/s^2$


"Motorway Chauffeur"
ID 10.
SAE LEVEL 4 ☐
SAE LEVEL 3 ☑
SAE LEVEL 2 ☐
SAE LEVEL 1 ☐
Eyes on
Hands off
Mind on
Manoeuvre:
- Lane following
- Lane change
15 sec.
0-120 kph
Ego vehicle
Infrastructure
Road environment
Traffic environment
Camera
Front
Radar
Front + surround
Steering
Driver monitoring
Lidar
Surround
Car sensors
Lateral < 3 Nm.
-4m/s²< Longi <1m/s²
Actuators

"Urban Chauffeur"

ID 11.

SAE LEVEL 4 ☐
SAE LEVEL 3 ☑
SAE LEVEL 2 ☐
SAE LEVEL 1 ☐



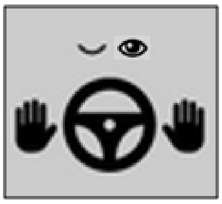
Camera	Front
Radar	Front + surround
Steering	Driver monitoring
Lidar	Surround

"Motorway Chauffeur"

ID 12.

SAE LEVEL 4 ☐
SAE LEVEL 3 ☑
SAE LEVEL 2 ☐
SAE LEVEL 1 ☐

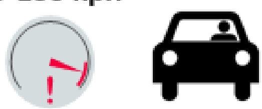
Ego vehicle



Eyes off
Hands off
Mind on

Manoeuvre:
- Lane following
- Lane change
- Emergency braking

0-130 kph



Infrastructure

Road environment

Traffic environment

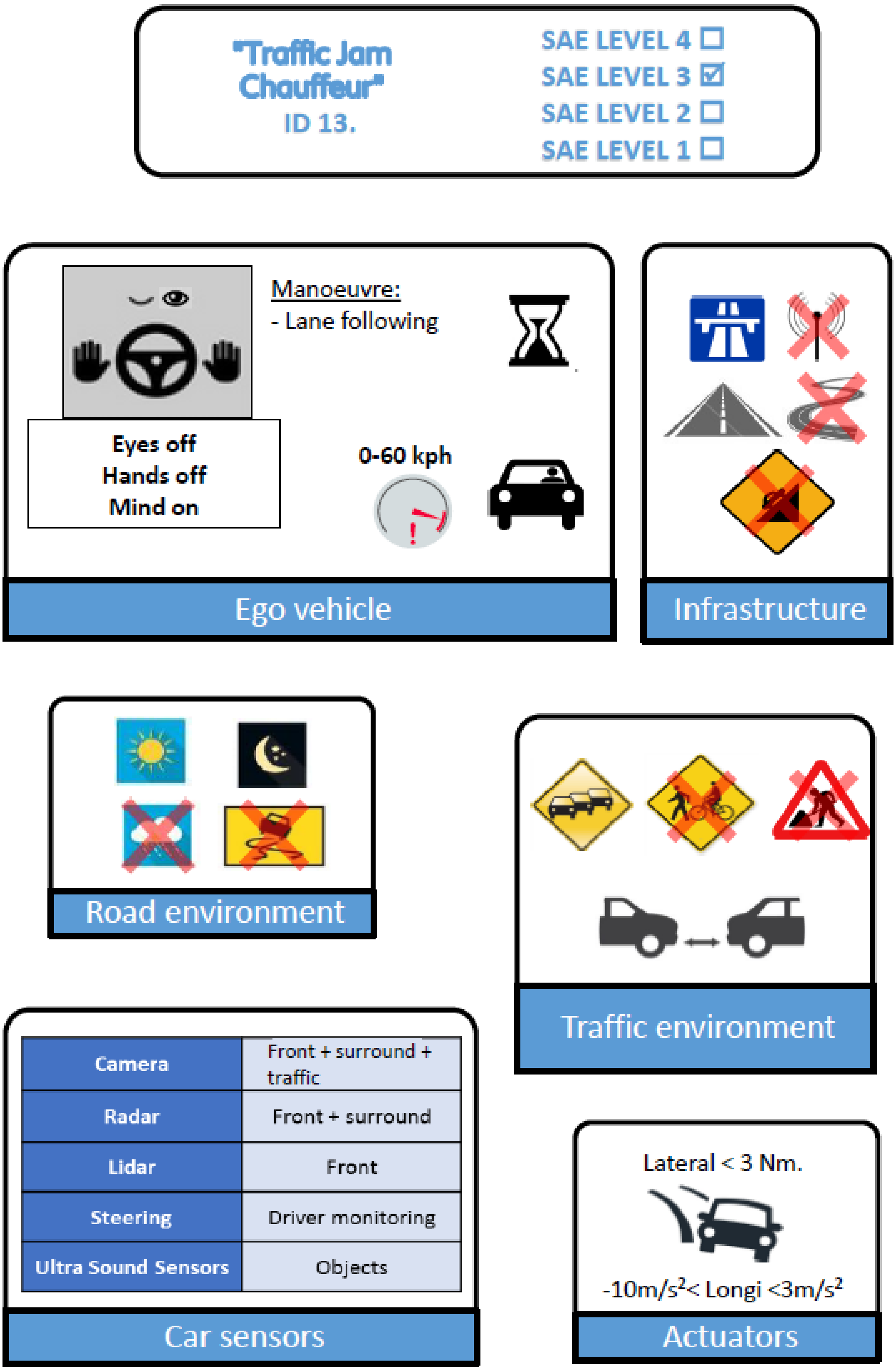
Car sensors

Camera	Frontal + surround view + interior + rear
Radar	Front + surround
Lidar	Front + Side object

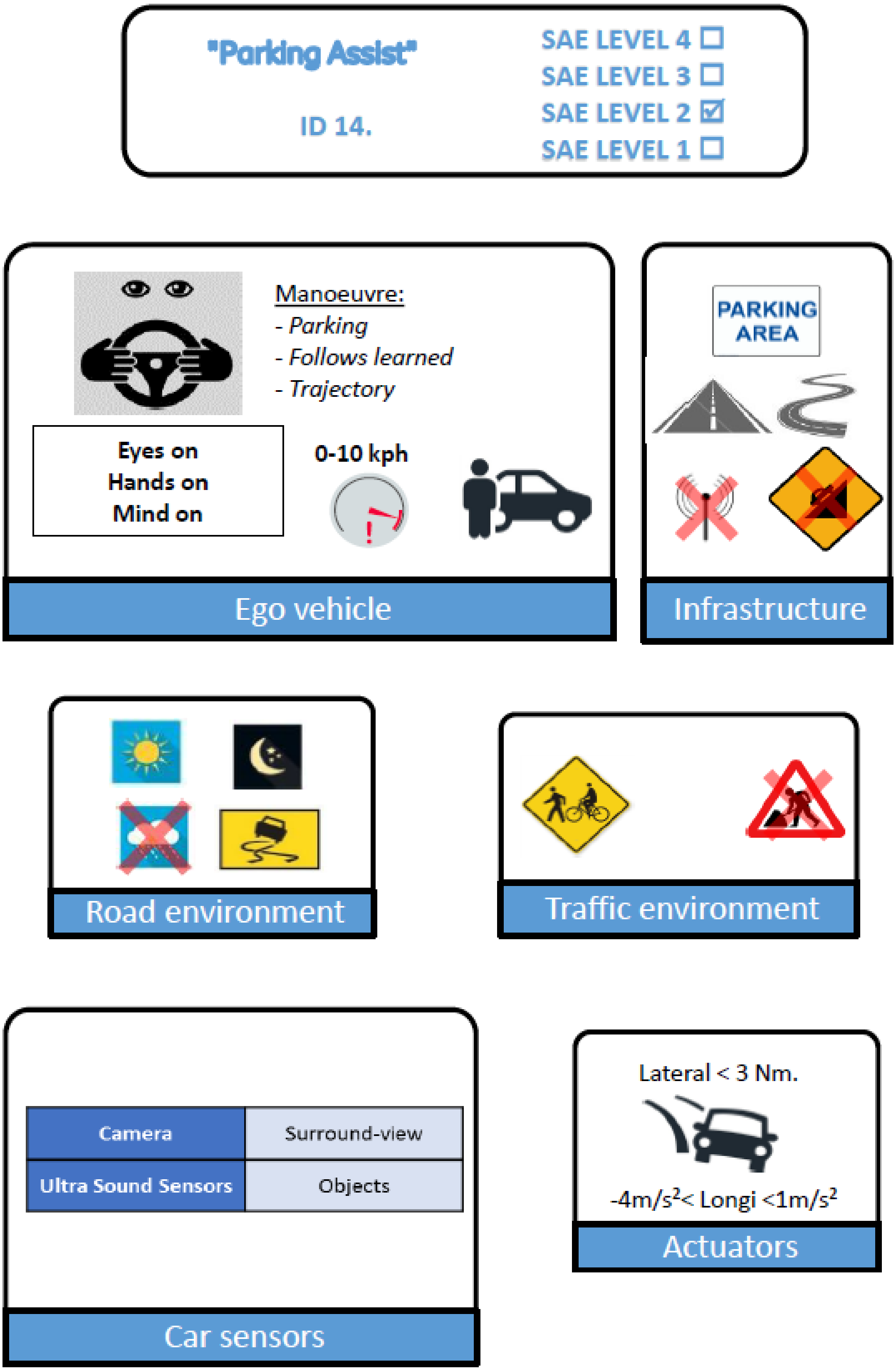
Actuators

Lateral < 6 Nm.

$-10 m/s^2 <$ Longi $< 3 m/s^2$



Camera	Front + surround + traffic
Radar	Front + surround
Lidar	Front
Steering	Driver monitoring
Ultra Sound Sensors	Objects


"Parking Assist"
ID 14.
SAE LEVEL 4 ☐
SAE LEVEL 3 ☐
SAE LEVEL 2 ☑
SAE LEVEL 1 ☐
Manoeuvre:
- Parking
- Follows learned
- Trajectory
Eyes on
Hands on
Mind on
0-10 kph
Ego vehicle
PARKING AREA
Infrastructure
Road environment
Traffic environment
Camera
Surround-view
Ultra Sound Sensors
Objects
Car sensors
Lateral < 3 Nm.
-4m/s²< Longi <1m/s²
Actuators

"Motorway Chauffeur"

ID 15.

SAE LEVEL 4 ☐
SAE LEVEL 3 ☑
SAE LEVEL 2 ☐
SAE LEVEL 1 ☐

Ego vehicle

Manoeuvre:
- Lane following
- Lane change
- Vehicle following (80-130 kph) & uninfluenced driving

Eyes off
Hands off
Mind on

0-130 kph

Infrastructure

Road environment

Traffic environment

Car sensors

Camera	Front, Back & Driver Status
Ultra Sound Sensors	Objects
Radar	Front & Back & Surround
Steering	Driver monitoring

Actuators

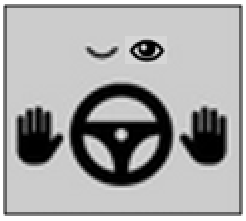
Lateral < 3 Nm.

$-10m/s^2 <$ Longi $< 3m/s^2$

"Urban Chauffeur"

ID 16.

SAE LEVEL 4 ☐
SAE LEVEL 3 ☑
SAE LEVEL 2 ☐
SAE LEVEL 1 ☐



Manoeuvre:
- Lane following
- Intersection crossing
- Obstacle avoidance
- Lane change

Eyes off
Hands off
Mind on

0-35 kph

Ego vehicle

Infrastructure

Road environment

Traffic environment

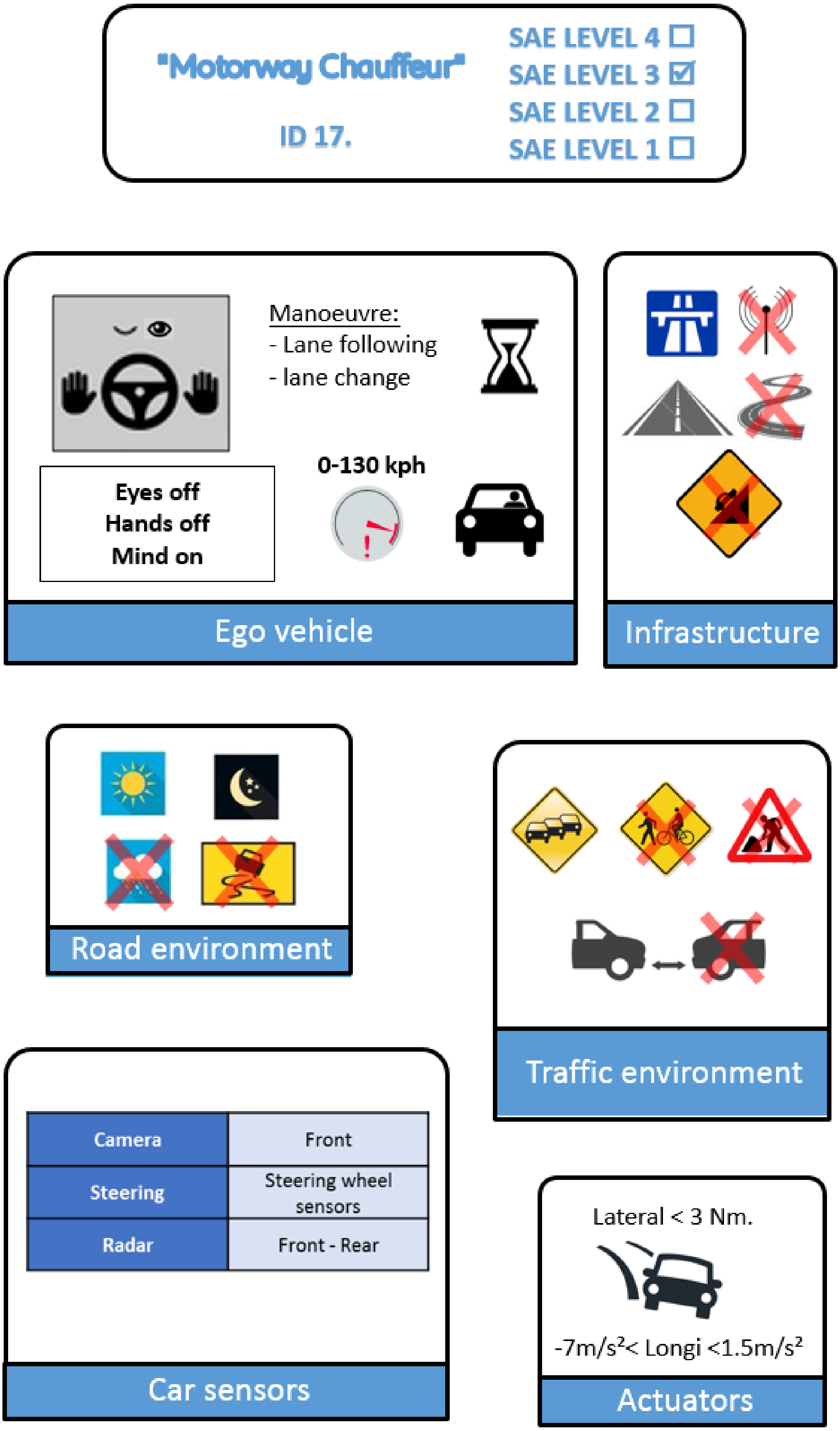
Camera	Front + Surrounding + Driver
Ultra Sound Sensors	Objects
Radar	Long for Front + Short for Side/Rear objects
Lidar	Front + Surrounding
Steering	Driver monitoring

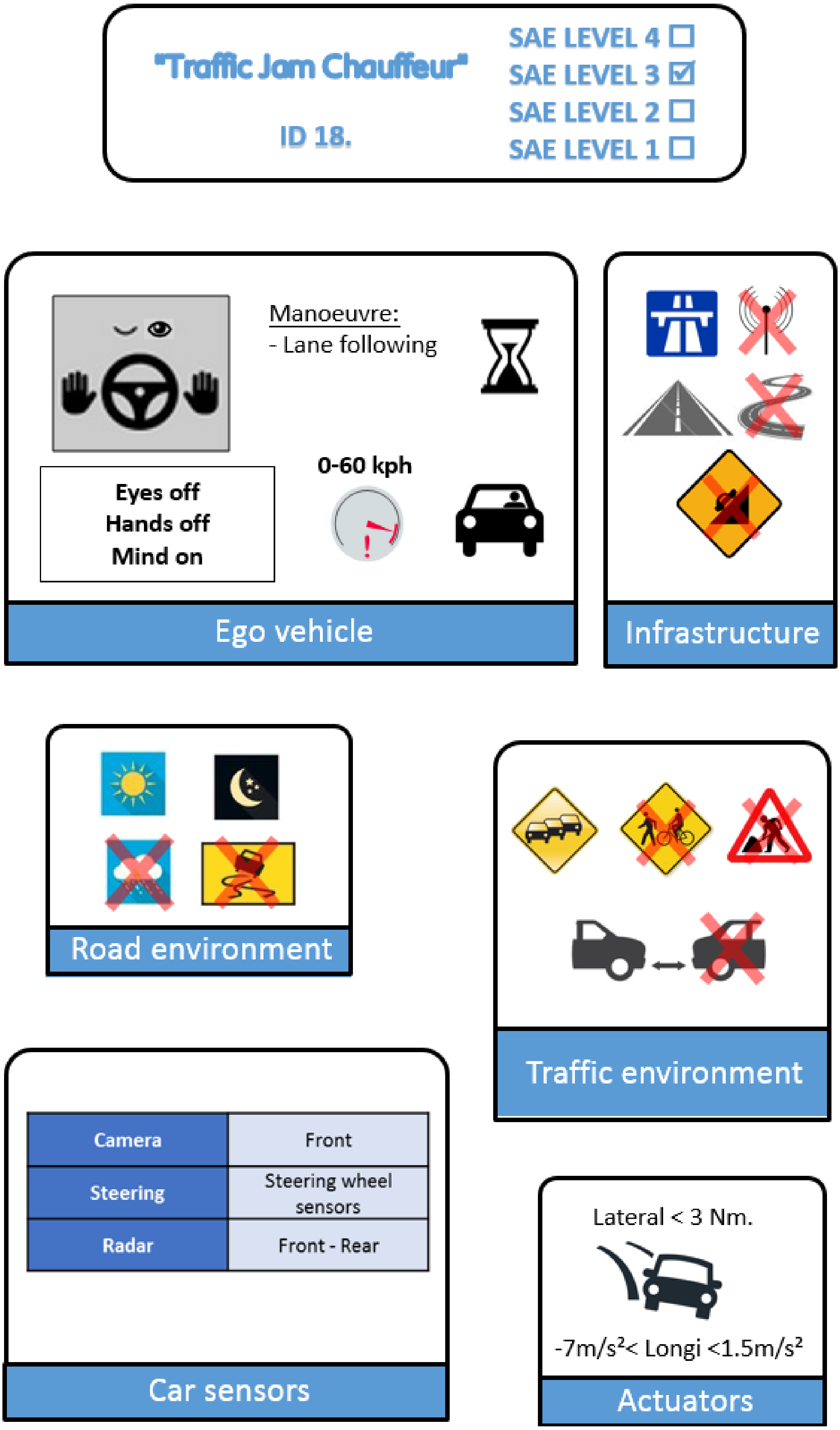
Car sensors

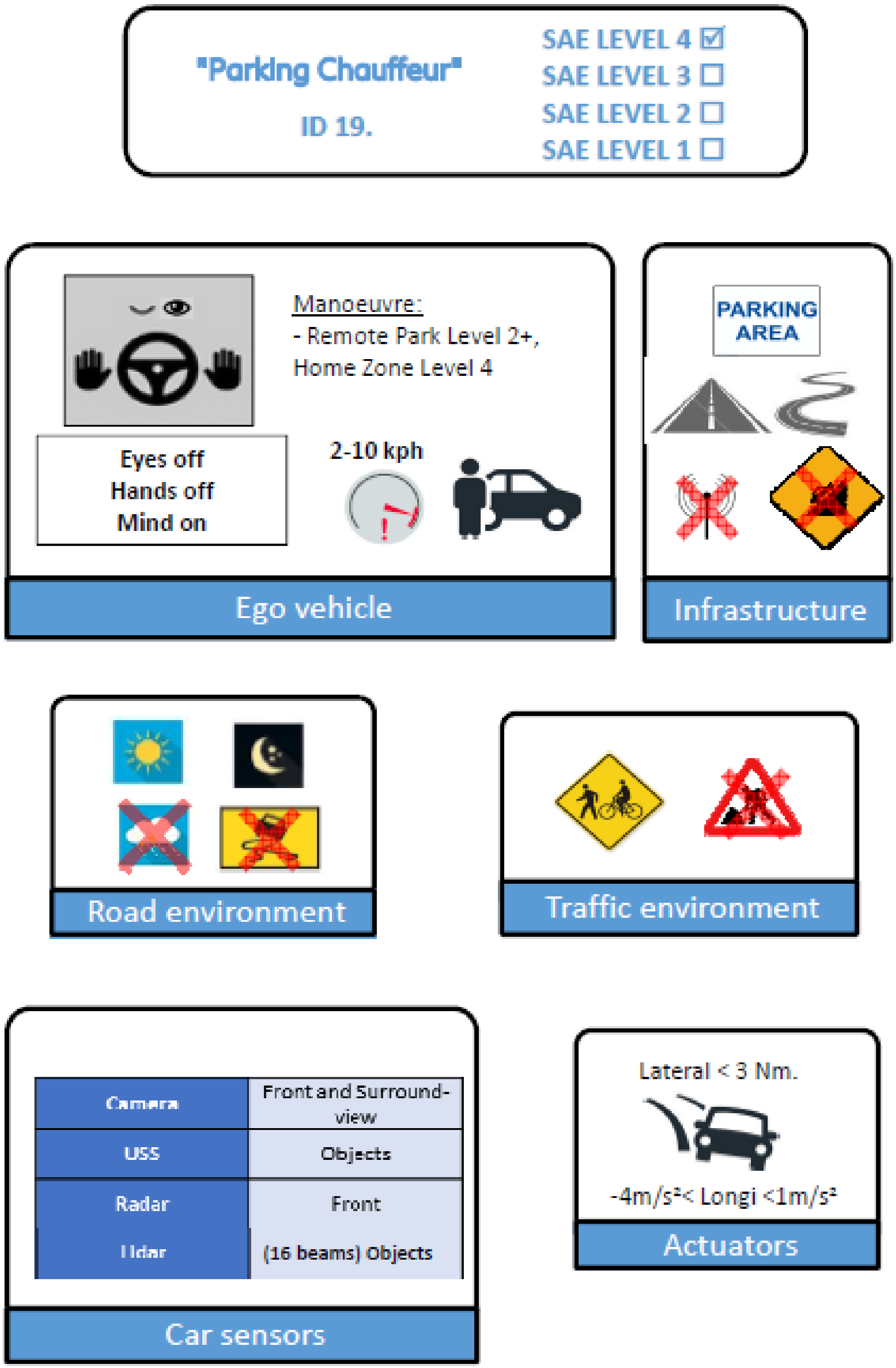
Lateral < 3 Nm.

$-10m/s^2 <$ Longi $<3m/s^2$

Actuators


"Motorway Chauffeur"
ID 17.
SAE LEVEL 4 ☐
SAE LEVEL 3 ☑
SAE LEVEL 2 ☐
SAE LEVEL 1 ☐
Manoeuvre:
- Lane following
- lane change
Eyes off
Hands off
Mind on
0-130 kph
Ego vehicle
Infrastructure
Road environment
Traffic environment
Camera
Front
Steering
Steering wheel sensors
Radar
Front - Rear
Car sensors
Lateral < 3 Nm.
-7m/s²< Longi <1.5m/s²
Actuators


"Traffic Jam Chauffeur"
ID 18.
SAE LEVEL 4
SAE LEVEL 3
SAE LEVEL 2
SAE LEVEL 1
Manoeuvre:
- Lane following
Eyes off
Hands off
Mind on
0-60 kph
Ego vehicle
Infrastructure
Road environment
Traffic environment
Camera
Front
Steering
Steering wheel sensors
Radar
Front - Rear
Car sensors
Lateral < 3 Nm.
-7m/s²< Longi <1.5m/s²
Actuators



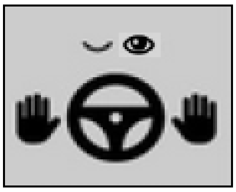
Camera	Front and Surround-view
USS	Objects
Radar	Front
Lidar	(16 beams) Objects

"Motorway Chauffeur"

ID 20.

- SAE LEVEL 4 ☐
- SAE LEVEL 3 ☑
- SAE LEVEL 2 ☐
- SAE LEVEL 1 ☐

Ego vehicle

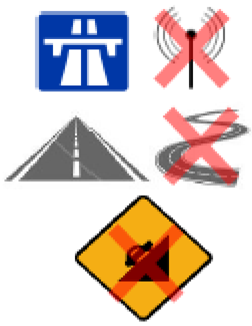


Eyes off
Hands off
Mind on

Manoeuvre:
L4 until 70 kph,
L3 until 130 kph,
- Lane following
- Lane change

0-130 kph

Infrastructure



Road environment

Traffic environment

Car sensors

Camera	Front & Surround-view & driver status
Ultra Sound Sensors	Objects
Eye tracking	Driver monitoring
Radar	Front + surround
Lidar	Front
Steering	Driver monitoring

Actuators

Lateral < 3 Nm.

$-10m/s^2 <$ Longi $< 3m/s^2$

4 Taxonomy of L3Pilot Automated Driving Functions

4.1 Taxonomy Used for General Comprehension and Communication

The different functions tested in L3Pilot differ not only in terms of the specific type of Operational Design Domain (motorway driving, traffic jam driving, urban driving, or parking) but also in the particular implementation (e.g. some functions combine motorway driving and traffic jam driving). In a large project such as L3Pilot the evaluation results for a single vehicle are not reported outside the project, in order to avoid any direct comparison between brands. Therefore, the results for different functions need to be combined and categorized, at the same time ensuring that useful conclusions are still possible. With this aim, a team of partners developed a taxonomy for clustering the results. To make this taxonomy, it was necessary to take into account not only the number of functions in a specific category, but also the data collected and the research questions examined by each test site.

It must be emphasized that all functions will be analysed within L3Pilot. Developing this taxonomy is only a way to ensure that the results can be shared outside the project without presenting the results of individual on-board systems. Therefore, the data collected will be analysed for each function separately and then the results will be combined.

The analysis will consider technical and traffic evaluation as well as users evaluation and acceptance. These two investigations require different approaches, since how drivers experience the system can be quite different from how the function performs. Hence, the way to combine the functions as well as the presentation of results will differ in the two cases. For this reason, two different classifications are chosen, as presented in the following.

Based on the information about the different functions, five different categories can be formed (see Figure 4.1):

- Highway function (HW or HC)
- Highway function combined with Traffic Jam function (HW/TJ)
- Only Traffic Jam (TJ or TJC)
- Parking function (PRK or PC)
- Urban function (URB or UC)

The numbers in the figure indicate how many functions are tested in L3Pilot (e.g. seven combined HW/TJ functions).

Figure 4.1: Distinction in functions and the number of car owners testing that function.

For the technical and traffic evaluation the results of all functions can be presented without needing to be combined. Moreover, if needed, the combined HW/TJ function can be separated based on the speed range (TJ involves speeds lower than 60 km/h). This would lead to a higher number of HW functions and TJ functions (respectively, 9 or 12; see Figure 4.2).

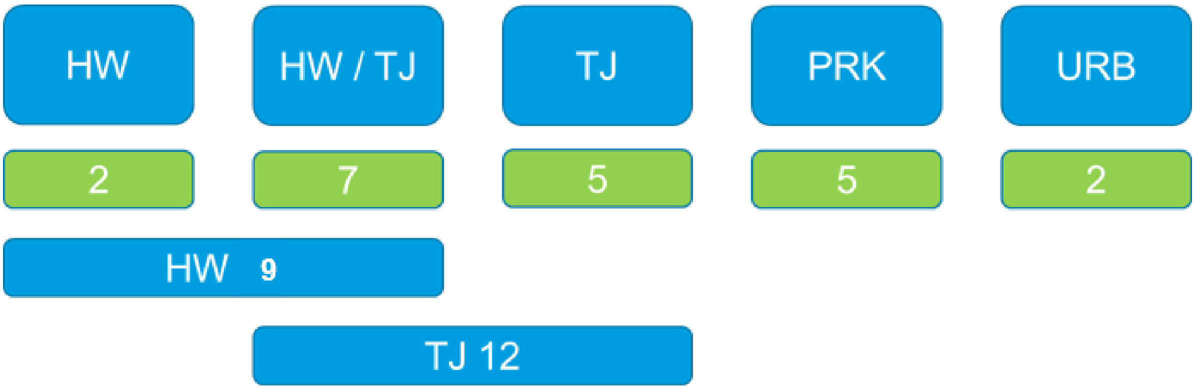


Figure 4.2: The classification and numbers when combining the HW and TJ functions.

For the user evaluation and acceptance, it is highly relevant to consider how the functions operate and what the drivers need to do. Therefore, a distinction was made by considering the following aspects: whether the driver monitors the environment or the car monitors the environment, if the automated system is in control, and if the driver needs to be ready for a take-over. The different functions were grouped in accordance with this approach, as presented in Figure 4.3.

The figure shows that by classifying the functions along these lines there is one function that falls in a single class. There can be two solutions for presenting the results, while avoiding a specific reference to this single case. The first solution is to combine the case with one of the other classes (see the grey areas in Figure 4.3). The result of this solution is presented in Figure 4.4. The second possibility is an option when the deviation of results in two classes is too large for them to be combined. In this case, the results of the single function are not combined and results are therefore not reported outside the project. The corresponding solution is presented in Figure 4.5.

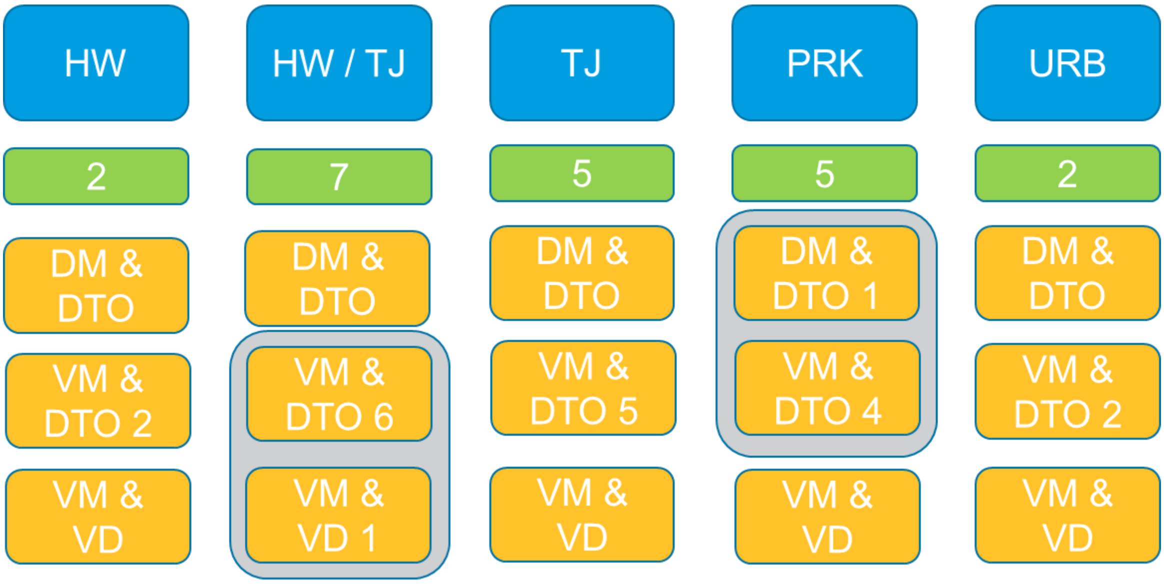


Figure 4.3: The number of different functions across different categories. DM = Driver monitors, DTO = Driver takes over, VM = Vehicle monitors, VD = Vehicle drives.

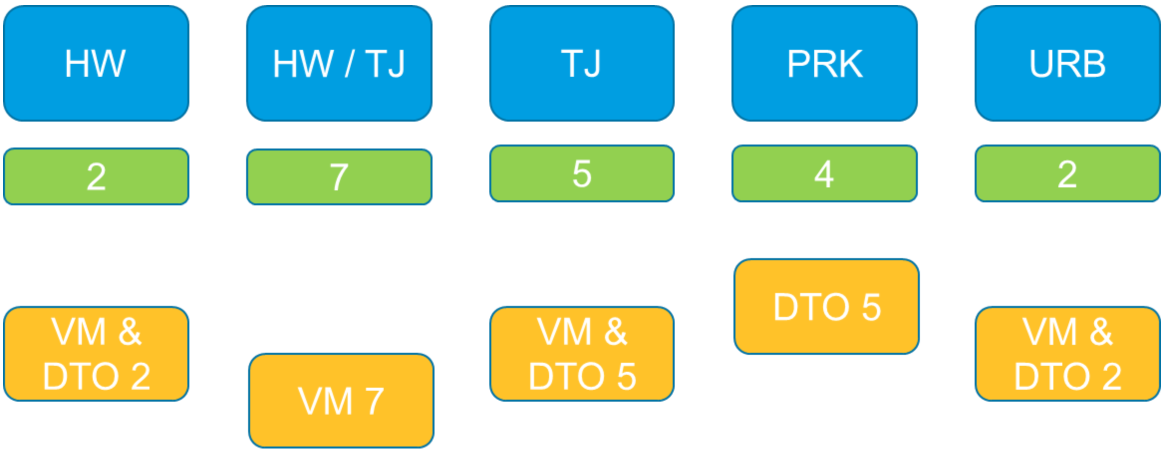


Figure 4.4: The number of different functions across different classes when combining different classes.

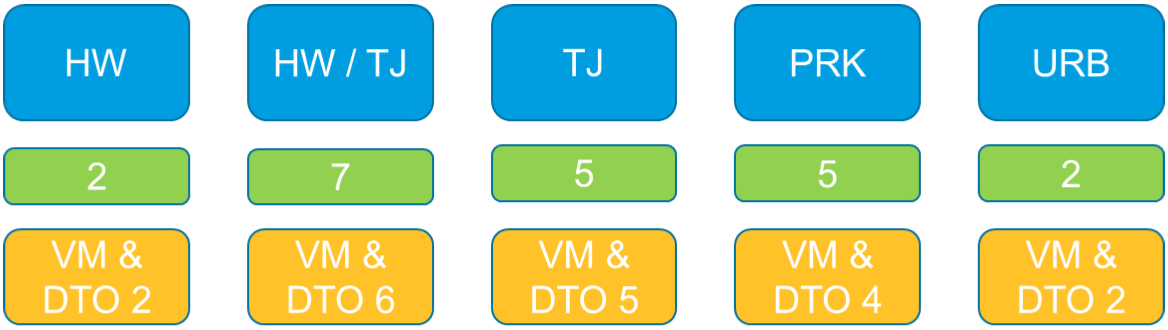


Figure 4.5: The number of different functions across different classes when leaving out classes with only one function.

Both solutions very much resemble the taxonomy chosen for the technical and traffic evaluation. The solution in Figure 4.4 is the same as the classification in Figure 4.1. The same is true for the solution in Figure 4.5 except for the number of functions. For the user evaluation and acceptance, however, it doesn't make much sense to group all HW functions and all TJ functions as is done in Figure 4.2. For a driver this distinction does not really exist since a combined HW/TJ function is experienced as a single system.

The final outcome, i.e. which of the possible taxonomies will be chosen in the end, will strongly depend on how the functions operate during the actual piloting phase.

4.2 Preparatory Work on Taxonomy

This section describes the overall process used to generate a taxonomy from the data obtained on the different L3Pilot functions. Two key aspects have been addressed: outlining the commonalities and differences and facilitating the classification needed for the evaluation phase. For this purpose, the following steps were followed:

a. The L3Pilot functions were split into four high-level classes based only on ODD (Operational Design Domain as defined in SAE J3061)-specific "road environment" and "traffic" attributes, leading to four classes:

- Highway Chauffeur (HC)
- Highway Traffic Jam Chauffeur (HTJC)
- Urban Chauffeur (UC)
- Parking (P) (may be further split into Parking Assistant (PA) and Parking Chauffeur (PC) if SAE level of automation is taken into account).

In addition, for each class we indicated the number of functions, the number of prototypes to be deployed, and a short description based only on speed range, Dynamic Driving Task manoeuvres, and fallback attributes (see Table 4.1).

b. Based on the set of AD function attributes (included in the template in Annex 1) and taking into account the SAE and FESTA guidelines, a small number of attribute clusters were derived and the variations among the functions within each cluster were presented for each high-level class. For this purpose, the descriptions of all the functions were processed in order to discover the attributes that each of the four high-level classes did or did not have in common. As a result, five clusters were defined, which are discussed below (Section 4.2.2). Next, for each of these clusters, tree-like graph diagrams were produced in order to be able to show how ADF attributes vary among the vehicles of the L3Pilot fleet. The results for each high-level class are presented in Section 4.2.2, Figures 4.7–4.14.

If step (a) represents a high-level viewpoint, step (b) goes deeper into details. The two views are independent and, for example, the final evaluation can be based either on the macro-view or on the detailed micro-view. The approach will eventually depend on the granularity of classification needed for clustering the results during the evaluation work.

4.2.1 Step (a): The big picture

Complementary to the information already provided in Section 3 with the visual representation of each L3Pilot function, Table 4.1 below summarizes the main characteristics of the 21 L3Pilot AD functions, split into the four high-level classes.

NB: Table 4.1 presents 20 L3Pilot AD functions that are detailed into 21 for the taxonomy because of ID19, which can be split into Level 4 and Level 2. It describes different possibilities for parking.

We indicate in each class the number of functions implemented by L3Pilot OEMs, the number of prototypes to be deployed, and the main characteristics based on SAE J3061: “ODD speed range”, “DDT manoeuvres”, “Driver monitoring as part of the function”, and “DDT fallback”.

Table 4.1: Overview: AD functions split into four high-level classes and their key characteristics

Class	No. of vehicle owners implementing this function (no. of prototypes)	SAE levels targeted	ODD-specific /Speed range	DDT-specific /Manoeuvre supported by at least two OEMs / not supported by all	Driver monitoring as part of the function (either for ADF conditional activation or for confirming successful give-back)	DDT fallback-specific /Take-over request (AD initiative)
Highway Chauffeur (HC)	9 (41) IDs 1, 3, 4, 6, 10, 12, 15, 17, 20	L3, L4	0 – 100 0 – 110 0 – 130 60 – 130 90 – 120 NOTE: 7 out of 9 IDs also deal with traffic jams (i.e. 0-60kph, presence of front vehicle).	▪ lane following ▪ lane change ▪ emergency braking ▪ obstacle avoidance ▪ management of cut-in vehicles NOTE: Lane change not supported by ID 6.	IDs 1, 12, 15, 20	Always included (on ODD exit or system failure) with one exception. NOTE: Not available for ID 10. ID 10 does not support ADF-specific HMI for the driver.
Highway Traffic Jam (HTJC)	5 (19) IDs 2, 7, 9, 13, 18	L3	0 – 60	▪ lane following ▪ emergency braking ▪ obstacle avoidance NOTE: Functions in this class do not handle lane changes.	IDs 2, 13	Always included (on ODD exit or system failure) with one exception. NOTE 1: ODD exit includes when traffic jam starts to dissipate. NOTE 2: IDs 13, 18 use camera system to derive abstract information regarding driver availability for transition demands.

Class		No. of vehicle owners implementing this function (no. of prototypes)	SAE levels targeted	ODD-specific /Speed range	DDT-specific /Manoeuvre supported by at least two OEMs / not supported by all	Driver monitoring as part of the function (either for ADF conditional activation or for confirming successful give-back)	DDT fallback-specific /Take-over request (AD initiative)
Urban Chauffeur (UC)		2 (4) IDs 11, 16	L3	0 35 0 50	▪ lane following ▪ intersection crossing ▪ obstacle avoidance ▪ lane change ▪ emergency braking NOTE: Traffic lights can be handled only by ID 11.	-- NOTE: ID 11 has driver recordings but no driver monitoring for activating the function.	Always included (on ODD exit or system failure) with one exception. NOTE: Not available for ID 11.
Parking	Parking Assistant – L2 (PA-L2)	1 (1) ID 21	L2+	0 10	Parallel and cross parking incl. back-out manoeuvres (one-shot or multiple) for parking into and out of a parking space. (The manoeuvre can be managed remotely by smartphone.)	--	-- (driver outside)
	Parking Chauffeur – L4 (PC-L4)	4 (15 max.) ID 5, 8, 14, 19	L4	0 1 0 10 2 10	▪ path learning ▪ learned path re-execute	--	-- (driver outside)

Other attributes to be taken into account during the evaluation of the system and user assessment are indicated here:

- Non-motorized participants are taken into account without exception only in Parking use cases. For the other classes, the analysis will partially address non-motorized road users in class HC (IDs 1, 3, 12, 20), in class UC (ID 11), and in class HTJC (ID 2).
- According to the HMI descriptions provided, only a few OEMs can visualize the object information acquired by on-board sensors in their specific HMI (an example is ID 16, which visualizes predicted trajectories of VRUs). This circumstance could be of importance when evaluating the perception of the take-over requests by the driver and the understanding of the AD function in general.
- A driver might be outside the vehicle in Parking use cases, when controlling the manoeuvre by means of a remote device.

4.2.2 Step (b): Zooming in

4.2.2.1 Grouping of attributes

The scheme for clustering the different attributes is primarily based on the information regarding the following topics: "Function", "Context", "Give-back" and "Vehicle'' (see Annex 1). Attributes that were identified as varying among all the AD functions have been clustered into two groups based on SAE J3016 and additional general considerations. These are Group A (Function) regarding the operational characteristics of the function and its evaluation and Group B (Context) regarding the application domain. The two groups and their sub-groups are summarized below:

Group "A": Function

This cluster considers attributes related to the driver's involvement in/during function activation and more generally to the transfer of control from the system to the driver. It also includes attributes related to the function's evaluation. See definition of the sub-group categories A1, A2, and A3 in Table 4.2.

Group "B": Context

In this second cluster, the attributes are related to the operating context, separating static and dynamic conditions. This differentiation of the Operational Design Domain is considered useful for the implementation and evaluation of an AD function, since the driver will have different behaviours while understanding the operational boundaries. See definition of the sub-group categories B1 and B2 in Table 4.4.

Links of the proposed categorization approaches with the SAE definitions and FESTA guidelines are indicated in Table 4.3 and Table 4.23 respectively.

Table 4.2: Sub-groups of the "Function" group and their associated list of attributes, based on the template of Annex 1.

Group A ("Function") Sub-Cluster ID	Title	Description	Associated list of attributes
A1	**Driver and Dynamic Driving Task (DDT) fallback**	Attributes related to the driver's involvement in/during function activation and to the transfer of control to the driver, described as "Give-back" in SP4 AD function description template.	• Driver monitoring is needed • AD function is system-initiated (as opposed to driver-initiated) • Side activities are allowed • Give-back (system-initiated) available • System failure is treated differently from scenario ending • Conditional activation of ADF based on driver status • Driver can choose automation level • Parameter X_i can be set by the driver
A2	**DDT by function**	Attributes related to the dynamic driving tasks performed by the AD function (without involving the driver)	• Lane following • Lane change • Intersection crossing • Emergency braking • Obstacle avoidance (example: swerving) • Reversing • Exit/Insertion lane • Management of cut-in vehicles
A3	**Evaluation specific**	Attributes related with the AD function-evaluation process (not necessarily present during actual ADF deployment)	• Professional drivers only • Driver can annotate events • Driver status is recorded

Table 4.3: Relation of A1, A2, A3 (as defined in Table 4.2) with SAE and FESTA

ID	Relevance to SAE J3016	Relevance to FESTA
A1	ODD related with the driver and DDT (Dynamic Driving Task) fallback. NOTE: As also discussed in [4], L3Pilot will also assume that if driver fails to respond to a system-initiated Give-back request (and resume control of the vehicle), the ADF may perform DDT fallback in order to restore the vehicle to a minimal risk condition as described in SAE J3016 2014 but not in SAE J3016 2016.	**Interaction with the user (incidents/conflicts)**: Some support systems require/enable the driver to activate/deactivate the system, to override the system, to select one system among other systems available, to select or to register certain vehicle-following or speed thresholds, and so on. In other words, using a system implies the application of a number of procedures, and these procedures should be registered and analysed. These procedures may be classified as the driver's direct or indirect interventions, depending on whether they are applied through vehicle controls (brake or accelerator) or through system controls.
A2	Part of DDT (Dynamic Driving Task). In (SAE 2016), dynamic driving task (DDT) is defined as a collection of the following five subtasks: (1) lateral vehicle motion control, (2) longitudinal vehicle motion control, (3) monitoring the driving environment via object and event detection, recognition, classification, and response preparation, (4) object and event response execution, (5) manoeuvre planning, and (6) enhancing conspicuity via lighting and gesturing, etc., in which (3) and (4) are referred to as object and event detection and response (OEDR).	**Manoeuvres as a type of event initiated by the system, when analysing driving data:** Event-based analysis is a popular way of segmenting driving data during evaluation (depending on the study, sections of time can be assigned categories such as "crash", "near-crash", "incident", "curve speed warning", "lane change", "crash avoidance by steering", etc.). An incident may also be a conflict created by the system. **Operationalization:** Changes in log profile should be annotated (e.g. free driving vs. performance of a manoeuvre for testing a function, which might require a denser logging of available data).
A3	**--**	Audio/video annotations from the driver are advisable. Video processing is time-consuming (in vehicle cameras/head/eye tracker) – better to have an automated process specified from the beginning.

Table 4.4: Sub-groups of the "Context" group and their associated list of attributes, based on the template of Annex 1.

Group B ("Context") Sub-Cluster ID	Title	Description	Associated list of attributes
B1	**Functions' Static ODD**	Attributes related with the set of environmental and roadway conditions with a fixed location and/or those that can be anticipated from knowledge of a particular route (e.g. entrance/exits to highways)	• Prior map info is required • Max. speed supported is over x kph • Curved and/or steep road geometry is supported • Slippery and/or bumpy road geometry is supported • Day or night conditions supported • Adverse weather conditions (rain, fog, and/or snow) are supported • Special infrastructure is compatible with the function
B2	**Functions' Dynamic ODD**	Attributes related with the set of environmental and roadway conditions that require on-board sensing to detect changes in state relative to vehicle position at a second-to-minute rate (e.g. lane marker visibility, presence of a leading vehicle, roadway curvature, etc.)	• Non-motorized traffic participants taken into account • Traffic flow condition is constrained • Reduced visibility due to infrastructure/other vehicles is handled • V2X coordination is part of the function ODD • Dynamic adaptation to road scenario is supported (infrastructure change detection such as traffic light or missing lane marker or construction zone presence, lane/road ending, snow on road surface)

Table 4.5: Relation of B1 and B2 (as defined in Table 4.4) with SAE and FESTA

ID	Relevance to SAE J3016	Relevance to FESTA
B1	An Operational Design Domain (ODD) refers to the **specific conditions under which** a given self-driving system or feature thereof **is designed to** function, including, but not limited to, driving modes.	**Situational descriptors:** These characterize a given situation as the combination of several situational variables.
B2	This sub-category focus on adaptation to dynamic changes in the vehicle's environment and also includes the detection of other traffic participants. Per SAE J3016 ADF Object and Event Detection should be described separately.	Functional description should also include limitations, boundary conditions, and additional information that is necessary to understand how the function works (e.g. factors external to the system being evaluated). Logging of situational variables: data of surroundings are needed. Effects of the system on the non-user (incl. vulnerable road users)

4.2.2.2 Data visual representation via classification tree graphs

Notation

In order to visualize the rich presentation of AD functions offered by the SP4 template, tree-like graphical representations have been produced.

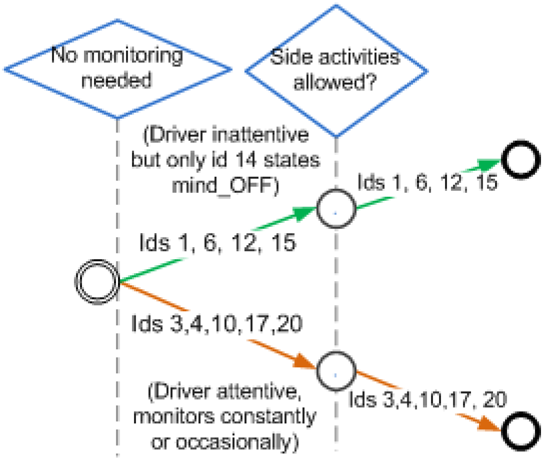


Figure 4.6: Graph extract showing how AD functions are split.

For example, the graph in Figure 4.6 shows how AD functions belonging to the “Highway Chauffeur” class (IDs 1, 3, 4, 6, 12, 15, 17, and 20) are grouped considering two of the attributes of cluster A1: the attributes are “No monitoring needed” and “Side activities allowed” (and are depicted as rhombus boxes). The figure shows how a tree-like graph with two branches is formed based on the (non-)support of each L3Pilot function of these two attributes; the result being that based on these two attributes we can cluster the L3Pilot functions into two groups:. i.e. IDs 1, 6, 12, and 15 form one group while IDs 3, 4, 10, 17, and 20 form another group.

The general hierarchical visual representation scheme is produced by following these steps:

- Each high-level class is described by a tree of five branches, each branch hosting information about one of the five sub-groups defined above, namely A1, A2, A3, B1, and B2.
- Each branch includes a set of attributes depicted as rhombus boxes.
- Under each rhombus, a tree node is placed to show how the L3Pilot functions are grouped according to the attribute defined inside the rhombus. If the attribute is of a binary nature (AD function supporting/not supporting the attribute) a green arrow from the node and upwards denotes a positive statement (AD function supports the attribute). An orange arrow from the node and downwards denotes a negative statement (AD function does not support the attribute). If the attribute involves multiple choices then different green arrows represent each choice. Tree-like graphs follow the formulation, described as follows:

- Each new graph begins with a starting *attribute node* (denoted with ◎) and ends with an *ending node* (denoted with **O**). Based on whether or not there is a group of L3Pilot functions that support multiple attributes, each starting node in the graph can be followed by another attribute node (the connected graph formation creates groupings of functions based on multiple attributes), denoted with ○, or an ending node (single attribute-based grouping).
- Above each *graph edge* (arrow) connecting two nodes, information about the set of AD functions (IDs) assigned to the attribute associated with the starting node is presented.

In the case of multiple independent graphs forming a connected sequence, the graph reveals the similarities among the involved AD function IDs (for example, in Figure 4.6 IDs 1, 6, 12, and 15 form one cluster while IDs 3, 4, 10, 17, and 20 form another cluster).

Visual graph analysis per class

- The overall results in graphical form for each high-level class are shown in the following figures (Figure 4.7 to Figure 4.14). For better readability two figures per high-level class are produced, one showing the results of grouping L3Pilot functions based on attributes of group A and one showing results based on attributes of group B.

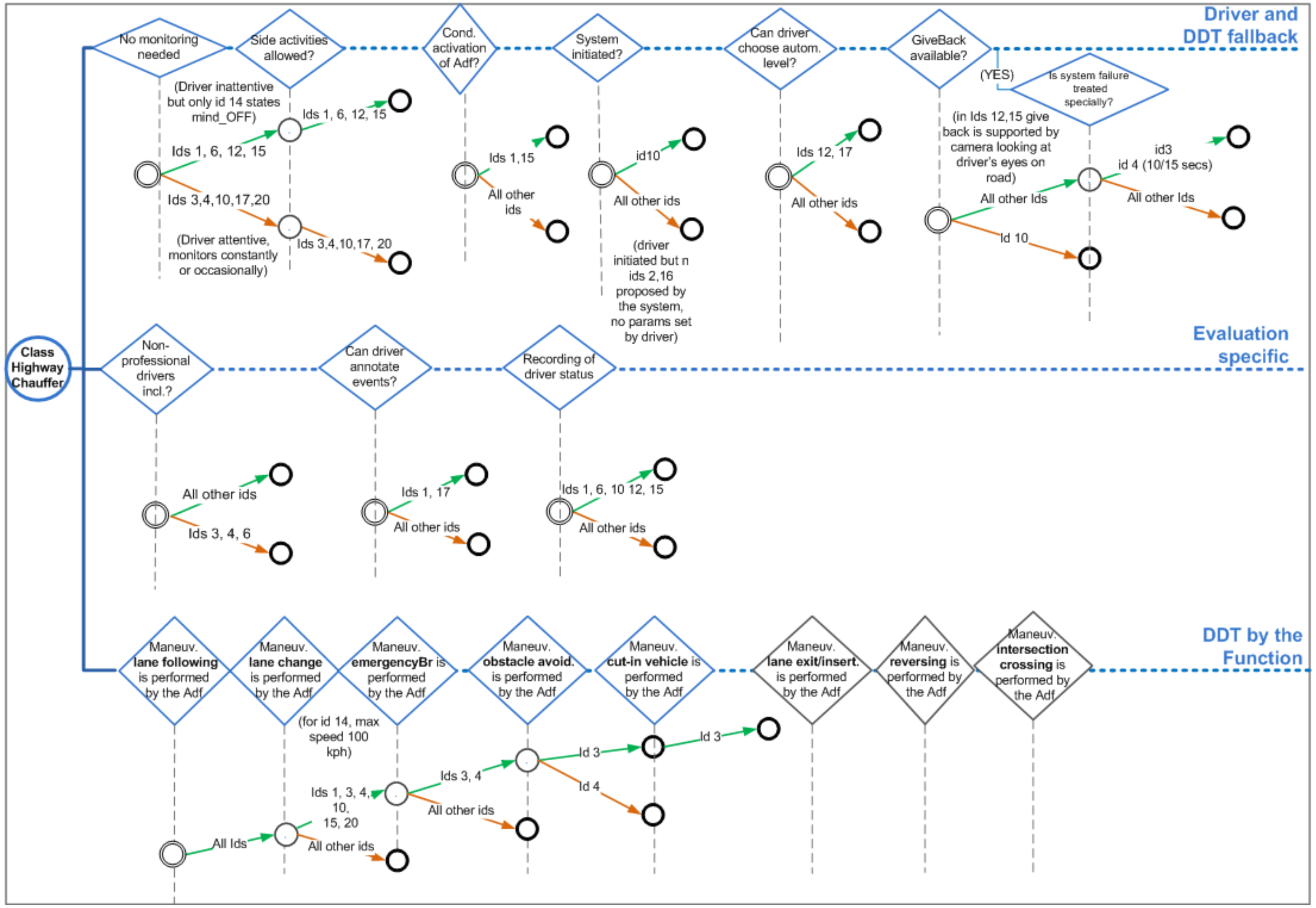


Figure 4.7: Class Highway Chauffeur (L3Pilot functions grouped per attributes belonging in A1, A2, A3).

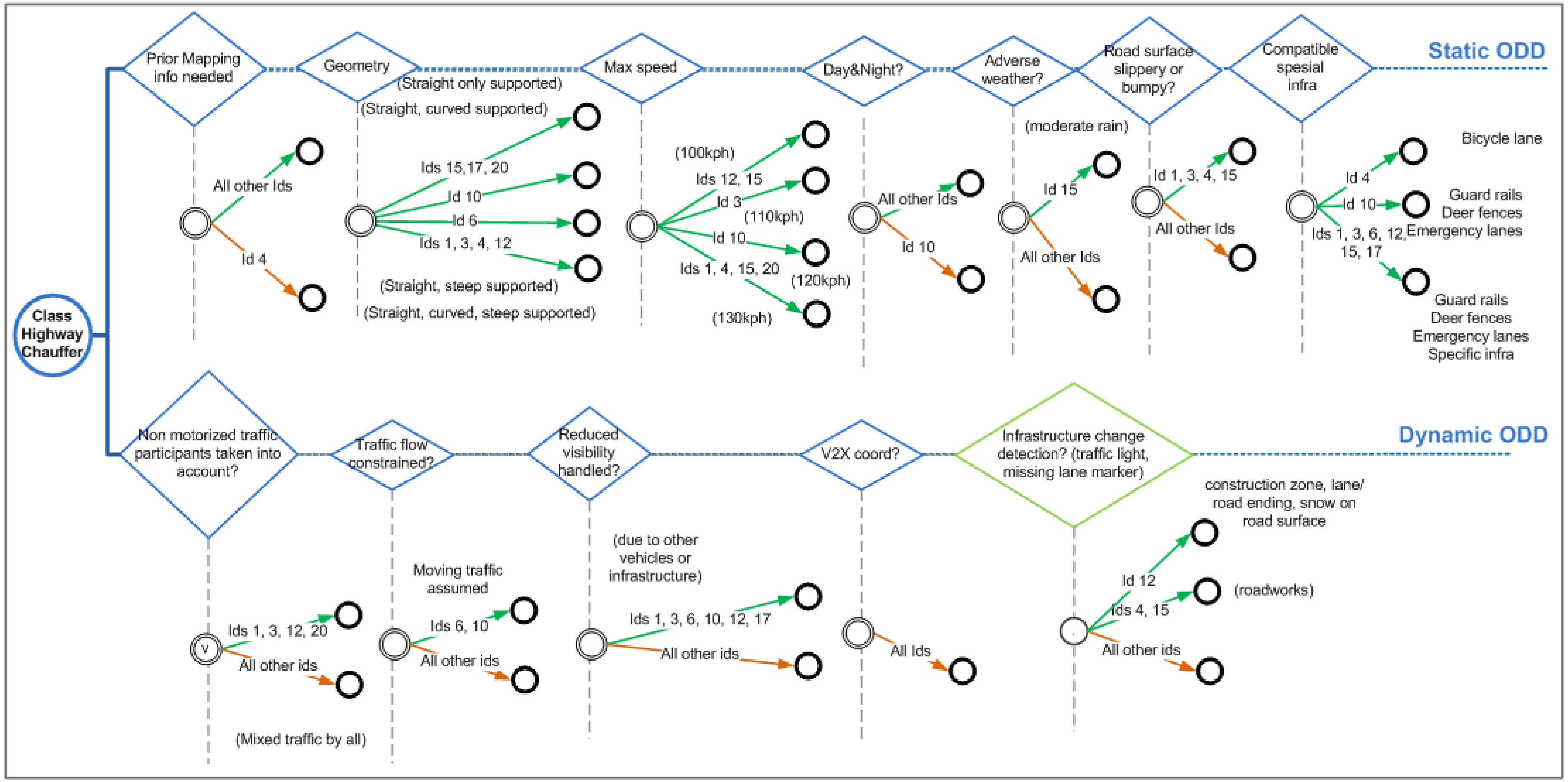


Figure 4.8: Class Highway Chauffeur (L3Pilot functions grouped per attributes belonging in B1, B2).

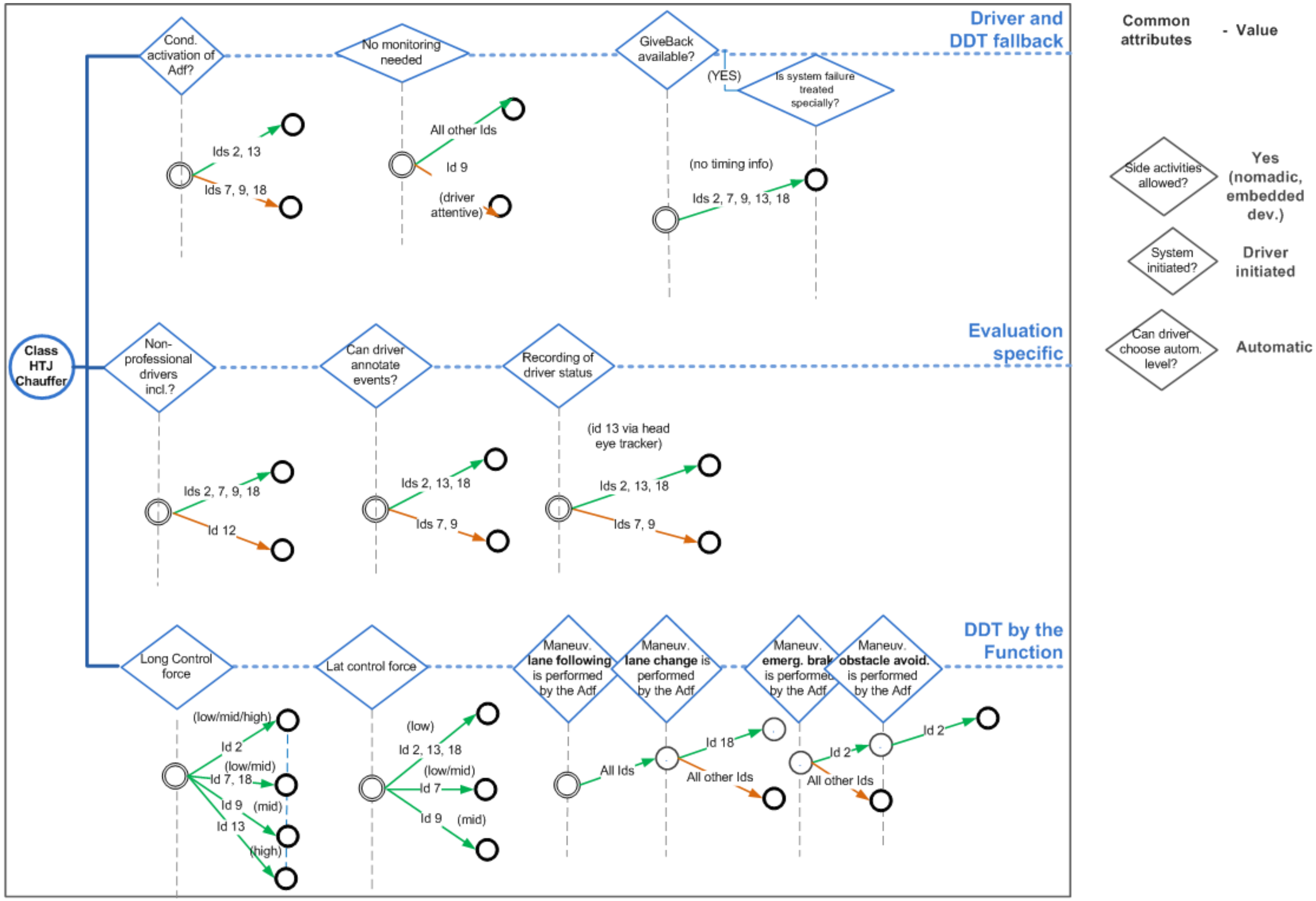


Figure 4.9: Class HTJC (L3Pilot functions grouped per attributes belonging in A1, A2, A3).

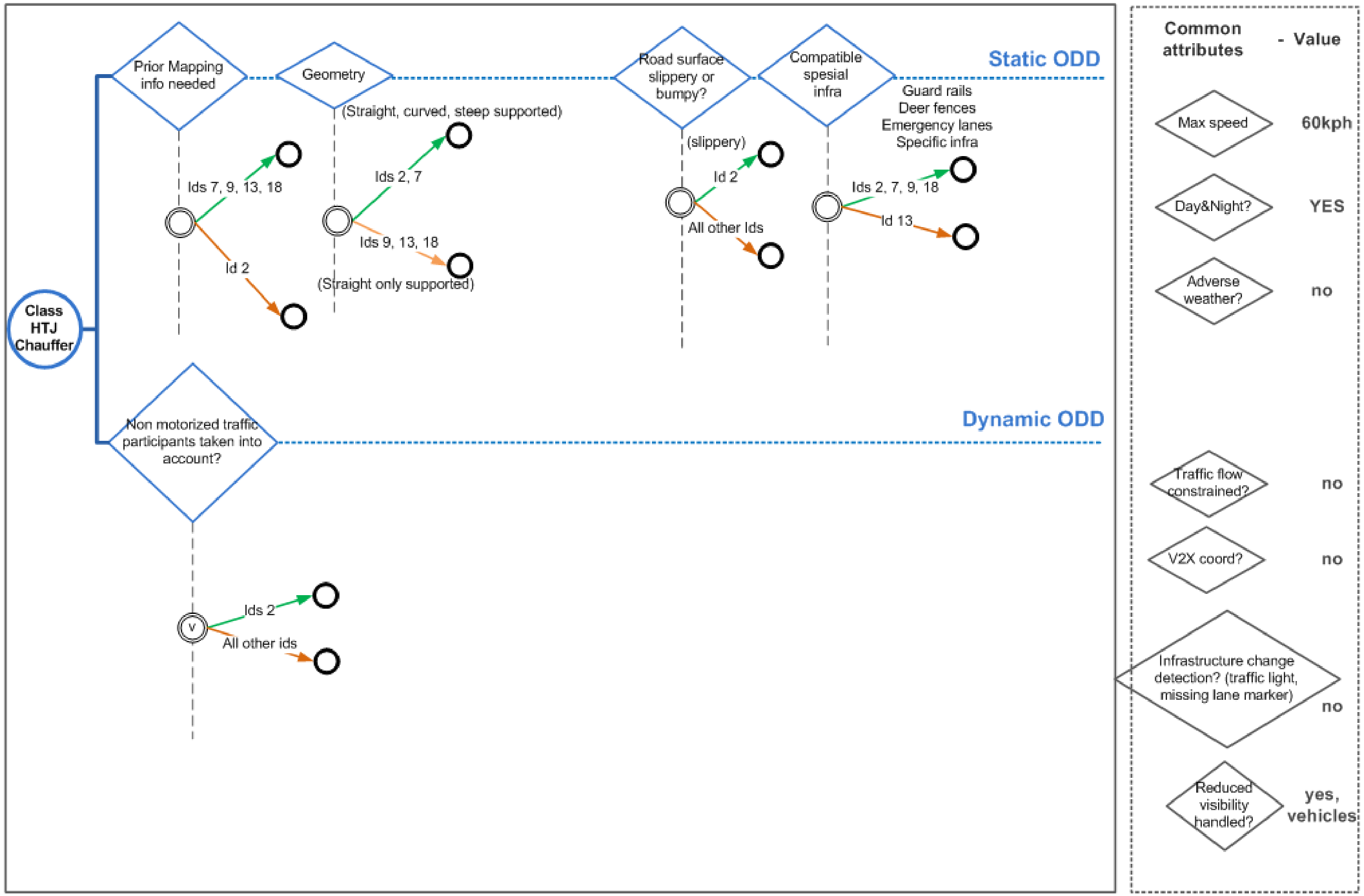


Figure 4.10: Class HTJC (L3Pilot functions grouped per attributes belonging in B1, B2).

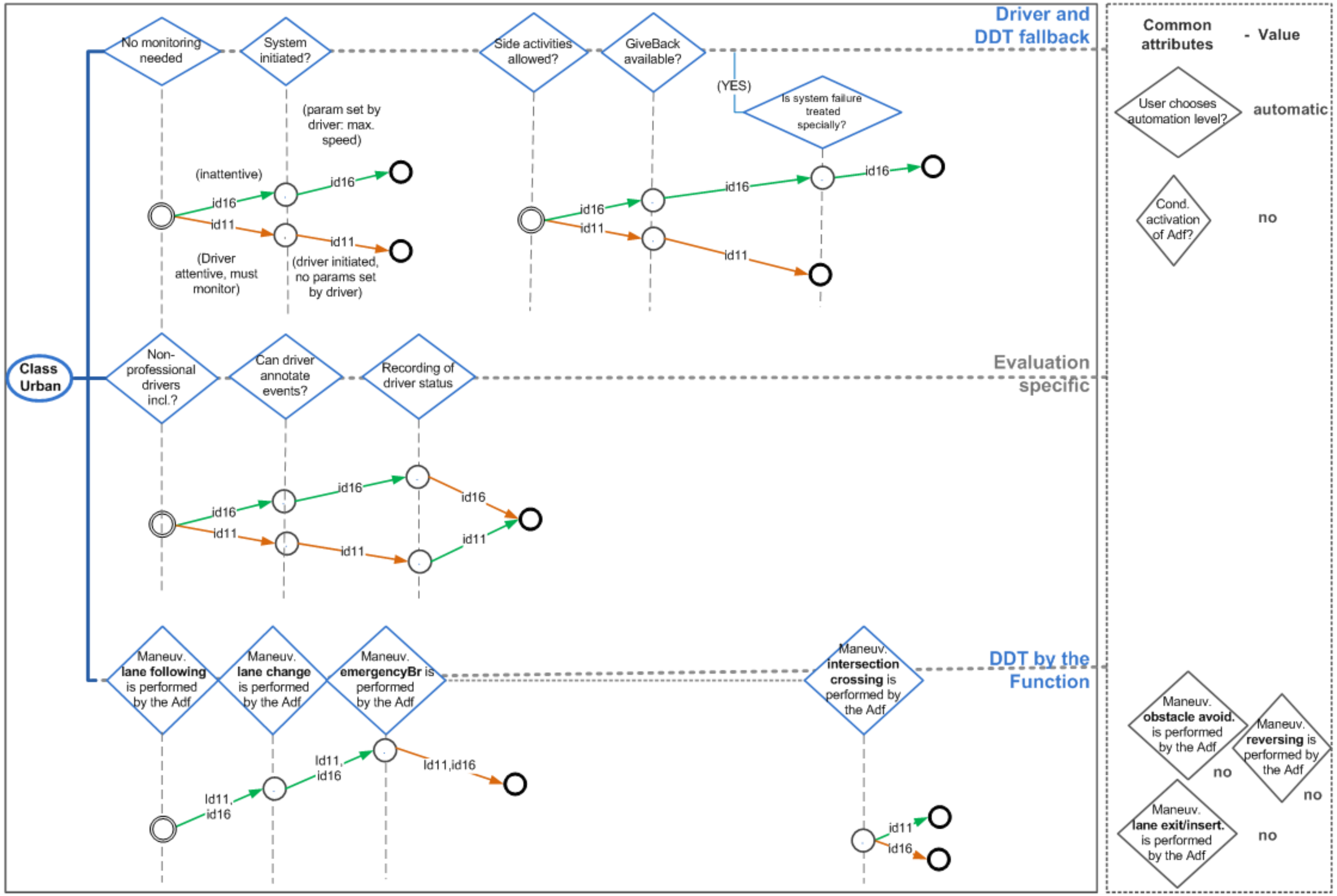


Figure 4.11: Class Urban (L3Pilot functions grouped per attributes belonging in A1, A2, A3).

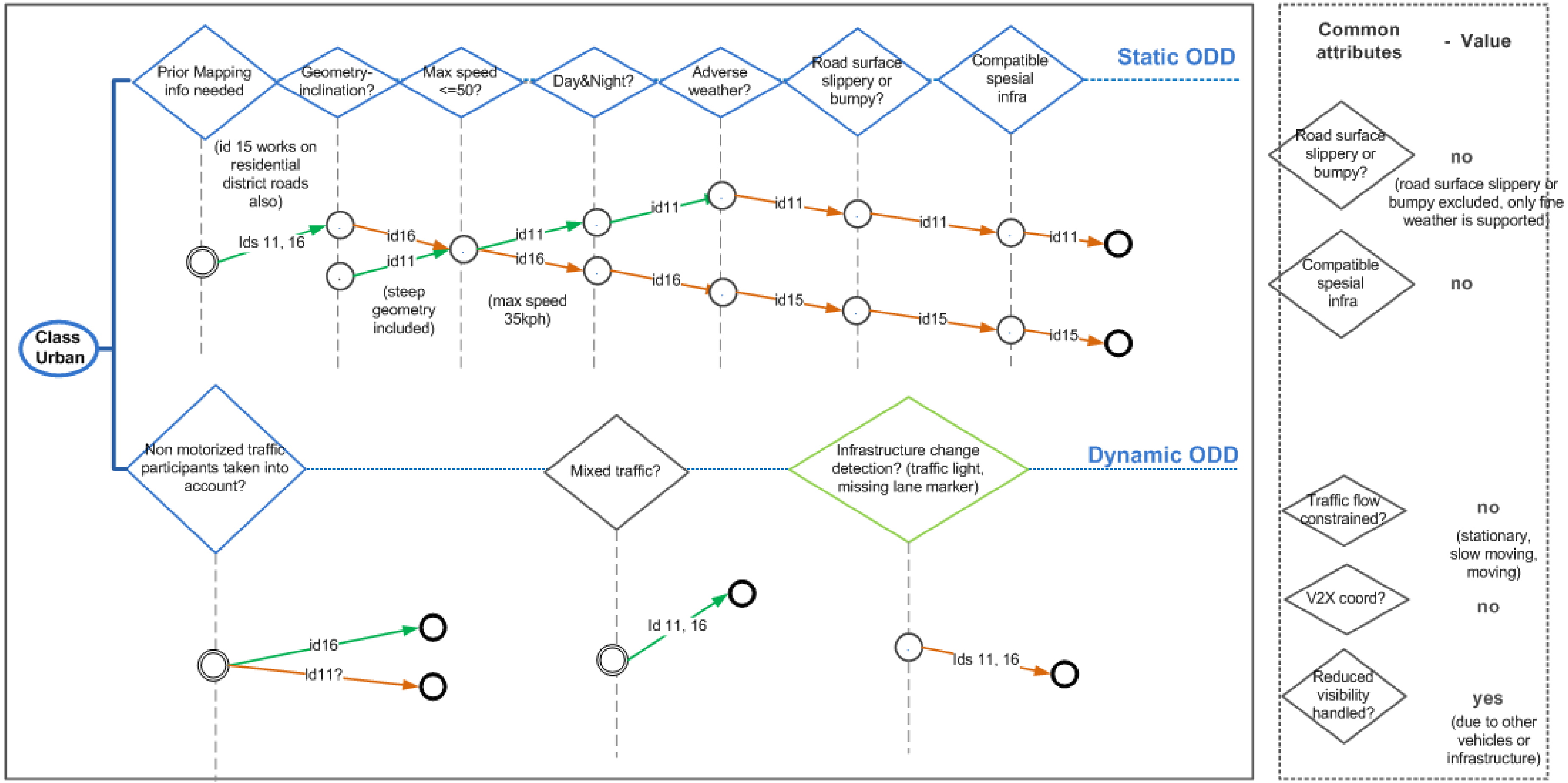


Figure 4.12: Class Urban (L3Pilot functions grouped per attributes belonging in B1, B2).

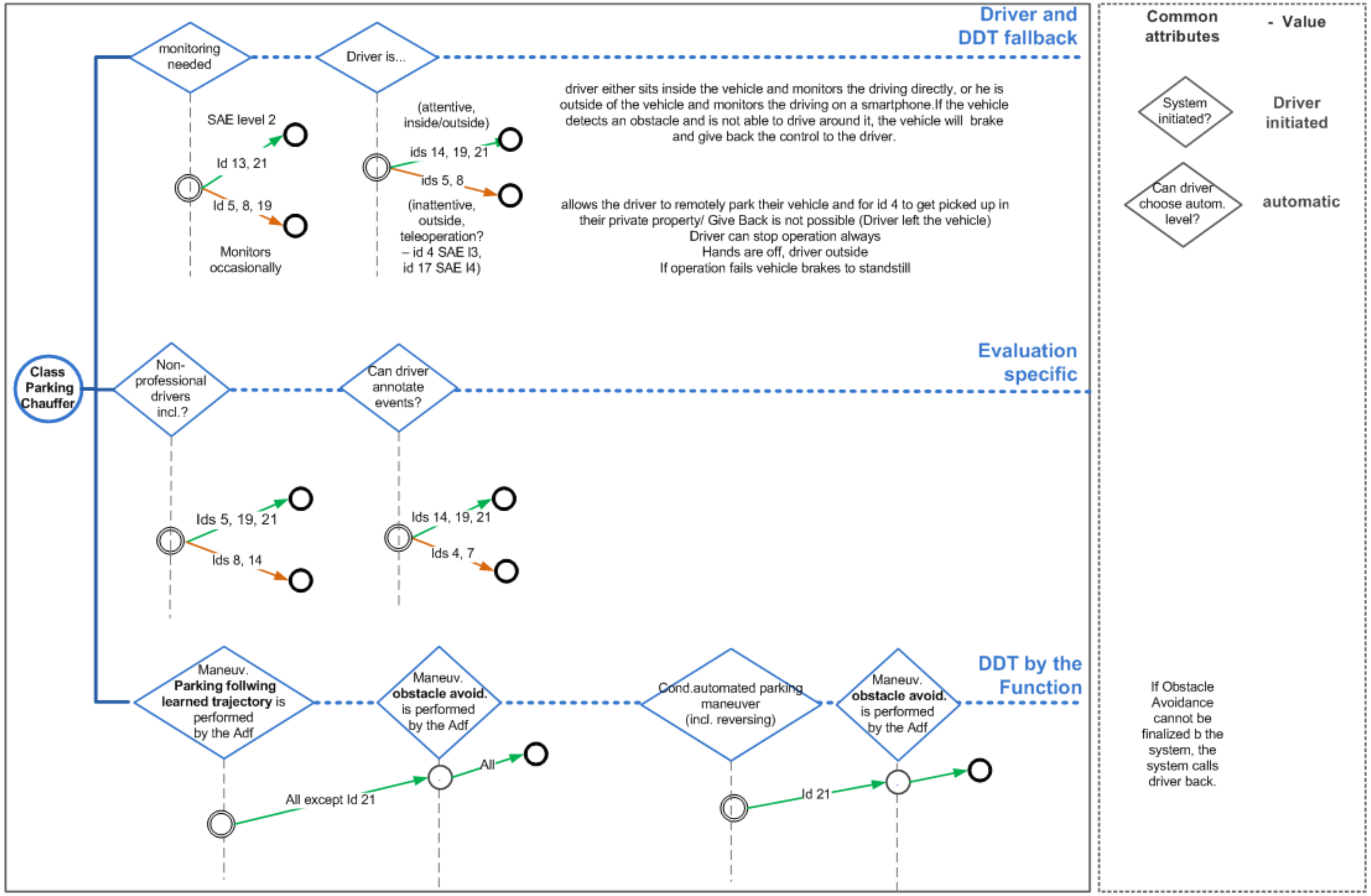


Figure 4.13: Class Parking (L3Pilot functions grouped per attributes belonging in A1, A2, A3).

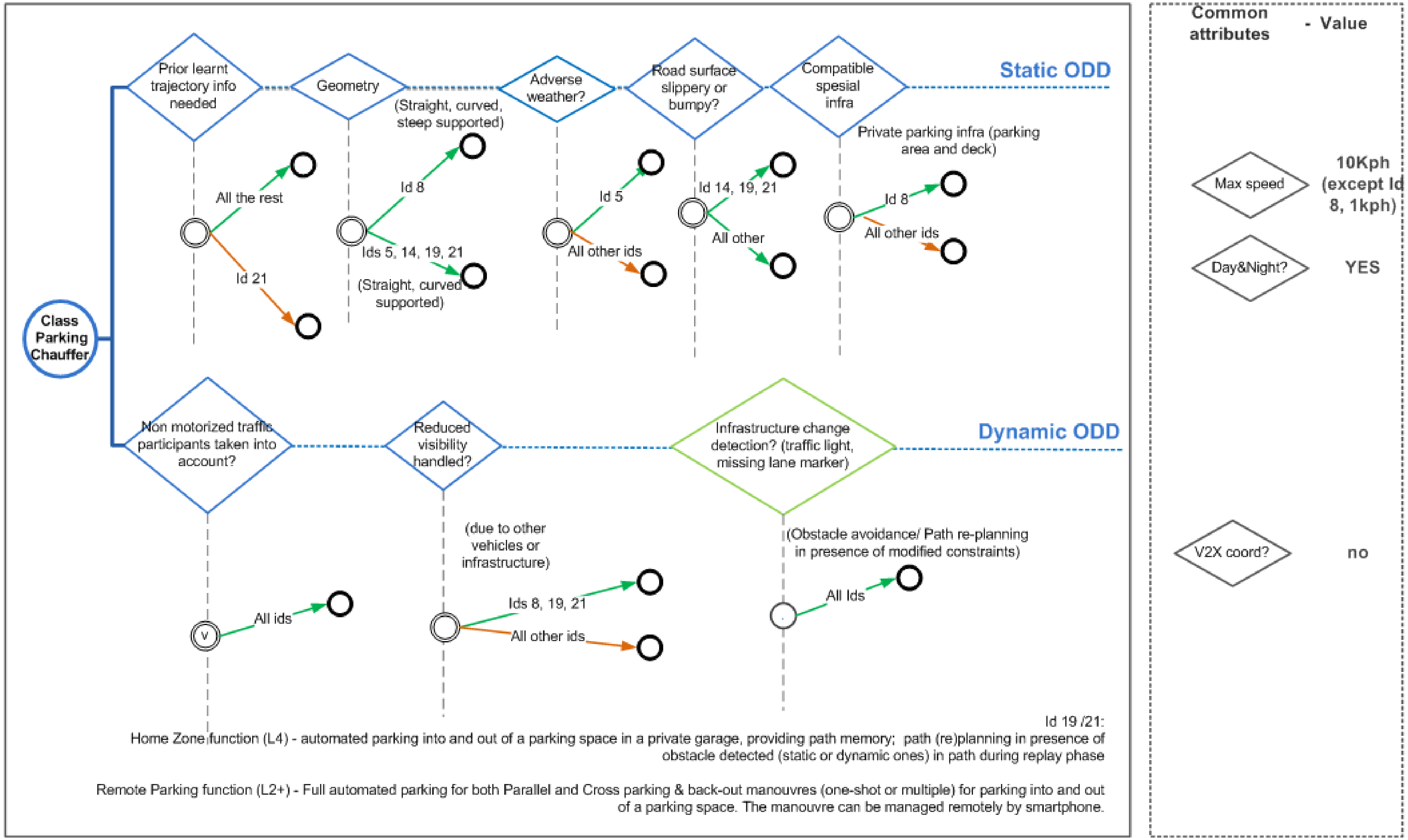


Figure 4.14: Class Parking (L3Pilot functions grouped per attributes belonging in B1, B2).

5 Conclusion

This deliverable provides a detailed description of the Automated Driving functions to be tested in L3Pilot vehicles. The description is complemented by a taxonomy organizing these functions into classes and designed with the aim of simplifying the final evaluation.

In order to define all the particular functions developed by different car companies, a specific template was prepared with a questionnaire administered to all vehicle owners. This made it possible to obtain an overall coherent picture for the applications in the project, avoiding references to the specific features and terminology that might characterize a brand.

The general specification of the functions was additionally deployed into a visual catalogue, intended to show commonalities and differences using an intuitive graphical approach based on icons and annotations.

As a result of the analysis leading to the taxonomy, five high-level classes were derived for the functions, based on the respective operational domains, in particular the road type (highway, urban) and traffic characteristics. These categories were further divided into subclasses by considering driver/vehicle activities such as secondary (non-driving) tasks, driver status, and take-over interventions.

The methodology here described with the template, the catalogue of functions, the visuals, and the taxonomy, is believed to support the subsequent phases dedicated to piloting and evaluation, since it clarifies the basic concepts, indicates the key details to be addressed, and allows a common representation (and language) when appropriate. Moreover, the evaluation phase will be simplified by the aggregation of functions into classes and by the possibility of avoiding references to a single implementation. The methodology was designed with flexibility in mind, so that it constitutes a basis for other future pilot tests, even in different scenarios. This flexibility is particularly relevant when considering the expected rapid evolution of Automated Driving technologies and the accompanying testing methods.

References

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List of Abbreviations and Acronyms

Abbreviation	Meaning
AD	Automated Driving
ADAS	Advanced Driver Assistance Systems
ADF	Automated Driving function
AV	Automated Vehicle
DDT	Dynamic Driving Task
HC or HW	Highway Chauffeur
HTJC	Highway Traffic Jam Chauffeur
ODD	Operational Design Domain
OEM	Original Equipment Manufacturer
PC or PRK	Parking Chauffeur
TJC or TJ	Traffic Jam Chauffeur
UC or URB	Urban Chauffeur
V2X / V2V / V2I	Vehicle to Everything / V. to Vehicle / V. to Infrastructure

Annex 1: Function Description Template

Click to open the attached file in Excel