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System Classification and Glossary

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AdaptIVe

Automated Driving Applications and Technologies for Intelligent Vehicles

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1.0	24.11.2014	Final version for review
1.1	30.01.2015	Final version
1.2	06.02.2015	Final version with language proofing

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1 Summary

This deliverable presents the systematic approach for the classification of automated driving and parking functionalities, as well as the glossary in the field of highly and fully automated driving functions.

For classification all categories, parameters and permitted parameter-values that are relevant for a classification of automated driving and parking functions with respect to an evaluation regarding legal, human factors and functional safety aspects are systematically collected in chapter 4. For this purpose, three main categories have been identified, namely “vehicle”, “driver” and “environment” have been identified and broken down into 10 parameters with 28 permitted parameter-values for “vehicle”, 5 parameters with 15 permitted parameter-values for “driver” and 11 parameters with 37 permitted parameter-values for “environment”.

Following this, unnecessary and redundant parameters were identified and eliminated, resulting in a set of 10 relevant parameters with 45 permitted parameter-values.

Subsequently, this parameter set was evaluated by SP2 WP23 “Safety Validation” regarding functional safety aspects; by SP2 WP24 “Legal Aspect” concerning legal aspects, and by SP3 WP33 “Use Case Design” concerning human factors aspects. As a result the number of relevant parameters could be reduced to 9.

Applying this parameter set to the automated driving and parking functions of SP4, SP5 and SP6 as well as the exemplary functions described in Annex 2, it could be verified, that ultimately 4 parameters must be considered in the combinatorics for class formation, namely vehicle automation level, vehicle maneuver duration, vehicle maneuver velocity and road type, resulting in a set of 33 functional classes. An extension of those classes – e.g. if new automated driving and parking functions will be designed in the future – is easily achievable and straight forward.

By this means, a systematic approach for an unambiguous classification of automated driving and parking functionalities has been provided, thus completing and exceeding existing functional definitions.

Relevant literature in the field of automated driving has been reviewed for the setup of a shared glossary concerning highly and fully automated driving functions. Existing definition of terms was extracted and summarized in a table. This initial glossary was shared on the project server and subsequently was reviewed and completed by project partners in the course of the project, resulting in a consolidated glossary for the AdaptIVe project. Definition of terms related to automated driving and parking are given in detail in Annex 4, taking into account definitions from BASt (German Federal Highway Research Institute) [1], SAE (SAE International, formerly the Society of Automotive Engineers (USA)) [2], NHTSA (National Highway Traffic Safety Administration) [3] and VDA (Association of Vehicle Manufacturers) [4].

Exemplary automated driving and parking functions for different automation levels are given in Annex 2.

2 Motivation

Automated driving and parking functions have been the focus of many nationally and internationally funded projects. Some of those projects have already addressed functional classification; e.g. the EU funded project HAVEit proposed a classification of different automation levels. Based on this, the definition of an automation spectrum has been aligned in the German nationally funded project “Legal Consequences of an Increase in Vehicle Automation” led by BASt. NHTSA, SAE and VDA proposed their own definitions of automation levels based on the BASt definition. Definitions by BASt, SAE and VDA have a common understanding yet, merely address different parties: BASt → legislation, VDA → politics, SAE → broader “Automated Vehicle” community (details see Annex 1). SAE definitions have been adopted by the AdaptIVe project and will be used in the following.

However, the level of automation is only one parameter which is relevant for the classification of automated driving and parking functions. Other parameters such as vehicle velocity, maneuver duration (short, long), road type (parking place, urban or rural road, motorway), driver location (in the vehicle, outside of the vehicle) and many others possibly must be taken into account. The challenge was to collect and to consider all relevant parameters without blowing up the number of classes to a vast size.

The results were harmonized within the consortium considering the needs of different OEM’s and suppliers. So there is a high probability, that this classification might provide a basis for future working groups dealing with standardization, creating new ISO (International Organization for Standardization) or ECE (Economic Commission for Europe) standards for the classification of automated driving and parking functionalities.

A side benefit will be a shared glossary in the field of highly and fully automated driving functions. This glossary shall be agreed to by public, scientific and industry project partners. Starting point are the results of former projects.

As a result relevant parameters and classes for the evaluation of legal, human factors and functional safety aspects regarding automated driving and parking functions are provided for the work in SP2 WP23 “Safety Validation”, SP2 WP24 “Legal Aspect” and SP3 WP33 “Use Case Design”. Furthermore this approach is evaluated by SP 4-6 regarding functionalities to be developed in these vertical subprojects.

3 Objective

The main objectives of this deliverable are an unambiguous classification of automated driving and parking functions as well as a shared glossary defining terms with regard to automated driving and parking.

For this purpose

- A classification scheme is established (see sections 4.1 to 4.4)
- The classification scheme is assessed regarding:
  - Legal aspects (see section 4.5.1)
  - Human factors aspects (see section 4.5.2)
  - Functional safety aspects (see section 4.5.3)
- Unnecessary classes are eliminated (see sections 4.6 and 4.7)
- Exemplary functions are defined (see Annex 2)
- The classification scheme is applied to those exemplary functions (see Annex 3)
- A shared glossary on the project server is established and assessed by the project members (see Annex 4)

4 Classification of Automated Driving and Parking Functions

In the following section an approach for the classification of automated driving and parking functions is explained and implemented.

4.1 Introduction

When designing a classification scheme for automated driving and parking functions, which functions are addressed by this classification scheme and which functions are excluded must be defined beforehand. For this purpose, Gasser [5] from BASt defined three basic operation mechanisms for vehicle functions (see Table 4.1).

Table 4.1: Three operation mechanisms for vehicle functions (table obtained from [5])

Operation type A: Informing and warning functions	*Operation type B:* Continuously automating functions	*Operation type C:* Intervening emergency functions (near-accident situations)
Take only indirect influence on vehicle control via the driver	Take immediate control over the vehicle. Division of tasks between the human driver and the function (usually convenience functions - control always remains overrideable)	Take immediate control over the vehicle in near-accident situations that de facto cannot be controlled/ handled by the driver (usually safety functions)
Popular examples (today): • Traffic sign recognition (display of current speed limit) • Lane departure warning (e.g. Vibration on the steering)	Popular examples (today): • Adaptive cruise control (ACC) • Lane keep assist (via steering interventions)	Popular examples (today): • Automatic emergency braking (system triggered)

According to this approach “intervening emergency functions (near accident situations)”, such as e.g. emergency braking are classified as a discrete functional type (operation type C) which are functions that “take immediate control over the vehicle in near-accident situations that de facto cannot be controlled/handled by the driver (usually safety functions)”.

Another functional type aside from automation (operation type A) is “informing and warning functions” that “take only indirect influence on vehicle control via the driver” such as Traffic Sign Recognition or Lane Departure Warning.

This approach has been adopted by AdaptIVe and other entities working on the definition of automation levels such as SAE and VDA. Consequently in the following, only “continuously automating functions” (operation type B) will be considered for classification of automated driving and parking functions.

An automated driving or parking function is capable of a single or multiple driving or parking maneuvers. E.g. a parking garage pilot is capable of (a) maneuvering in a parking garage while searching for a free parking space and (b) maneuvering into the free parking space. A classification of those maneuvers requires their discrimination through the use of parameters.

An important parameter for the classification of automated driving and parking functions is their *level of automation*. Figure 4.1 shows an automation scale, composed of graduated levels of automation, recently published by SAE [2] and VDA [4]. A detailed description and genesis of automation levels can be found in Annex 1.

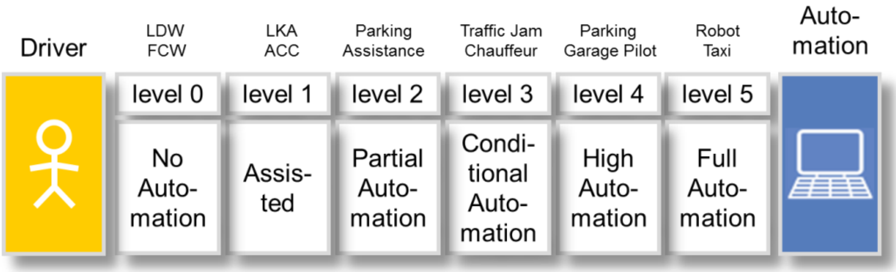

Figure 4.1: Terms related to automated driving according to SAE and VDA

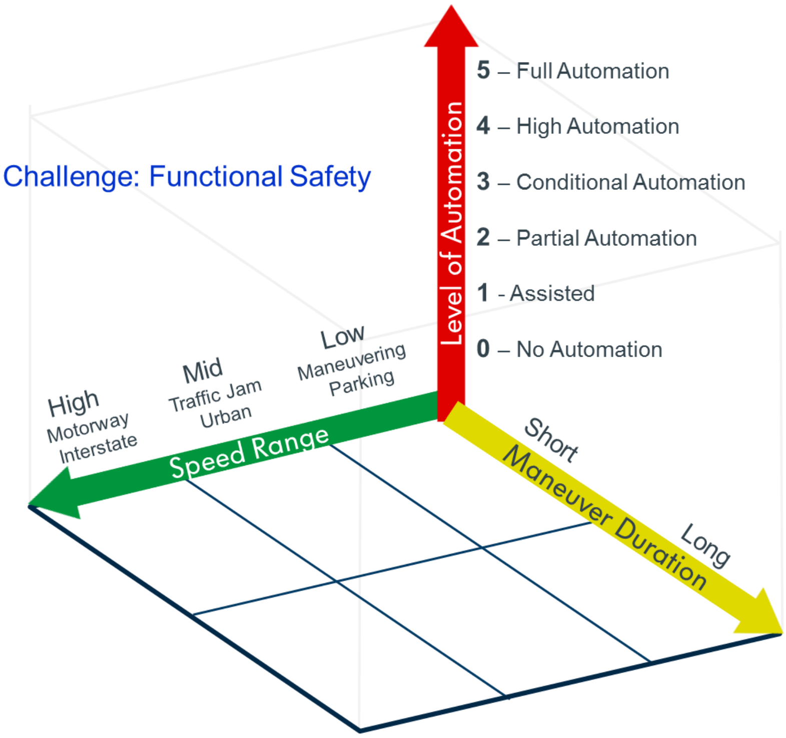

Figure 4.2: Dimensions of automated driving and parking systems, inspired by [3]

Other parameters might be considered alongside the automation level. Tom Gasser from BASt proposed to add *speed range* and *maneuver duration* (refer to Figure 4.2). Goal-directed brainstorming revealed further potential relevant parameters such as *vehicle type*, *road type*, *driver location*, *road condition* and *infrastructure*, to name just a few.

Finally it must be ensured that no relevant parameter has been forgotten, granting sufficient discriminability for all users (legal, human factors and functional safety experts). But it should also be considered that the number of parameters is not too high so as to maintain manageable number of classes. A systematic approach was essential for this purpose. Therefore, in the following subsection the basic approach of Gasser et al. [3] was adopted and systematically refined.

4.2 Approach

This subsection describes the systematic approach for an identification of relevant and distinctive parameters for the classification of automated driving and parking functions. For this purpose the following methodology was used:

a) Collect all potentially relevant parameters for classification in the design space of automated driving and parking functions which might be helpful to distinguish between functional classes (see 4.3)
b) Identify and eliminate unnecessary parameters (see 4.4): Unnecessary are all those parameters that do not differentiate the functions, such as
    - Parameters used for all functions
    - Parameters that are redundant in a way that they describe the same thing
c) Identify relevant parameters for clusters from a legal, human factors and functional safety perspective (see 4.5)
d) Combine remaining parameters for definition of functional classes (see 4.6)
e) Eliminate unnecessary functional classes for parameter combinations which will not occur in real life (see 4.7)

4.3 Collection of all potentially relevant parameters

Collecting all potentially relevant parameters required a systematic approach to ensure no major aspects get ignored. For this study, the following three main categories were identified in order to reduce the complexity of the problem:

1) Vehicle
2) Driver
3) Environment

Assigned to those categories are sets of parameters which are described in the following.

Figure 4.3 shows the “Vehicle” parameter set. The parameter set of the category “Vehicle” is subdivided into **vehicle type** (truck, car) and **vehicle maneuver**; the latter can be characterized by the following parameters: *maneuver time to collision* (large, small), *maneuver duration* (short time, long time), *maneuver automation* (Level 0 – 5), *maneuver speed range* (low, mid high), *maneuver control force* (low, mid, high), *maneuver time headway* (standard, reduced, small), *maneuver trigger* (system initiated, driver approved, driver initiated) and *maneuver coordination* (with coordination, without coordination).

A more detailed description of the “Vehicle” parameter set can be found in Table 4.2.

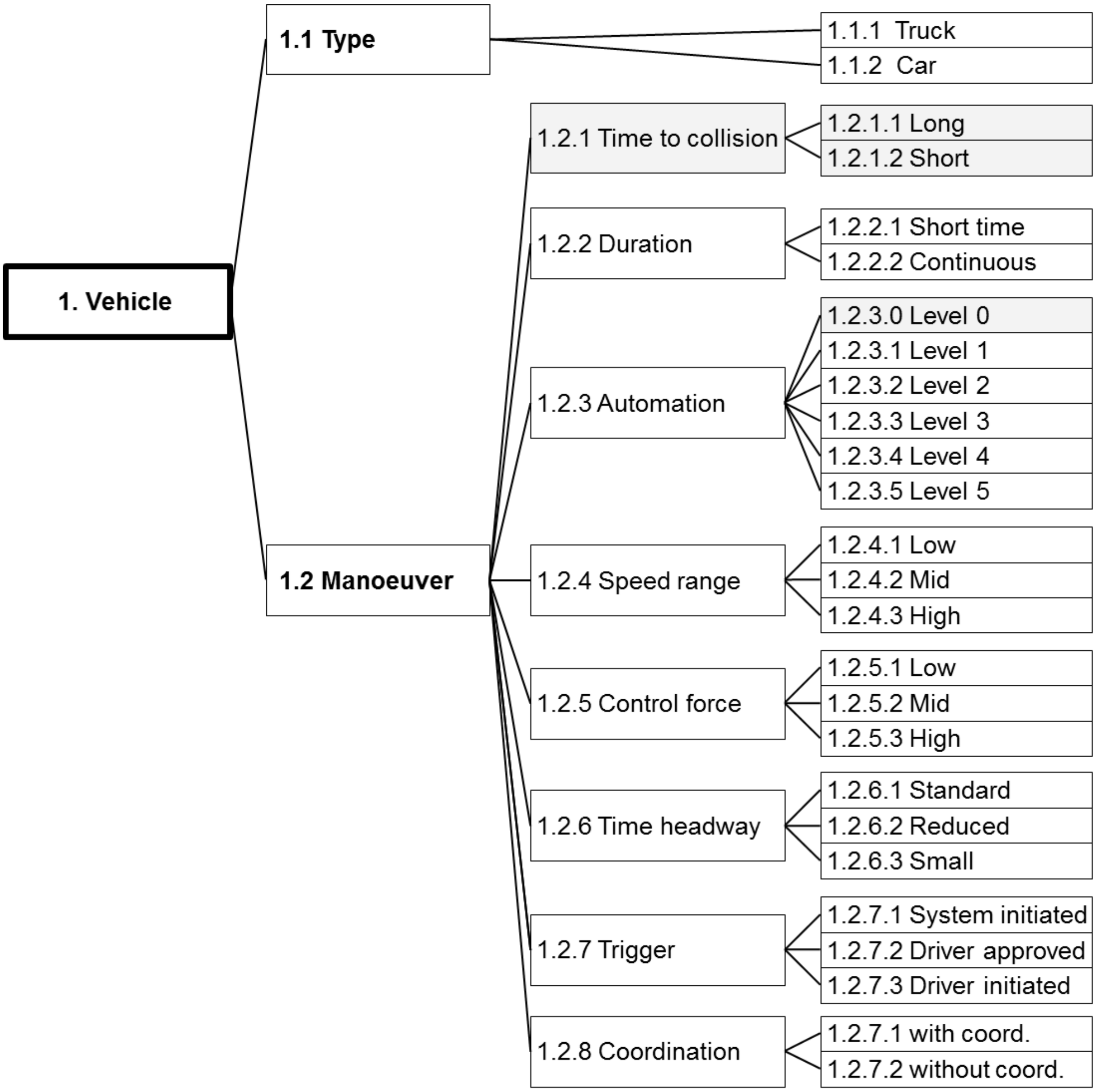

Figure 4.3: Relevant parameters for functional classification regarding “Vehicle”

Table 4.2: Detailed description of “Vehicle” parameter set

Parameter name		Parameter values		Description of parameter values
1.1	vehicle type	1.1.1	Truck	The category truck includes vehicles of class M2, M3, N2 and N3 according to UNECE [7]. M2: Vehicles used for the carriage of passengers, comprising more than eight seats in addition to the driver's seat, and having a maximum mass not exceeding 5 tons. M3: … and having a maximum mass exceeding 5 tons N2: Vehicles used for the carriage of goods and having a maximum mass exceeding 3.5 tons but not exceeding 12 tons.

				N3: … and having a maximum mass exceeding 12 tons. Examples: commercial truck, bus Remark 1: 1 ton is equal to 1,000 kg.
		1.1.2	Car	The category car includes vehicles of type M1 and N1 according to UNECE [7]. M1: Vehicles used for the carriage of passengers and comprising not more than eight seats in addition to the driver's seat. N1: Vehicles used for the carriage of goods and having a maximum mass not exceeding 3.5 tonnes. Examples: passenger car, pick-up truck Remark 1: Not included are vehicles of the following categories: L: motor vehicles with less than four wheels. Examples: Motor cycles, quads O: Trailers (including semi-trailers) -: Special purpose vehicle. Examples: Motor caravan, armored vehicle, ambulance, hearse T: Agricultural and Forestry tractors -: Non-road mobile machinery G: Off-road vehicles Remark 2: Some transport vehicles are offered in different versions with maximum mass below and above 3.5 tonnes. Here the attribution to the class “car” or “truck” has to be in dependence of the vehicle version’s maximum mass.
1.2.1	Vehicle maneuver time-to-collision	1.2.1.1	Large	Collision is not imminent. Example: Driver assistance systems such as ACC, LKA, etc.
		1.2.1.2	Small	Collision is imminent. Example: emergency braking e.g. if lead vehicle brakes hard suddenly
1.2.2	Vehicle maneuver duration	1.2.2.1	Short	Short time, event based operation, no continuous operation, single event. Example: lane change, backing into a parking space
		1.2.2.2	Long	Long time, continuous operation, no single event Example: long distance highway driving, driving in a traffic jam, searching a parking place
1.2.3	vehicle maneuver automation	1.2.3.0	Level 0 no automation	Description see A 1.1.1 Examples: Lane departure warning (LDW), forward collision warning (FCW), blind spot warning (BSW) Remark: As the name suggests Level 0 systems are not automated and therefore will be disregarded in the following classification scheme for automated driving and parking functions.
		1.2.3.1	Level 1 assisted	Description see A 1.1.2 Examples: Adaptive cruise control (ACC, refer to A2.2), lane keeping assist (LKA, refer to A2.3), combination of ACC and LKA Type II (refer to A2.5), parking assistance with steering (refer to A2.12) Remark: For discussion about LKA vs. lane centered lateral vehicle guidance, refer to A 1.1.2, remark 2 and 3.
		1.2.3.2	Level 2	Description see A 1.1.3

			partial automation	Examples: Traffic jam assistance (refer to A2.9), highway assistance (refer to A2.10), key parking (refer to A2.14)
		1.2.3.3	Level 3 conditional automation	Description see A 1.1.4 Example: Traffic jam chauffeur (refer to A2.15), highway chauffeur (refer to A2.16)
		1.2.3.4	Level 4 high automation	Description see A 1.1.5 Example: Driverless valet parking (refer to A2.19), automated mining vehicles (refer to A2.25)
		1.2.3.5	Level 5 full automation	Description see A 1.1.6 Example: Universal robot taxi (refer to A2.27) Remark: This level of automation is not in the scope of AdaptIVe
1.2.4	vehicle maneuver velocity	1.2.4.1	Low	$v < 20$ km/h Examples: Parking, maneuvering on parking garage or on car park, very slow moving traffic while stop & go in a traffic jam
		1.2.4.2	Mid	$20 \leq v \leq 60$ km/h Examples: Urban traffic, driving in congestions or traffic jams
		1.2.4.3	High	$v > 60$ km/h Examples: Driving on a highways, interstates or rural roads
1.2.5	Vehicle maneuver control force	1.2.5.1	Low	$-4\ m/s^2 \leq a_{longit} \leq 1\ m/s^2$; $m_{steer} \leq 3$ Nm Examples: Deceleration of an ACC system, steering momentum of a LKA system Remark: The steering momentum is equivalent to the torque which would be induced by the driver.
		1.2.5.2	Mid	$-7\ m/s^2 \leq a_{longit} \leq 1{,}5\ m/s^2$; $m_{steer} \leq 6$ Nm Examples: Deceleration of an emergency braking system with moderate braking force, steering momentum of an emergency steering system with moderate steering force
		1.2.5.3	High	$-10\ m/s^2 \leq a_{longit} \leq 3\ m/s^2$; $m_{steer} \leq 10$ Nm Examples: Deceleration of an emergency braking system with full braking force, steering momentum of an emergency steering system with full steering force Remark: Linear acceleration from 0 to 100 km/h needs 27,8 sec with 1 m/s^2, 18,5 sec with 1,5 m/s^2 and 9,3 sec with 3 m/s^2
1.2.6	vehicle maneuver time headway	1.2.6.1	Standard	Time headway > 0,9 sec Examples: ACC, Traffic Jam Assistance (refer to A2.9)
		1.2.6.2	Reduced	Time headway 0,5 … 0,9 sec Example: truck platooning with 15m distance
		1.2.6.3	Small	Time headway < 0,5 sec Example: truck platooning with 5m distance Remark: Backing into a parking space, vehicle maneuver time headway is not applicable (n.a.) since distance control to a leading vehicle does not occur. Driving while searching a parking space, maneuver time headway is applicable, since distance control to a leading vehicle might occur.

1.2.7	Vehicle maneuver trigger	1.2.7.1	System initiated	Maneuver is solely initiated by system Example 1: Overtaking Pilot (refer to A2.23) - initiation of lane change maneuver solely by system without any help of the driver. Example 2: Urban robot taxi (refer to A2.24) – vehicles does not have a driver. Maneuvers are solely initiated by system. Remark: System's initiation of vehicle maneuvers can further be subdivided in intended and unintended initiations.
		1.2.7.2	Driver approved	Maneuver is suggested by system but has to be approved by the driver. Example: Overtaking chauffeur (refer to A2.17) - system suggests lane change e.g. by icon, driver approves e.g. by actuation of turn signal indicator. Remark: Driver's approval of vehicle maneuvers can further be subdivided in intended and unintended approvals.
		1.2.7.3	Driver initiated	Maneuver is initiated by driver. System does not suggest maneuver. Example 1: Overtaking assistance (refer to A2.11) - driver initiates lane change by actuation of turn signal indicator, system may indicate "lane change possible" but does not actively suggest lane change maneuver. Example 2: Traffic jam chauffeur (refer to A2.15) – driver activates system by actuation of on-off switch, system may indicate "system ready" but does not actively suggest activation. Remark: Driver's initiation of vehicle maneuvers can further be subdivided in intended and unintended initiations.
1.2.8	Vehicle maneuver coordination	1.2.8.1	With coordination	Maneuver involves several vehicles which are coordinating their behavior. Example: Automated filtering at on-ramp of a motorway - vehicle that wants to enter motorway asks vehicles on motorway via V2V communication to increase headway so to ease filter-in maneuver. Remark: The term "cooperation" has been deliberately avoided in this context because cooperative behavior can be also achieved without communication, e.g. facilitating merging at onramps by increasing ACC headway. For maneuver coordination the emphasis is on communication between vehicles.
		1.2.8.2	Without coordination	Maneuver is not coordinated between involved vehicles. Example: Lane change at overtaking maneuver – if the adjacent lane is not occupied the lane change is initiated without any coordination or communication between involved vehicles.

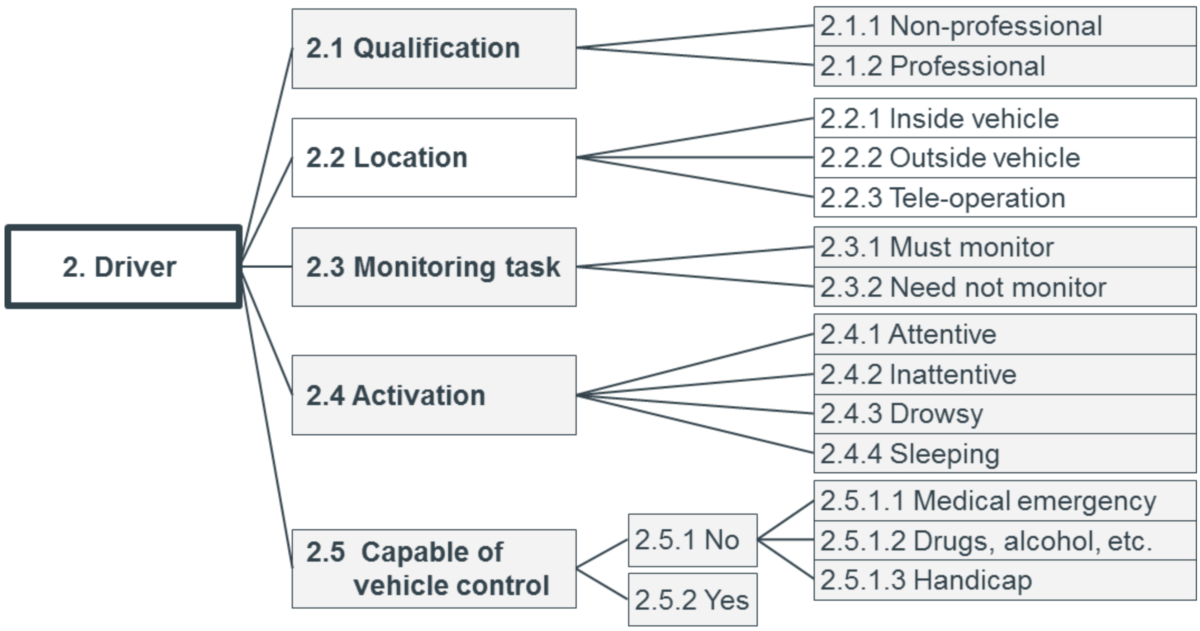

Figure 4.4: Relevant parameters for functional classification regarding "Driver"

Figure 4.4 shows the "Driver" parameter set. Parameters of the category "Driver" are: *driver qualification* (non-professional, professional), *driver location* (inside vehicle, outside vehicle, tele-operation), *driver monitoring task* (must monitor, need not monitor), *driver activation* (attentive, inattentive, drowsy, sleeping) and *driver's capability to control his vehicle* (capable, not capable due to driver medical emergency, drugged or drunken driver, handicapped driver).

A more detailed description of the "Driver" parameter set can be found in Table 4.3.

Table 4.3: Detailed description of "Driver" parameter set

Parameter name		**Parameter values**		**Description of parameter values**
2.1	Driver qualification	2.1.1	Non-professional	Drivers with an ordinary driving license not having any other qualification or training
		2.1.2	Professional	Drivers with a driver license and an extra qualification or training Examples: Truck drivers, taxi drivers, test drivers
2.2	Driver location	2.2.1	Inside vehicle	The driver is located inside of the vehicle, sitting on the driver's, co-driver's or rear seat. In dependence of automation mode he must be in the position to control the vehicle via steering wheel & pedals or joystick. Example 1: Driver is sitting on driver's seat behind the steering wheel Example 2: Driver is sitting on co-driver's seat with dual pedals Example 3: Driver is sitting on rear seat with remote control device, e.g. joystick.
		2.2.2	Outside vehicle	The driver is located outside of the vehicle. He is obliged to monitor vehicle and environment and has direct visual contact to vehicle and environment.

				Example: Key parking (refer to A2.14) – driver is located outside of the vehicle and must monitor the parking maneuver Remark: For driverless applications such as driverless valet parking (refer to A2.19), or robot taxis (refer to A2.24, A2.27) this parameter would not be applicable (n.a.).
		2.2.3	Tele-operation	The driver is located outside of the vehicle without direct visual contact to vehicle or environment, controlling the vehicle (e.g. accelerating, braking, steering) and/or monitoring vehicle's environment and/or setting vehicle's route and destination via wireless device. Example: Tele-operated taxi - urban (refer to A2.20). Remark: Assuming that during the specific use case the tele-operator becomes the "driver" of the vehicle and persons in the vehicle are merely passengers or there are no persons at all, then the SAE/VDA/BASt definition of automation levels can be adopted in principle: Level 2: Vehicle automation has longitudinal and lateral control. Tele-operator must monitor the system at all times and must immediately intervene if required ("permanent" tele-operator). Level 3: Vehicle automation has longitudinal and lateral control, recognizes its performance limits and requests tele-operator to resume control with sufficient time margin. Tele-operator does not have to monitor the system at all times; must always be in a position to resume control if requested (tele-operator "on demand"). Level 4: Vehicle automation can cope with all situations automatically in a specific use case. Tele-operator is not required; is setting vehicle's route and destination (tele-operator as "dispatcher"). Level 5: See Level 4, now without restrictions to a specific use case but for any on-road journey.
2.3	Driver's monitoring task	2.3.1	Must monitor	The driver must always monitor system and environment and has to intervene if required. Secondary tasks are not allowed. Examples: Level 0…2 systems Remark 1: Sometimes called "driver in the loop" Remark 2: "Secondary tasks" does not include commonly accepted non-driving-related activities such as changing the radio or air conditioning settings but activities such as watching TV, internet surfing or texting.
		2.3.2	Need not monitor	The driver need not constantly monitor system and environment. Secondary tasks are allowed. Examples: Level 3…5 systems Remark: Sometimes called "driver out of the loop".
2.4	Driver activation	2.4.1	Attentive	Driver is alert and ready to intervene.
		2.4.2	Inattentive	Driver is not alert and not ready to intervene but prepared to drive. Example: Distracted driver while texting or day dreaming or sleeping.
		2.4.3	Drowsy	Driver is drowsy, reduced ability to intervene.
		2.4.4	Sleeping	Driver is sleeping and not ready to intervene

2.5	Driver is capable to control his vehicle	2.5.1.1	No: medical emergency	Driver suffers medical emergency and is suddenly not capable to safely control his vehicle. Example: heart attack, stroke, blackout
		2.5.1.2	No: drugs, alcohol, etc.	Driver has consumed drugs, alcohol, etc. and therefore is not capable to safely control his vehicle. Remark 1: Such persons are not permitted to drive a vehicle. Remark 2: Some Level 4 systems (high automation) and all Level 5 systems (full automation) will not need a human driver, e.g. automated mining vehicles and universal robot taxis (refer to A2.25, A2.27. Here human driving capabilities are irrelevant.
		2.5.1.3	No: handicap	Driver suffers permanent physical or mental handicap and therefore is constantly not capable to control a vehicle. Example: Blind person Remark: Such persons will not have a valet driving license.
		2.5.2	Yes	Driver has all physical and mental capacities to safely control his vehicle.

Figure 4.5 shows the “Environment” parameter set. Sub-categories of the “Environment” category are **Traffic**, **Road** and **Visibility**.

Traffic parameters are: *mixed traffic* (yes, no), *traffic participants* (non-motorized, motorized: slow, motorized: fast) and *traffic flow* (moving traffic, slow moving traffic, stationary traffic).

Road parameters are: *road type* (motorway, highway, interstate, rural road, arterial road, urban road, residential district road, parking area/parking deck and garage), *road accessibility* (public, private), *road condition* (good, slippery, bumpy), *road geometry* (straight, curved, steep) and *road infrastructure* (physical cut-off, good lane markings, guardrails, deer fences, emergency lanes, hard shoulder and traffic lights).

Visibility parameters are: *good visibility, reduces visibility due to obstacles* (vehicles, infrastructure) and *reduced visibility due to weather* (fog, heavy spray, heavy rain, heavy snow).

A more detailed description of the “Environment” parameter set can be found in Table 4.4.

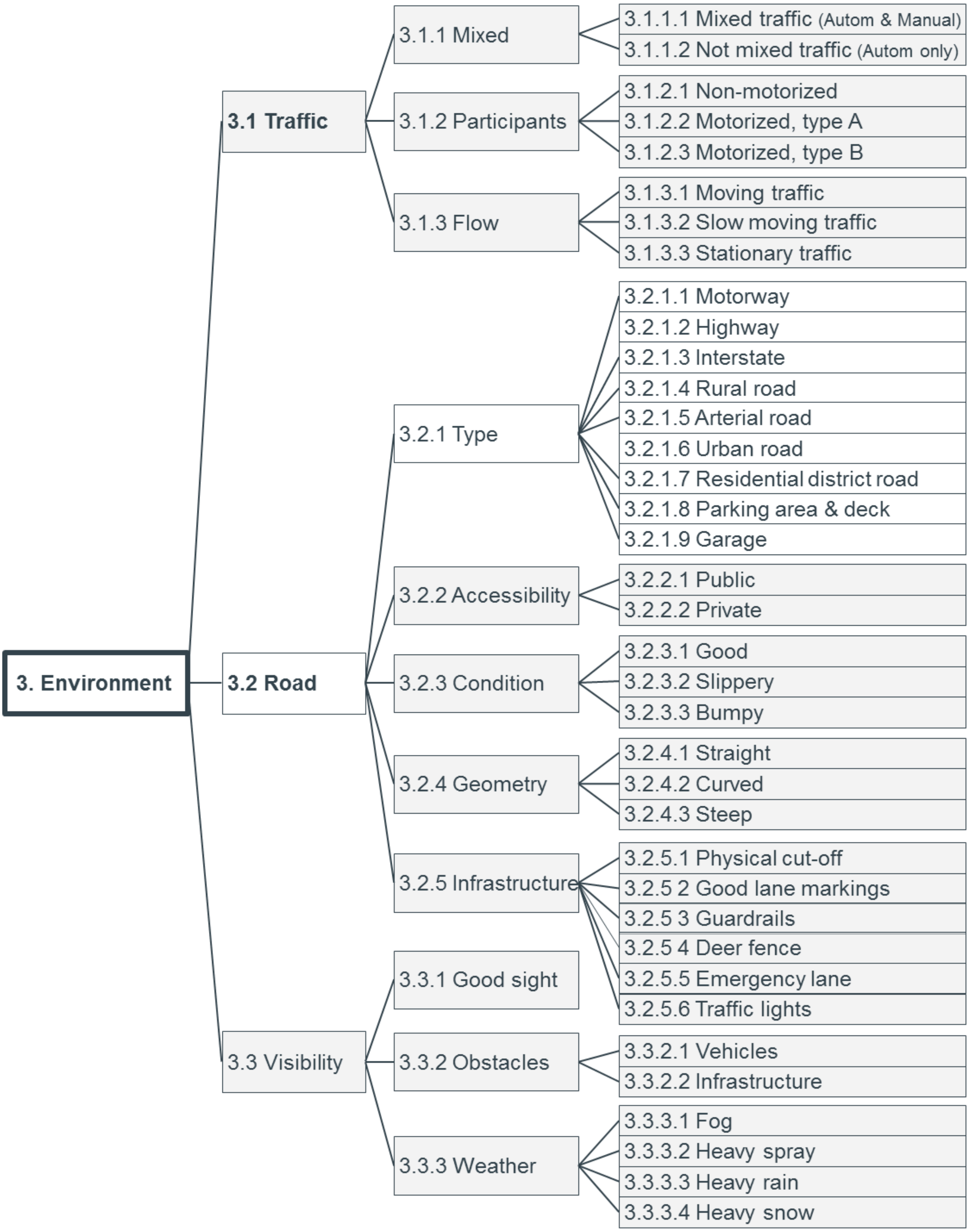

Figure 4.5: Relevant parameters for functional classification regarding “Environment”

Table 4.4: Detailed description of “Environment” parameter set

Parameter name		Parameter values		Description of parameter values
3.1.1	Traffic mixed	3.1.1.1	Yes	With active automation the vehicle is driving in an environment where also driver controlled vehicles are present. Example: Motorway without dedicated lanes for automated vehicles.
		3.1.1.2	No	With active automation the vehicle is driving in an environment where only automation controlled vehicles are present. Example: Parking garage with extra parking levels reserved for automated vehicles.
3.1.2	Traffic participants	3.1.2.1	Non-motorized	Non-motorized road users, such as pedestrians and cyclists. Examples: pedestrians on a crosswalk, construction side worker, bicyclists Remark: Motorcyclists belong to the group of vulnerable road users such as pedestrians or cyclists. Those have not been joined in a common group named e.g. “vulnerable road users” because the behavior of motorcyclists is more comparable to that of a car than that of a pedestrian or cyclists: motorcyclists do not abruptly change their direction of movement so that their behavior is more predictable compared to pedestrians or cyclists. This is also true from a perception perspective: motorcyclists are spatially wide extended objects which drive unhidden in the middle of the road so that they are easier to detect compared to pedestrians or cyclists.
		3.1.2.2	Motorized, type A	Motorized road users with vehicles whose means of propulsion maximum design speed not exceeding 50 km/h, hereinafter referred to as “motorized, type A”. Remark: Engine type (electric, thermic) or number of wheels (2, 4) is irrelevant. Examples: Drivers of electric bicycles or small mopeds.
		3.1.2.3	Motorized, type B	Motorized road users whose means of propulsion maximum design speed exceeding 50 km/h, hereinafter referred to as “motorized, type B. Remark: Engine type (electric, thermic) or number of wheels (2, 4) is irrelevant. Examples: Drivers of motorbikes, passenger cars or trucks.
3.1.3	Traffic flow	3.1.3.1	Moving traffic	Traffic is moving nearly with recommended speed of particular road type. Traffic density is low or medium.
		3.1.3.2	Slow moving traffic	Traffic is moving distinctly below recommended speed of particular road type. Traffic density is medium to high.
		3.1.3.3	Stationary traffic	Traffic is nearly at a standstill or is at a standstill. Traffic density is high.
3.2.1	Road type	3.2.1.1	Motorway	Roads between villages and towns with physical cut-off between oncoming lanes, good lane markings, guardrails, deer fences and emergency lane. Low curvature and incline. Very low probability of pedestrians and bicyclists. No Crosswalks, junctions or traffic lights to be expected. Maximum speed: unlimited. Remark: “Good lane markings” means that lane markings of motorways are usually considerably better than those of e.g.

				rural roads. But also on motorways it has to be expected that lane markings are not always in good shape.
		3.2.1.2	Highway	Refer to motorway. No emergency lane but hard shoulder. No deer fences. Low probability of pedestrians and bicyclists. Maximum speed: 70 mph (113 km/h).
		3.2.1.3	Interstate	Refer to Highway. No physical cut-off between oncoming lanes, no guardrails. Low probability of pedestrians and bicyclists. Moderate curvature and incline. Crosswalks, junctions or traffic lights to be expected. Maximum speed: 100 km/h.
		3.2.1.4	Rural road	Refer to interstate. No good lane markings. No hard shoulder. Moderate probability of pedestrians and bicyclists. Maximum speed: 100 km/h
		3.2.1.5	Arterial road	Roads in or in immediate vicinity of towns with good lane markings and hard shoulder. No physical cut-off between oncoming lanes, no guardrails, no deer fences, no emergency lane. Medium probability of pedestrians and bicyclists. Low curvature and incline. Crosswalks, junctions and traffic lights are present. Maximum speed: 60 km/h
		3.2.1.6	Urban road	Roads in villages and towns. High probability of pedestrians and bicyclists. High curvature and incline. Crosswalks, junctions and traffic lights are present. Maximum speed: 50 km/h.
		3.2.1.7	Residential district roads	Roads in residential districts of villages or towns. Very high probability of pedestrians and bicyclists. High curvature and incline. Crosswalks, junctions and traffic lights are present. Maximum speed: 30 km/h.
		3.2.1.8	Parking area & paring deck	Parking place or parking garage or parking structure without access restrictions. Very high probability of pedestrians and bicyclists. Maximum speed: 20 km/h.
		3.2.1.9	Garage	Garage for passenger cars on private ground. High probability of pedestrians and bicyclists. Maximum speed: 20 km/h.
3.2.2	Road accessibility	3.2.2.1	Public	Roads and places without access limitations for vehicles. Examples: Public roads, public parking places.
		3.2.2.2	Private	Roads and places with restricted access for vehicles. Example: Private garage, company's car park
3.2.3	Road condition	3.2.3.1	Good	Surface of the road is smooth, with good adhesion.
		3.2.3.2	Slippery	Surface of the road is slippery. Reduced adhesion. Examples: Aqua planning, snow, ice, dirt, leaves.
		3.2.3.3	Bumpy	Surface of the road is not smooth but bumpy. Examples: Potholes, wavy asphalt.
3.2.4	Road geometry	3.2.4.1	Straight	Straight road without relevant curvature, ascend or descend. Example: Motorway.
		3.2.4.2	Curved	Road with relevant curvature Examples: Motorway interchange, rural road, serpentine.
		3.2.4.3	Steep	Road with relevant ascend or descend. Example: Mountain road, serpentine.

3.2.5	Road infrastructure	3.2.5.1	Physical cut-off	Physical cut-off between oncoming lanes. Example: Guardrail, separating green area.
		3.2.5.2	Good lane markings	White / yellow painted stripes or botts' dots to separate lanes of a road.
		3.2.5.3	Guard rails	Mechanical construction to prevent vehicles from veering off the roadway into oncoming traffic, crashing against solid objects or falling into a ravine. Examples: Guard rails, mural, concrete wall, taut steel rope, mound
		3.2.5.4	Deer fences	Fence at the roadside which prevents animals and pedestrians from entering the road. Remark: "No deer fence" does not mean "no automation". The evaluation of minimal infrastructure requirements for specific applications is a separate topic. Example: A Traffic Jam Pilot might not need a deer fence. For high speed application is has to be assessed if occurrence probability of deer in combination with perception performance results in an acceptable risk.
		3.2.5.5	Emergency lanes	Separate lane at the roadside which is reserved for vehicles with technical defects. Remark: Hard shoulders is a synonym for emergency lane
		3.2.5.6	Traffic light	Traffic light at intersections of e.g. urban or rural roads.
3.3.1	Good visibility	3.3.1.1		Full visibility of vehicles and obstacles. Remark: Modest fog, spray, rain or snow shall not hamper system functionality.
3.3.2	Poor visibility due to obstacles	3.3.2.1	Vehicles	Visibility of vehicles and obstacles is masked by other vehicle. Example: Vehicle at standstill cannot be seen due to leading vehicle in front. If vehicle in front changes lane, then vehicle at standstill abruptly becomes visible.
		3.3.2.2	Infrastructure	Visibility of vehicles and obstacles is masked by infrastructure. Example: Vehicle at standstill cannot be seen due to road curvature.
3.3.3	Poor visibility due to weather conditions	3.3.3.1	Fog	Reduced visibility of vehicles and obstacles due to fog.
		3.3.3.2	Heavy spray	Reduced visibility of vehicles and obstacles due to heavy spray.
		3.3.3.3	Heavy rain	Reduced visibility of vehicles and obstacles due to heavy rain.
		3.3.3.4	Heavy snow	Reduced visibility of vehicles and obstacles due to heavy snow.

4.4 Elimination of unnecessary and refinement of remaining parameters

In the following section unnecessary parameters for functional classification were identified and eliminated, and remaining parameters were refined. A parameter is unnecessary or irrelevant if

a) All functionalities have this parameter in common, or if;
b) It describes the same property like another parameter (redundancy).

4.4.1 Common parameters

Table 4.5 shows those parameters, which are common for all automated driving and parking functionalities.

Table 4.5: Detailed description

2.5.1.2	Not capable of vehicle control: drugs, alcohol, etc.	No automated driving or parking functionalities will enable drunken or drugged drivers to control a vehicle. As today such persons are not permitted to drive a vehicle.
2.5.1.3	Not capable of vehicle control: handicap	No automated driving or parking functionality will enable severely handicapped people, which are legally not capable of vehicle control, to drive a vehicle. As today such persons are not permitted to drive a vehicle.
3.1.3	Traffic flow	All automated driving and parking functionalities are suited for all kinds of traffic flow. Remark 1: A Highway chauffeur must manage scenarios on an empty road as well as on a crowded road. Remark 2: A platooning vehicle or a Traffic Jam Pilot needs a leading vehicle in front. Demanding a leading vehicle does not result in requirements or restrictions to traffic flow.
3.2.3	Road condition	All automated driving and parking functionalities shall only be activated or active, if minimum requirements for road quality are met. If the road is too slippery or too bumpy then the automated driving functions shall not be activated or active. Remark 1: From this is might be concluded that some Level 3-5 systems must detect road condition. Remark 2: Minimum requirements to road conditions might depend on the specific application. E.g. automated highway applications might have higher requirements to road condition than automated mining vehicles.
3.3.1	Good visibility	All automated driving and parking functionalities must be suited to manage scenarios with good visibility
3.3.2	Reduced visibility due to obstacles	All automated driving and parking functionalities must be suited to manage scenarios with reduced visibility due to obstacles such as other vehicles or road curvature that may occur during their specific use case.
3.3.3	Reduced visibility due to weather conditions	All automated driving and parking functionalities shall only be activated or active, if minimum requirements for visibility with respect to weather conditions are met. If visibility is unduly reduced due to fog, spray, rain or snow, then the automated driving functions shall not be activated or active. Remark 1: From this is might be concluded that some Level 3-5 systems must detect visibility with respect to weather conditions. Remark 2: Minimum requirements to visibility might depend on the specific application. E.g. automated high speed driving might have higher requirements for visibility than automated parking systems.

4.4.2 Redundant parameters

Table 4.6 shows those parameters, which are redundant for all automated driving and parking functionalities:

Table 4.6: Redundant parameters for all automated driving and parking functionalities

1.2.1	Vehicle maneuver time to collision.	Stand-alone systems, intervening at emergency or near-emergency situations (e.g. emergency braking / steering / stopping) are not considered in this classification scheme (see 4.1). Accident avoidance capabilities of automated systems are defined in automation levels.
2.1	Driver qualification	In the following it is assumed that trucks (1.1.1) are always driven by professional drivers (2.1.2) while passenger cars (1.1.2) are driven by non-professional drivers (1.1.1). Remark: This is a simplification because e.g. taxi drivers or professional test drivers might drive passenger cars.
2.3	Driver's monitoring task	Requirements to driver's monitoring task (2.3) are explicitly defined at vehicle maneuver automation (1.2.4). Systems with no automation (1.2.4.1), assistance (1.2.4.2) and partial automation (1.2.4.3 require the driver to monitor the system. Systems with conditional automation (1.2.4.4), high automation (1.2.4.5) and full automation (1.2.4.6) do not require the driver to monitor the system.
2.4	Driver activation	Vehicle maneuver automation (1.2.4) implicitly defines the level of associated driver activation (2.4). Systems with no automation (1.2.4.1), assistance (1.2.4.2) and partial automation (1.2.4.3) require the driver to be attentive (2.4.1). An inattentive (2.4.2) drowsy (2.4.3) or sleeping (2.4.4) driver is not allowed. Systems with conditional automation (1.2.4.4) allow an inattentive driver (2.4.2) but forbid a sleeping driver (2.4.4). Systems with high automation (1.2.4.5) and full automation (1.2.4.6) allow an inattentive (2.3.2), drowsy (2.3.3) or sleeping (2.3.4) driver Remark: *If an unintended use with insufficient driver activation at a specific automation level is foreseeable, then a technical countermeasure which assesses the driver's capability to resume control might be required.*
2.5.1.1	Driver is not capable of vehicle control: medical emergency	*Drivers with a disease, who might suffer a sudden, unforeseeable medical emergency, are not excluded from automated driving if they are legally qualified to drive a vehicle.*
2.5.2	Driver is capable of vehicle control	*For Level 0-4 systems the driver must potentially be in the position to control his vehicle. For Level 5 systems no driver is required.* Example 1: If the traffic jam scenario ends, the Traffic Jam Pilot (refer to A2.21) requests the driver to resume control. Then the driver must be capable to control his vehicle. Example 2: If the Driverless Valet Parking system (refer to A2.19) provides the vehicle at the exit of the parking garage, the driver resumes control and then must be capable to control his vehicle.
3.1.1	Traffic mixed	*For the different road types (3.2.1) it will be defined if mixed traffic (3.1.1) has to be assumed.* "No mixed traffic" example 1: Parking structures for automated valet parking without human driven vehicles. "No mixed traffic" example 2: Automated mining vehicles in company owned, restricted areas (refer to A2.25).
3.1.2	Traffic participants	Which kind of traffic participants (3.1.2) have to be expected is strongly related to road type (3.2.1). Decisive is the occurrence probability of pedestrians and bicyclists. *Therefore for the different road type (3.2.1) the occurrence probability of pedestrians and bicyclists will be defined.*

3.2.2	Road accessibility	*For the different road types (3.2.1) the accessibility (3.2.2) will be defined.* “Private” example: Company owned, restricted ground, e.g. marshalling area of distribution company or proving grounds of OEM’s and suppliers.
3.2.4	Road geometry	Road geometry is strongly related to road type. Decisive for road geometry are curvature and incline. *Therefore for the different road types (3.2.1) the road geometry (3.2.4) regarding curvature and incline will be defined.*
3.2.5	road infrastructure	Road infrastructure (3.2.5) is strongly related to road type (3.2.1). *Therefore for the different road types (3.2.1) the road infrastructure (3.2.5) will be defined.*

4.4.3 Parameter refinement

From the considerations above it was concluded that the definition of road types must be more refined, including considering road infrastructure, road geometry regarding curvature and incline, occurrence probability for pedestrians and bicyclists, road accessibility as well as road types for non-mixed traffic scenarios. Table 4.7 shows a proposal for the definition of 17 different road types. A checkmark indicates that the specific road type is regularly equipped with the respective infrastructure feature. A checkmark in parentheses indicates that the specific road type is often but not always equipped with the respective infrastructure feature.

Table 4.7: Definition of different road classes

No.	Road type name	Infrastructure							Speed	Curvature and incline	Occurrence probability of pedestrians and bicyclists	Road accessi-bility	Mixed Traffic
		physical cut-off	good lane markings	guardrails	deer fence	emergency lane	hard shoulder	traffic lights					
1	Motorway	✓	✓	✓	✓	✓			high	low	very low	public	yes
2	Interchange	✓	✓	✓	✓	(✓)				high	very low		
3	On/Off-ramp	✓	✓	✓	✓	(✓)				high	low		
4	Construction zone	✓		✓	✓					mid	mid		
5	Highway	✓	✓	✓		✓	✓			low	low		
6	Interstate		✓	(✓)		(✓)	✓	✓		mid	low		
7	Rural road		(✓)					✓	mid	mid	mid		
8	Arterial road		✓				✓	✓		low	mid		
9	Urban road							✓		high	high		
10	Intersection							✓		very high	very high		
11	Residential district road							✓	low	high	very high		
12	Parking area, parking deck									n.a.	very high		
13	Garage								low	n.a.	high	private	no
14	Parking deck for driverless valet parking								low	n.a.	very low		

16	Shuttling road on mining area								mid	mid	very low		
17	Marshalling area of forwarding company								low	n.a.	very low		

Remark 1: The name of the road type should not be over-interpreted. If e.g. a road is categorized as interstate but has infrastructure features similar to a highway (e.g. physical cut-off between oncoming lanes), then it belongs to road type no. 5 “highway”.

Remark 2: Bridges and tunnels are assumed to be a common infrastructure feature for all road types. Therefore they are not mentioned separately in the list of infrastructure features. It is also assumed that bridges and tunnels of a specific road type are equipped with most of the infrastructure features of that specific road type.

Remark 3: The existence of a road is always assumed for automated driving applications. Off-road functionalities such as automated rally cars are not considered.

Remark 4: Unpaved roads might be relevant for military or agricultural vehicles. These kinds of vehicles are not considered in the classification of automated driving and parking functions (see 4.3). An evident use case for trucks on unpaved roads is automated driving in mining areas, which is taken into consideration in road type 16 “shuttling road on mining area”. Furthermore dirt roads which are common in rural areas of the country are not considered, which is why unpaved roads are not mentioned separately.

Remark 5: One-lane roads, including bridges and tunnels, typical for e.g. field, forest, grassland, tundra and desert roads as well as mountain passes, are not considered.

4.4.4 Relevant parameter set

As a result of the considerations above it was concluded that the parameter set depicted in Figure 4.6 and Table 4.8 is ultimately relevant for the classification of automated driving and parking functions.

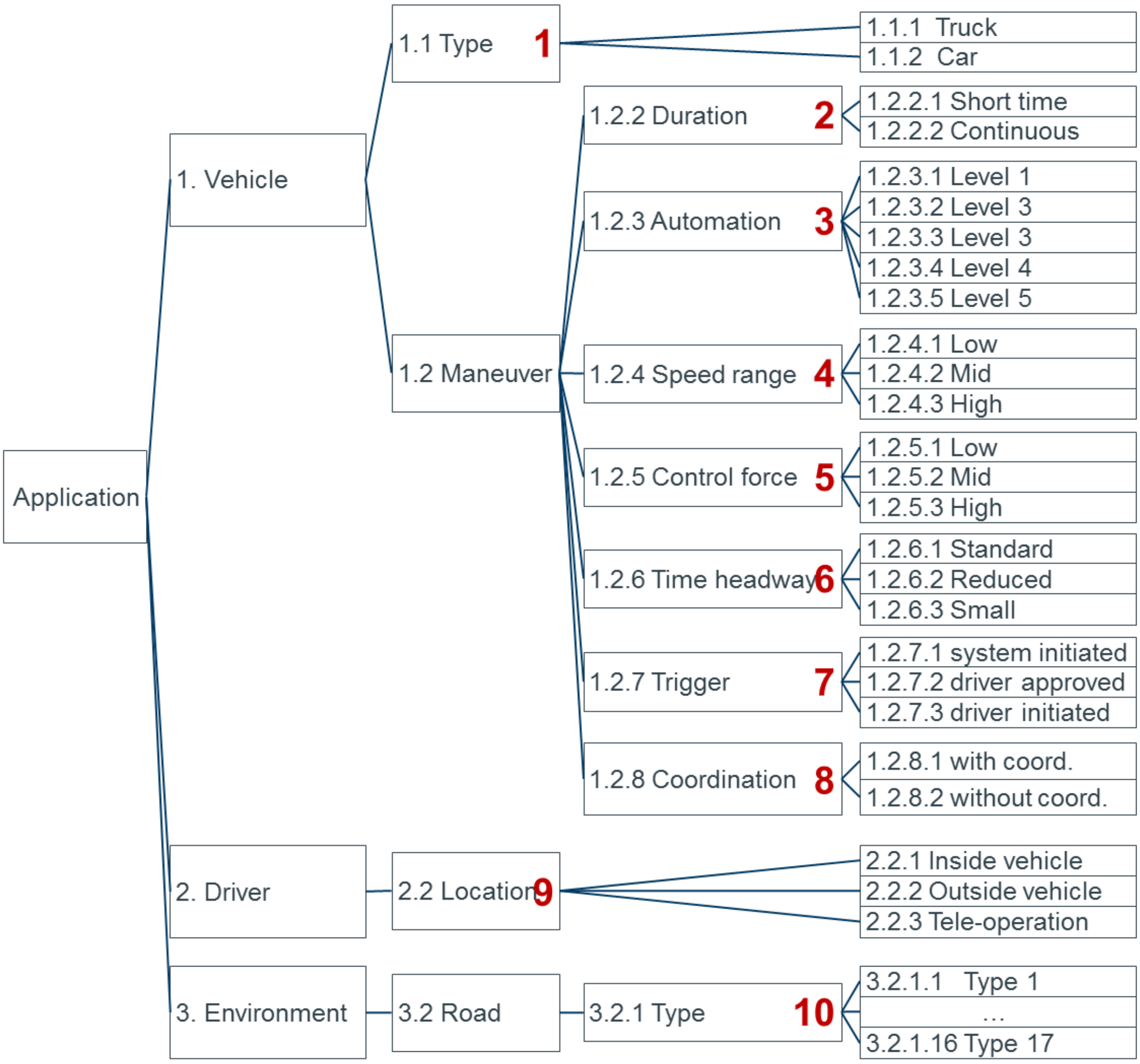

Figure 4.6: Overview of remaining parameters relevant for functional classification

Table 4.8: Parameter set for the classification of automated driving and parking functions

No.	Parameter	Range of values
1	Vehicle type	truck, car
2	Maneuver duration	short, long
3	Maneuver automation	Level 1 - 5
4	Maneuver velocity	low, mid, high
5	Maneuver control force	low, mid, high
6	Maneuver time headway	standard, reduced, small
7	Maneuver trigger	system initiated, driver approved, driver initiated
8	Maneuver Coordination	with coordination, without coordination
9	Driver's location	in vehicle, outside vehicle, tele-operated
10	Road type	type 1 -17 (see Table 4.7)

4.4.5 Assignment of relevant parameters to exemplary functions

In Table 4.9, several exemplary functionalities are included with their individual corresponding set of parameters. The particular functionalities are described in Annex 2.

Table 4.9: Exemplary driving and parking functionalities with corresponding parameters

	Exemplary function	*Maneuver automation*	*Road type*	*Maneuver duration*	*Maneuver velocity*	*Maneuver control force*	*Maneuver Time headway*	*Maneuver trigger*	*Maneuver coordination*	*Driver location*	*Vehicle type*
1	Cruise Control			long			n.a.				
2	Adaptive Cruise Control						standard				
3	Lane Keeping Assistance, Type II		1, 5- 9	long	high						
4	Active Lane Change Assistance			short							
5	Combined ACC and LKA, Type II	1		long			standard				
6	Active Traffic Light Assistance		10	short		Low					car truck
7	Narrowing Assistance		8-11		mid		n.a.			inside	
8	Construction Site Assistance		4	long							
9	Highway Assistance							driver initiated			
10	Overtaking Assistance	2	1,5 - 7	short	high		standard		no		
11	Traffic Jam Assistance			long	mid						
12	Parking Assistance with steering	1									
13	Parking Assistance with steering and accelerating/braking		11-13	short	low		n.a.				car
14	Key Parking	2								outside	
15	Tele Operated Driving - Urban		8 - 12	long	mid					tele	
16	Highway Chauffeur										
17	Overtaking Chauffeur	3	1,5	short	high	high	standard	driver approved		inside	car truck
18	Traffic Jam Chauffeur				mid						
19	Platooning			long	high		small	driver initiated	yes		
20	Highway Pilot			long	high						car truck
21	Overtaking Pilot		1,5	short				system initiated		inside	
21	Traffic Jam Pilot	4			mid			driver initiated			
22	Driverless Valet Parking		14		low	high					car
23	Urban Robot Taxi		8-12	long	mid					n.a.	car
24	Automated Mining Vehicles		16					System initiated			truck
25	Automated marshalling of trucks		17		low					n.a.	
26	Universal Robot Taxi	5	1-14		high						car

AdaptIVe

4.5 Identification of relevant parameters from legal, human factors and functional safety perspective

The following section evaluated which of the parameters identified above are relevant from a legal, human factors and functional safety perspective.

4.5.1 Relevant parameters from a legal perspective

The following questions should be answered to identify the relevant parameters for automated driving and parking functions from a legal perspective:

a) Which laws and regulations must be changed?

Table 4.10: Parameter relevance check-up from legal perspective

#	Parameter	Question	Relevance	Remark
1	Vehicle type	a)	Low	Not relevant for legal assessment
2	Maneuver duration	a)	Low	Not relevant for legal assessment
3	Maneuver automation	a)	**High**	According to the guiding principles of most traffic regulations, the driver must at least monitor and control any kind of action taken. If he is taken out-of-the-loop a variety of legal problem arises. Hence, for Levels 3+ systems Vienna Convention of 1968, national road traffic laws and vehicle regulations (e.g. UN ECE-R 79) have to be adopted. Liability issues may arise, burden of proof may be problematic.
4	Maneuver velocity	a)	Low	Not relevant for legal assessment
5	Maneuver control force	a)	Low	Not relevant for legal assessment
6	Maneuver time headway	a)	Low	Not relevant for legal assessment
7	Maneuver trigger	a)	**High**	If a maneuver is triggered by the system, the driver might not be able to exercise sufficient control. For Level 3+ systems Vienna Convention of 1968, national road traffic laws and vehicle regulations (e.g. UN ECE-R 79) have to be adopted. Liability issues may arise, burden of proof may be problematic.
8	Maneuver coordination	a)	**High**	Maneuver coordination requires the exchange of data. If one car provides faulty data, another car might have an accident. Therefore data liability issues may arise, burden of proof may be problematic. If the maneuvers are automatically executed and/or are triggered by the system, parameter 3 and 7 problems arise.
9	Driver's location	a)	**High**	If the driver is located outside of the vehicle, the vehicle steering would have to be controlled by externals signals. This is not permissible under UN ECE-R 79. Moreover it has to examined, if Art. 8 I Vienna Convention and national road traffic laws require the driver to be located in the driver's seat.
10	Road type	a)	**Mid**	Only relevant: public or private road.

4.5.2 Relevant parameters from a human factors perspective

The following questions should be answered to identify the relevant parameters for automated driving and parking functions from the human factors perspective:

a) Has inner compatibility between system and driver been assured (e.g. is the system behaving according to the driver's expectation and vice versa)?
b) Has outer compatibility between system and driver been assured? Is the driver physically able to interact according to what's expected from the system? E.g. can (s) he reach the controls and do so in a timely manner?
c) Are the transitions between different levels of automation designed such that the driver is kept in the loop in a way that allows the driver to respond in an accurate manner? E.g. humans are normally bad at monitoring system state for prolonged time and cannot always be considered a good back-up during e.g. system limitations or failures of system components.
d) Are all possible transitions taken into account in the design? E.g. driver or system initiated transitions, intended and unintended transitions.
e) Is the manner how the driver performs at transitions taken into account in the design?

Table 4.11: Parameter relevance check-up from human factors perspective

#	Parameter	Ques-tion	Rele-vance	
1	Vehicle type	a) b) c) d) e)	Low	From a human factors perspective the driver-vehicle interaction can be same/similar between different vehicle types (e.g. truck, passenger car). Individual characteristics such as vehicle load, lengths etc. might have an impact on selected maneuvers which directly transfers to how these maneuvers correspond to drivers' intent and own actions.
2	Maneuver duration	a) b) c) d) e)	**High**	Driver's abilities and actions can differ a lot depending on whether automation is presented during short or longer periods and if continuous or event-based interventions. Both conscious and reflexive driver actions should be taken into account in the design.
3	Maneuver automation	a) b) c) d) e)	**High**	Levels of automation depict different expectations on the driver where the driver is expected to be taking a more active role in lower levels compared to higher. Also for higher levels of automation (e.g. Conditional automation) the driver is expected to perform some kind of backup to the automated system and should be able to "promptly respond to a request to intervene". Also, systems acting on higher levels of automation might transfer to lower levels of automation for certain times. I.e. the transitions between levels of automations are crucial to appropriate design from a human factors perspective.
4	Maneuver velocity	a) b) c) d) e)	**Mid**	In higher speeds drivers might have less time to intervene when prompted by the system to do so. Drivers' ability to respond is also connected to headway and road type.
5	Maneuver control force	a) b) c) d) e)	**Mid**	A short and strong system action might demand a very high level of inner compatibility. If not the driver might reflexively counteract the system action resulting in unintended situations (e.g. driver might countersteer if the system's steering intervention is much stronger than what the driver would expect in a particular situation).
6	Maneuver time headway	a) b) c) d) e)	Low	Important from a driver response time perspective. Connected to maneuver velocity and road type.

7	Maneuver trigger	a) b) c) d) e)	**High**	It is very important from a Human Factors point of view to investigate how both system and driver initiated actions should be designed in an optimal way. In addition to this it is also crucial to not forget the unintended actions which can be initiated both from driver or system.
8	Maneuver coor-dination	a) b) c) d) e)	Low	V2X communication would allow for improved functionality and from a Human Factors perspective is seen as yet another sensor allowing for improved functionality.
9	Driver's location	a) b) c) d) e)	**Mid**	Will have an impact on the type of information needed from the system to the driver/operator, the type of I/O devices suitable, the possibility for the driver/operator to intervene etc.
10	Road type	a) b) c) d) e)	**Mid**	Road type complexity along with traffic density will have a strong influence on drivers' ability to e.g. promptly respond to a takeover request. This parameter is strongly linked to headway and velocity.

4.5.3 Relevant parameters from a functional safety perspective

The following questions should be answered to identify the relevant parameters for automated driving and parking functions from functional safety perspective:

a) Influence of parameter on potential risk as classified during hazard analysis and risk assessment

b) Influence of parameter on fail safe/fail operational requirements and safety concept

c) Influence of parameter on verification strategy

Table 4.12: Parameter relevance check-up from functional safety perspective

#	Parameter	Ques-tion	Rele-vance	Remark
1	Vehicle type	a)	Low	Levels 3, 4: Only relevant for a functional assessment regarding specific and individual vehicles.
		b)	Low	
		c)	Low	
2	Maneuver duration	a)	**Mid**	Levels 3, 4: Controllability of the vehicle in case of malfunctioning behavior may be better for functions with short maneuver duration where the driver cannot engage in other tasks compared to maneuvers with long duration.
		b)	Low	Levels 3, 4: Because the driver is not required to monitor[1] the driving environment and to respond to objects and events, the maneuver duration is not relevant for all durations exceeding the take over time for the driver.
			Mid	Level 3: The required fault tolerant system architecture will need to have a fault tolerance time of at least the take over time. Level 4: The required fault tolerant system architecture will need to have a fault tolerance time of at least the time to conclude a minimal risk maneuver.
		c)	Low	
3	Maneuver automation	a)	**High**	Levels 3+: Significant difference. Levels 3, 4, 5 are different from Levels 1, 2 since the driver is not required to monitor[1] the driving environment at all times.

[1] If the driver is not required to monitor the driving environment, then he does not need to accomplish comprehensive object and event detection, recognition, classification, and response (OEDR), as needed to competently perform the dynamic driving task. See also the definition of the term "monitor" in Annex 4.

		b)	**High**	Levels 3+: The most significant difference. Levels 3, 4, 5 are different from Levels 1, 2 since the driver is not required to monitor[1] the driving environment at all times. The system has to take over the responsibilities that remained with the driver for levels 1, 2.
		c)	**High**	Levels 3+: Out of the 10 parameters this is the one with significant influence. All the others are of minor interest from a methodological point of view. Main difference is for functional insufficiencies that need additionally to be covered for Levels 3+.
4	Maneuver velocity	a)	**Mid**	All levels: With increasing maneuver velocity severity of harm resulting from a malfunctioning behavior may increase.
		b)	Low	All levels: Velocity does not have a direct impact on the safety concept. Determining factor is level of automation.
		c)	Low	
5	Maneuver control force	a)	**Mid**	Levels 1, 2: Because the driver is required to monitor[1] the driving environment, the level of the control force is of interest.
			Low	Levels 3, 4: Because the driver is not required to monitor[1] the driving environment, the level of the control force is of minor interest.
		b)	**Mid**	Levels 1, 2: Because the driver is required to monitor[1] the driving environment, the level of the control force is of interest.
			Low	Levels 3, 4: Because the driver is not required to monitor[1] the driving environment, the level of the control force is of minor interest
		c)	Low	
6	Maneuver time headway	a)	Low	Levels 3+: Because the driver is not required to monitor[1] the driving environment, a differentiation of maneuver time headway that is shorter than a defined take over time is of minor interest
		b)	Low	Levels 3+: Because the driver is not required to monitor[1] the driving environment, a differentiation of maneuver time headway that is shorter than a defined take over time is of minor interest.
			Mid	Level 3: The required fault tolerant system architecture will need to have a fault tolerance time of at least the take over time. Level 4: The required fault tolerant system architecture will need to have a fault tolerance time of at least the time to conclude a minimal risk maneuver.
		c)	Low	
7	Maneuver trigger	a)	Low	All levels: Malfunctioning behavior of a system, no matter whether it results in an inadvertent activation (not attended or anticipated by the driver) or a wrong control action for the vehicle may both pose a risk for the driver
		b)	Low	All levels: Whether a function is driver initiated or activated by the system will have an influence on the system design, but not on the fail operational requirements
		c)	Low	
8	Maneuver coordi-nation	a)	Low	
		b)	Low	
		c)	Low	
9	Driver's location	a)	Low	All levels: Assuming that the driver's possibilities to react are similar from different locations (remote controlled, in the driver's seat)
		b)	Low	All levels: Assuming that the driver's possibilities to react is similar from different locations (remote controlled, in the driver's seat)
		c)	Low	

10	Road type	a)	**Mid**	Level 3, 4: Relevant for vehicle systems that are limited to a subset of road types and must not be operational on certain other road types.
		b)	**Mid**	Level 3, 4: Relevant for vehicle systems that are limited to a subset of road types Whether a system may be activated for a certain road type will have an influence on the system design, but not on the fail operational requirements.
		c)	Low	

4.5.4 Overview of relevant parameters

The following table shows an overview of the parameter set for the classification of automated driving and parking functions and their relevance regarding legal, human factors and functional safety aspects.

Table 4.13: Parameter relevance check overview

#	Parameter	Legal aspects	HMI aspects	Functional safety aspects		
	Question	a)	a)	a)	b)	c)
1	Vehicle type	Low	Low	Low	Low	Low
2	**Maneuver duration**	Low	**High**	**Mid** L3,4	**Mid** L3,4	Low
3	**Maneuver automation**	**High**	**High**	**High** L3+	**High** L3+	**High** L3+
4	**Maneuver velocity**	Low	**Mid**	**Mid** L1+	**Mid** L1+	Low
5	**Maneuver control force**	Low	**Mid**	**Mid** L1,2	**Mid** L1,2	Low
6	**Maneuver time headway**	Low	Low	Low	**Mid** L3,4	Low
7	**Maneuver trigger**	**High**	**High**	Low	Low	Low
8	**Maneuver coordination**	**High**	Low	Low	Low	Low
9	**Driver's location**	**High**	**Mid**	Low	Low	Low
10	**Road type**	**Mid**	**Mid**	**Mid** L3,4	**Mid** L3,4	Low

The following parameter shows only low relevance from a legal, human factors and functional safety perspective and therefore will be disregarded in the following for functional classification: (1) vehicle type.

4.6 Functional class forming by parameter combinatorics

In the following it was assumed, that relevant parameters which must be systematically combined with each other for a classification of automated driving and parking functions are (2) maneuver duration, (3) maneuver automation, (4) maneuver velocity and (10) road type.

The following parameters were not considered in the combinatorics for class formation but were evaluated separately in the following subsection taking into account the functions of SP 4–6 as well as the exemplary functions explained in Annex 2: (5) maneuver control force, (6) maneuver time headway, (7) maneuver trigger, (8) maneuver coordination and (9) driver's location. Table 4.14 shows a systematic approach for building up different classes using the parameters automation level, maneuver duration, maneuver velocity and road type.

Table 4.14: Parameter combinatorics for class forming

	maneuver duration	Short			Long		
	maneuver velocity	Low	Mid	High	Low	Mid	High
Automation level	Level 1	road type A	road type A	road type A	road type A	road type A	road type A
		road type B	road type B	road type B	road type B	road type B	road type B
	Level 2	road type A	road type A	road type A	road type A	road type A	road type A
		road type B	road type B	road type B	road type B	road type B	road type B
	Level 3	road type A	road type A	road type A	road type A	road type A	road type A
		road type B	road type B	road type B	road type B	road type B	road type B
	Level 4	road type A	road type A	road type A	road type A	road type A	road type A
		road type B	road type B	road type B	road type B	road type B	road type B
	Level 5	n.a.			road type A		
					road type B		

The following combinations have been excluded:

- Level 5 systems with short maneuver duration: Level 5 means continuous and full automation for any on-road journey from origin to destination which cannot be short

Furthermore, a differentiation in maneuver velocity is inadequate for level 5 systems since Level 5 systems must accomplish any on-road journey from origin to destination which includes all velocities, and all on-road locations and conditions in which a human driver can legally operate a vehicle. Level 0 systems are not considered because they do not automate any part of the dynamic driving task on a sustained basis.

4.7 Elimination of unnecessary functional classes

Table 4.15 shows the classification of all functions of SP4, SP5 and SP6 as well as the classification of the exemplary functions (ExF) mentioned above and explained in detail in Annex 2. It becomes obvious that

- Level 1, 2: Long time maneuvers at low speed are not relevant
- Level 3: Long and short time maneuvers at low speed are not relevant
- Level 4: Short time maneuvers at mid speed are not relevant
- Level 5: Short time maneuvers are not relevant

Remark 1: Various automated driving functions are designed for the full speed range, thus are operated at high, medium and low speeds. E.g. a full speed range ACC (Level 1) can be operated on a highway with fast moving traffic (high speed), in a traffic jam (mid speed) or in a stop-and-go situation below 20 km/h (low speed). The same applies for a highway assist (Level 2), a highway chauffeur (Level 3) or a highway pilot (Level 4). For simplification those systems are noted only once in Table 4.15 at maneuver velocity “high”.

Remark 2: Table 4.15 does not distinguish between integrated functions and single functions with integrated functions being composed of multiple single functions. E.g. the integrated exemplary function “highway chauffer” is at a minimum composed of the SP6 single functions “lane following”, “lane change (and overtaking)”, “stop & go driving” and “danger spot intervention”.

Remark 3: Specific single functions might be qualified to be stand-alone functions that can be sold as a product, e.g. “adaptive cruise control”, “active lane change assistance” or “overtaking assistance”. Other single functions should be part of an integrated function and appear to be pointless as stand-alone functions. This is mostly the case for short time Level 3 and Level 4 driving functions, e.g. the SP6 functions “cooperative merging with speed adaptation” and “speed time gap adaptation at a motorway entrance ramp” or the exemplary Level 3 function “overtaking chauffer” or the exemplary Level 4 function “overtaking pilot”.

Driver’s location “outside vehicle”: The only relevant functions with driver location “outside vehicle” are Level 2 parking functions. Here functions with the driver being inside of the vehicle (parking assistance with steering and accelerating/braking) as well as functions with the driver being outside of the vehicle occur (key parking). Consequently, for these kinds of functions the driver’s location will be considered by forming two separate classes with driver “inside” and “outside”.

Maneuver time headway: The only relevant functions with maneuver time headway “small” are Level 3 high speed driving functions on motorways. Here functions with standard time headway (highway chauffeur) as well as functions with small time headway occur (platooning). Consequently for these kinds of functions, maneuver time headway will be considered by forming two separate classes with maneuver time headway “standard” and “small”.

Driver location “Tele-operated”: This parameter is relevant from the legal and human factors perspectives. In theory tele-operated systems are thinkable for Level 2, 3, 4 and 5 automation (see Table 4.3, row 2.2.3, tele-operation) with different velocities, maneuver durations and road types. If tele-operation is taken into account, the number of classes must consequently be doubled. In practice, tele-operated functions have little relevance. Therefore tele-operated functions will be disregarded in the following for simplification.

Maneuver trigger: Looking at the specific functional parameters of SP4, SP5 and SP6 as well as the exemplary functions (see Table 5.7, Table 5.8, Table 5.9, Table 5.10), it becomes obvious that maneuvers are triggered by the system for robot taxis, trucks in mining and marshalling areas as well as for overtaking pilot. These functions are still considered as separate classes.

Therefore considering maneuver trigger will not lead to new classes and therefore will be disregarded in the combinatorics for class forming.

Maneuver control force: Looking at the specific functional parameters of SP4, SP5 and SP6 as well as the exemplary functions (see Table 5.7, Table 5.8, Table 5.9, Table 5.10), it becomes obvious that there is a strong correlation between velocity and control force: high velocity ⇨ low control force, medium velocity ⇨medium control force, low velocity ⇨high control force. Here the magnitude of control force is primarily defined by the steering momentum. Velocity is still considered as a parameter. Considering control force will not lead to new classes and therefore will be disregarded in the combinatorics for class forming.

Maneuver coordination: From a legal perspective, the relevance of this parameter has been evaluated as "high", because burden of proof may be problematic in the case of an accident due to faulty V2V data. It is proposed to treat this specific legal issue – namely burden of proof in the case of faulty V2V data – separately as a higher-level topic and not to consider this in the combinatorics for class formation.

Table 4.15: Classes with functions from SP4, SP5, SP6 and exemplary functions from Annex 2

Automation level	Maneuver duration	Short			Long		
	Maneuver velocity	**Low**	**Mid**	**High**	**Low**	**Mid**	**High**
Automation level	Level 1	Road type: parking area/deck, roadside - ExF - Parking Assistance with steering	Road type: Urban road - ExF - Active Traffic Light Assistance	Road type: Motorway or similar road - ExF - Active Lane Change Assistance	n.a.	Road type: Urban road - ExF - Narrowing Assistance Road type: Construction site - ExF - Construction Site Assistance	Road type: Interstate, Highway, Motorway - ExF - Cruise Control - ExF - Adaptive Cruise Control - ExF - Lane Keeping Assistance, Type II - ExF - Combined ACC and LKA, Type II
Automation level	Level 2	Road type: parking area/deck, roadside - ExF - Parking Assist. with steering and accelerating/braking - ExF - Key Parking[1] - SP4 - Pholova Park Assistant[1] Road type: Private parking garage - SP4 - Automated Parking Garage Pilot[1]	Road type: Urban road - SP5 - Supervised City Control: obstacle or VRU on the road Road type: Construction site - SP4 - Construction Site Maneuver	Road type: Motorway or similar road - ExF - Overtaking Assistance - SP6 - enter and exit of a motorway - SP6 - cooperative response on emergency vehicle on duty	n.a.	Road type: Urban road - SP5 - Supervised City Control: vehicle following in lane - SP5 - Supervised City Control: lane following and speed adaptation Road type: Interstate, Highway, Motorway - ExF - Traffic Jam Assistance	Road type: Motorway or similar road - ExF - Highway Assistance

	Maneuver duration	Short			Long		
	Maneuver velocity	**Low**	**Mid**	**High**	**Low**	**Mid**	**High**
Automation level	Level 3	n.a.	Road type: Urban road - SP5 - City Chauffeur: lane change - SP5 - City Chauffeur: intersections handling - SP5 - City Chauffeur: roundabouts handling - SP5 - City Chauffeur: traffic lights handling - SP5 - City Chauffeur: obstacle or VRU on the road	Road type: Motorway or similar road - ExF - Overtaking Chauffeur - SP6 - danger spot intervention - SP6 - cooperative merging with lane change - SP6 - cooperative merging with speed adaptation - SP6 - speed / time gap adaptation at a motor-way entrance ramp - SP6 - lane change (and overtaking)	n.a.	Road type: Motorway or similar road - ExF - Traffic Jam Chauffeur - SP6 - stop & go driving Road type: Urban road - SP5 - City Chauffeur: lane following and speed adaptation - SP5 - City Chauffeur: vehicle following in lane	Road type: Motorway or similar road - ExF - Highway Chauffeur - ExF - Platooning[3] - SP6 - predictive automated driving - SP6 - lane following
	Level 4	Road type: Parking area/deck - SP4 - Automated Park Assistant	n.a.	Road type: Motorway or similar road - ExF - Overtaking Pilot[2]	Road type: Private parking area/deck ExF - Driverless Valet Parking Road type: Private marshalling area of forwarding company - ExF - Automated marshalling of trucks[2]	Road type: Motorway or similar road - ExF - Traffic Jam Pilot Road type: Urban road - ExF - Urban Robot Taxi[2] Road type: Private shuttling road of mining company - ExF - Automated Mining Vehicles[2]	Road type: Motorway or similar road - ExF - Highway Pilot

	Maneuver duration	Short			Long		
	Maneuver velocity	Low	Mid	High	Low	Mid	High
Autom. level	Level 5	n.a.			Road type: parking area/deck, Urban road, Interstate, Highway, Motorway - ExF - Universal Robot Taxi[2]		

[1] driver location: outside of vehicle, [2] maneuver trigger: system, [3] maneuver time headway: small

After filtering out the irrelevant classes, 33 relevant functional classes were identified and are depicted in Table 4.16 together with one functional example per class (*in parentheses*). The number of classes might be increased in the future if automated driving functions are extended to other road types such as rural roads. Fortunately an extension of the classification with new road types is easily achievable and straightforward.

Table 4.16: Classes with functions from SP4, 5, 6 and exemplary functions

<table>
<tr><th></th><th>Maneuver duration</th><th colspan="3">Short</th><th colspan="3">Long</th></tr>
<tr><th></th><th>Maneuver velocity</th><th>Low</th><th>Mid</th><th>High</th><th>Low</th><th>Mid</th><th>High</th></tr>
<tr><td rowspan="7">Automation level</td><td rowspan="2">Level 1</td><td rowspan="2">1
Parking area/deck, roadside
(Parking Assist. with steering)</td><td rowspan="2">2
Urban road
(Active Traffic Light Assist.)</td><td rowspan="2">3
Motorway or similar road
(Active Lane Change Assist)</td><td rowspan="2">n.a.</td><td>4
Urban road
(Narrowing Assistance)</td><td rowspan="2">6
Interstate, Highway, Motorway
(ACC)</td></tr>
<tr><td>5
Construction site
(Construction Site Assistance)</td></tr>
<tr><td rowspan="3">Level 2</td><td>7
Parking area/deck roadside, driver inside
(parking assist. with steering accel./braking)</td><td>10
Urban road
(Supervised City Control: VRU on the road)</td><td rowspan="3">12
Motorway or similar road
(Overtaking assistant)</td><td rowspan="3">n.a.</td><td rowspan="2">13
Urban road
(Supervised city control)</td><td rowspan="3">15
Motorway or similar road
(Highway assistant)</td></tr>
<tr><td>8
Parking area/deck roadside, driver outside*(key parking)*</td><td rowspan="2">11
Construction site
(Constr. site maneuver)</td></tr>
<tr><td>9
Private parking garage
(Automated garage paring)</td><td>14
Interstate, Highway, Motorway
(Traffic jam assistance)</td></tr>
<tr><td rowspan="2">Level 3</td><td rowspan="2">n.a.</td><td rowspan="2">16
Urban road
(City Chauff. - lane change)</td><td rowspan="2">17
Motorway or similar road
(Highway Chauffeur - overtaking)</td><td rowspan="2">n.a.</td><td>18
Motorway or similar road
(Traffic Jam Chauffeur)</td><td>20
Motorway or similar road Time headway standard
(Highway Chauffeur)</td></tr>
<tr><td>19
Urban road
(City Chauff. - lane following)</td><td>21
Motorway or similar road Time headway small
(Platooning)</td></tr>
</table>

<table>
<tr><th></th><th>Maneuver duration</th><th colspan="3">Short</th><th colspan="3">Long</th></tr>
<tr><th></th><th>Maneuver velocity</th><th>Low</th><th>Mid</th><th>High</th><th>Low</th><th>Mid</th><th>High</th></tr>
<tr><td rowspan="4">Automation level</td><td rowspan="3">Level 4</td><td rowspan="3">22
Parking area/deck
(Automated Parking)</td><td rowspan="3">n.a.</td><td rowspan="3">23
Motorway or similar road[2]
(Highway Pilot - overtaking)</td><td rowspan="2">24
Private parking area/deck
(Driverless valet parking)</td><td>26
Motorway or similar road
(Traffic jam pilot)</td><td rowspan="3">29
Motorway or similar road
(Highway Pilot)</td></tr>
<tr><td>27
Urban road
(Urban robot taxi)</td></tr>
<tr><td>25
Private marshalling area of forwarding company[2]
(Automated marshalling of trucks)</td><td>28
Private shuttling road of mining company[2]
(Automated mining vehicles)</td></tr>
<tr><td>Level 5</td><td colspan="3">n.a.</td><td colspan="3">30
parking area/deck, roadside, urban road, interstate, highway, motorway[2]
(Universal robot taxi)</td></tr>
</table>

[2] maneuver trigger by system

5 Conclusion

A systematic approach for the unambiguous classification of automated driving and parking functions has been provided, completing and exceeding existing functional definitions.

A classification scheme has been established for this purpose: All relevant parameters for a classification of automated driving and parking functions have been systematically collected. The amount of parameters was reduced by identifying and eliminating redundant and unnecessary parameters, including by assessing those parameters regarding legal, human factors and functional safety aspects.

By applying the remaining parameter set to the automated driving and parking functions defined in SP4, 5 and 6 as well as the exemplary functions described in Annex 2, a set of 33 functional classes has been finally identified using 4 parameters for combinatorics (automation level, maneuver duration, maneuver velocity, road type) and 2 parameters for special cases (driver location and time headway). An extension of those classes – e.g. if new automated driving and parking functions will be designed in the future – can be easily achievable in a straight forward manner by adding more classes for a specific parameter or even by adding a new parameter (although the proposed set of parameters is considered representative for the problem at hand).

Annex 1 Definition of automation levels

The following section provides an overview of the current status regarding definition of automation levels. Definitions of SAE, VDA, BASt, NHTSA and others are briefly explained with an emphasis on SAE definitions; common and distinguishing features of those definitions are identified and explained. Example functions are given together with a descriptive differentiation between adjacent automation levels.

A 1.1 SAE

The SAE working group “On-roads Automated Vehicle Standards Committee” was established in 2011. Members include engineers from different OEM’s and suppliers as well as universities, government agencies and civil & military research institutes. One objective of the working group was the development of standard J3016 “Taxonomy and Definitions for Terms Related to On-Road Motor Vehicle Automated Driving Systems” [2] published in January 2014. Some extracts from this standard which were published at TRB workshop at Stanford University in July 2013 [8] are shown and discussed in the following section. The complete standard can be ordered via the SAE homepage.

Table 5.1: Terms and categorization of autom. driving and parking functions acc. to SAE [2]

SAE Level	SAE name	SAE narrative definition	Execution of steering and acceleration/ deceleration	Monitoring of driving environment	Fall-back performance of dynamic driving task	System capability (driving mode)	BASt Level	NHTSA level
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.	Driver Only	0
1	Driver Assisted	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	Assis-ted	1
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* performs all remaining aspects of the *dynamic driving task*	System	Human driver	Human driver	Some driving modes	Partial Auto-mated	2
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	Highly Auto-mated	3
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	Fully Auto-mated	3/4
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		

A 1.1.1 Level 0

Level 0 systems cannot execute longitudinal or lateral control but may issue warnings to the driver.

The driver's task is to monitor the driving environment and to execute the complete dynamic driving task (steering, accelerating/braking, OEDR). The system does not provide any automation of the dynamic driving task on a sustained basis but may provide warnings [2].

Typical examples include: Forward collision warning (FCW), blind spot warning (BSW), lane departure warning (LDW).

Remark 1: Automation in the sense of SAE, VDA and BASt means, that parts of the driving task are deliberately delegated to the technical system so that the driver is released from those tasks. This does not include systems which are active in the background ready to intervene if the driver cannot manage the driving situation. Those systems would only intervene in emergency or crash imminent situations.

This might be illustrated with the following metaphor: Non-automated systems react similarly to a driving instructor while automated systems act like a chauffeur. The driving instructor does not release the driver from the driving task and intervenes only in case of an emergency or crash imminent situations. In contrast, the chauffeur replaces the driver and releases him from the specific driving task.

Remark 2: According to this definition non-automated systems would include FCW, BSW and LDW as well as emergency braking, emergency steering and emergency stopping. Those non-automated systems might be classified as follows: (A) informing or warning systems: FCW, BSW, LDW; (B) intervening systems at emergency or crash imminent situations: emergency braking, emergency steering and emergency stopping. These systems have been classified by Gasser et al. as a discrete functional class apart from automation as "Intervening emergency functions (near accident situations) that take immediate control over the vehicle in near-accident situations that de facto cannot be controlled/handled by the driver (usually safety functions)" [5]. This approach has been adopted by AdaptIVe and VDA (for more details see 4.1).

Remark 3: Such non-automated functions will intervene with lateral and/or longitudinal control for short non-sustained periods of time and may control the vehicle system in ways that no driver could achieve. Electronic Stability Control (ESC) affects lateral and longitudinal control through applying the brakes on individual wheels to control the vehicle heading and can limit motor torque, but is still considered to be non-automated because such interventions are momentary and not considered as performance of the dynamic driving task on a sustained basis.

A 1.1.2 Level 1

While Level 0 systems cannot execute any parts of the dynamic driving task, Level 1 systems execute parts of the dynamic driving task (steering, accelerating/braking) The driver is in the loop completing the dynamic driving tasks consisting of the object and event detection and response (OEDR) subtask and either lateral or longitudinal control that is not being automated.

The driver's task is to monitor the driving environment, to execute either longitudinal (acceleration/braking) or lateral (steering) dynamic driving task, to constantly supervise the dynamic driving task executed by driver assistance system, to determines when activation or deactivation of assistance system is appropriate and to take over immediately when required [2].

The system executes those portions of the dynamic driving task which are not executed by the human driver when activated and can deactivate immediately with request for immediate takeover by the human driver [2].

Typical examples include: Adaptive Cruise Control (ACC), Parking Assistance with automated steering, Lane Keeping Assistance (LKA) Type II and a combination of ACC with LKA Type II systems.

Remark 1: The driver may not perform secondary side-tasks as this will hamper him in taking over immediately when required. This shall be without prejudice to commonly accepted non-driving-related activities such as changing radio stations or air conditioning settings.

Remark 2: Current LKA systems require the driver to apply a steering momentum. If the driver doesn't do so, the system is disengaged and a takeover request is issued. The driver is still responsible for supervising and executing lateral control in parts (he must apply a steering momentum) and therefore is still continuously involved into the dynamic driving task. This is true for LKA systems, which apply a course corrective steering momentum, if the vehicle is going to leave the lane (Type I systems) and also if the vehicle is going to leave the center of the lane (Type II systems). This is also true for a combination of ACC and Type I or Type II LKA so this combination is still a Level 1 system. Only a combination of ACC and lane centered lateral control, where the driver need not apply any steering momentum (LKA Type III), would be a Level 2 system.

Remark 3: Existing driver assistance systems continuously affecting longitudinal and lateral control as well as combinations of such systems are depicted in Table 5.2 together with their level of automation. Cruise Control (CC), Adaptive Cruise Control (ACC) and Lane Keeping Assistance (LKA) are explained in A2.1, A2.2 and A2.3, respectively. LKA Type I & II systems refer to LKA systems that apply a course corrective steering momentum if the vehicle is going to leave the lane or the center of the lane, while LKA Type III systems center the vehicle in the middle of the lane without the driver applying any steering momentum. It becomes obvious, that those systems and their combination are mostly Level 1 systems.

Table 5.2: Automation level of existing driver assistance systems and their combinations

<table>
<tr><th rowspan="3">No.</th><th rowspan="3">Example</th><th colspan="3">Driving Task accomplished by system</th><th rowspan="3">Level of auto-mation</th></tr>
<tr><th colspan="2">Longitudinal Control</th><th>Lateral Control</th></tr>
<tr><th>speed keeping</th><th>distance keeping</th><th>lane keeping</th></tr>
<tr><td>1</td><td>CC</td><td>completely</td><td colspan="2">none</td><td>1</td></tr>
<tr><td>2</td><td>ACC</td><td colspan="2">completely</td><td>none</td><td>1</td></tr>
<tr><td>3</td><td>LKA Type I&II</td><td colspan="2">none</td><td>in parts</td><td>1</td></tr>
</table>

4	LKA Type III	none		completely	1
5	CC + LKA Type I&II	completely	none	in parts	1
6	CC + LKA Type III	completely	none	completely	1
7	ACC + LKA Type I&II	completely		in parts	1
8	ACC + LKA Type III	completely			2

It might be argued from a technical perspective, that the Level 1 systems in Table 5.2 should be divided into sub classes, e.g. one sub class for lateral and another sub class for longitudinal control. Both from a legal perspective and from a human factors perspective, what all these systems have in common is that the driver is physically in the loop – i.e. he is still obliged to perform object and event detection and response (OEDR), and to steer or to accelerate/decelerate at any time. Therefore SAE, VDA, BASt and NHTSA have decided to merge those systems in a single automation level.

A 1.1.3 Level 2

While Level 1 systems share the dynamic driving task (steering, accelerating/braking, OEDR) between driver and system, Level 2 systems execute the lateral and longitudinal control dynamic driving subtasks completely with the driver in the loop executing the OEDR subtask.

The driver's task is to execute the OEDR by monitoring the driving environment and responding if necessary, to constantly supervise the lateral and longitudinal control dynamic driving subtasks executed by the system, to determine when activation or deactivation of the system is appropriate, and to take over immediately when required [2].

The system executes longitudinal (accelerating, braking) and lateral (steering) dynamic driving tasks when activated and can deactivate immediately upon request for immediate takeover by the human driver [2].

Typical examples include: Traffic Jam Assistance (refer to A2.9) and Key Parking (refer to A2.14).

Remark 1: As for Level 1 systems the driver may not perform secondary tasks which will hamper him in taking over immediately when required. This shall be without prejudice to commonly accepted non-driving-related activities such as changing radio stations or air conditioning settings.

Remark 2: In Level 2 systems the driver is no longer continuously involved in the lateral and longitudinal control subtask of the dynamic driving task; the driver does not have to constantly steer or accelerate/brake, so he is disengaged from constantly physically operating the vehicle e.g. by having his hands off the steering wheel and foot off pedal at the same time. Although the driver is physically disengaged, mentally the driver must be engaged and must monitor the driving environment and must immediately intervene when required, e.g. in case of an emergency or system failure.

A 1.1.4 Level 3

While Level 2 systems require the driver to be attentive and to monitor the driving environment, Level 3 systems allow the driver to turn his attention away from the complete dynamic driving task (steering, accelerating/braking, OEDR) in certain domains that the system is designed to operate in, e.g. during a traffic jam on a motorway.

The driver’s task is to determine when activation of the automated driving system is appropriate and to take over upon request within a limited period of time. The driver may also request deactivation of the automated driving system [2].

The system monitors the driving environment when activated; permits activation only under conditions (use cases and operational design domain) for which it was designed; executes longitudinal (accelerating/braking) and lateral (steering) portions of the dynamic driving task when activated; deactivates only after requesting the driver to take-over with a sufficient lead time; may – under certain, limited circumstances – transition to minimal risk condition if the human driver does not take over; and may momentarily delay deactivation when immediate human takeover could compromise safety [2].

Typical example: Traffic Jam Chauffeur (refer to A2.15).

Remark 1: For Level 3 systems, with the driver providing the ultimate fallback performance, he must be in position to resume control within a short period of time when a takeover request occurs. This may happen with an increased lead time, but the driver must react. Therefore only secondary tasks with appropriate reaction time are allowed. This would in an extreme case exclude e.g. sleeping. Driver activation monitoring might be used to avoid such unintended use. Potential technical solutions range from detecting the driver’s manual operations to monitoring cameras to detect the driver’s head position and eyelid movement.

Remark 2: To enable predictable and reproducible takeover scenarios it would be beneficial if vehicle displays that are controlled by the automation system would be used for secondary tasks (e.g. texting, internet surfing, video-telephony). If a takeover request occurs the secondary task content on the display is faded out and the takeover request is displayed instead.

Remark 3: The driver is not capable of reacting to emergency braking maneuvers of the vehicle in front of the driver due to secondary tasks. Such scenarios must be accomplished by the system.

A 1.1.5 Level 4

While Level 3 systems have some restrictions concerning secondary tasks and have the human driver providing fallback performance, Level 4 systems do not have those restrictions. Secondary tasks with long reaction times (e.g. reading a newspaper) are allowed and even driverless applications such as Driverless Valet Parking are possible (see below).

The driver's task is to determine when activation of the automated driving system is appropriate, and to take over upon request within lead time. The driver may also request deactivation of automated driving system [2].

The system monitors the driving environment when activated, permits activation only under conditions (use cases and operational design domain) for which it was designed, and executes longitudinal (accelerating, braking) and lateral (steering) portions of the dynamic driving task as well as OEDR when activated. It also initiates deactivation when design conditions are no longer met – e.g. requests driver to take over and initiates deactivation to reach a minimal risk condition if driver does not respond to the takeover request – fully deactivates only after human driver takes over or minimal risk condition is achieved; transitions to minimal risk condition if human driver does not take over, and may momentarily delay deactivation when immediate human takeover could compromise safety [2].

Typical example: Driverless Valet Parking, Traffic Jam Pilot (refer to A2.19, A2.21).

Remark: Level 4 systems do not require the driver to provide fallback performance. Therefore the system must be capable of transferring the vehicle to a minimal risk condition within the operational design domain. This might increase technical effort.

A 1.1.6 Level 5

While Level 4 systems accomplish vehicle guidance only in a specific operational design domain – e.g. during a traffic jam on a motorway – and do not offer high automation apart from that specific operational design domain, level 5 systems can accomplish the complete journey from origin to destination in a high automation modus, and can do so anywhere on-road that a human can legally drive a vehicle. Except activation, deactivation and determining waypoints and destinations, no human driver is required any longer.

The driver may activate the automated driving system and may request deactivation of the automated driving system [2].

When activated, the system monitors the driving environment, executes longitudinal (accelerating/ braking) and lateral (steering) as well as the OEDR subtasks of the dynamic driving task, deactivates only after the human driver takes over or vehicle reaches its destination, transitions to a minimal risk condition as necessary if failure in the automated driving system occurs, and may momentarily delay deactivation when immediate human driver takeover could compromise safety [2].

Typical example: Universal Robot Taxi (refer to A2.27).

Remark 1: Level 5 systems can complete any on-road journey from origin to destination without the help of a human driver. Consequently typical driver controls are not required in an extreme scenario (no steering wheel, pedals or instrument cluster). Completely new vehicle designs or even completely new classes of vehicles are possible.

Remark 2: In a theoretical analysis of vehicle automation, Level 5 systems must be considered because they complete the automation scale. Such systems are not in the focus of AdaptIVe because it is unlikely that they will be available as a product in the foreseeable future.

A 1.2 AdaptIVe flow chart

The flow chart in Figure 5.1 may be helpful for the assignment between functions and automation levels.

Check-up question for Level 0 systems: Assuming that a driver assistance system is active, are lateral control (steering) and/or longitudinal control (accelerating/braking) – in part or completely – continuously assigned to the system? If no, then it is a Level 0 system.

Check-up question for Level 1 systems: Assuming that parts of lateral and/or longitudinal control are continuously accomplished by the system; is the driver still constantly required to steer or to accelerate/decelerate in response to certain driving events? If yes, then it is a Level 1 system.

Check-up question for Level 2 systems: Assuming that the driver neither has to steer nor to accelerate/brake constantly; is the driver still obliged to constantly monitor the system and the driving environment and to be ready to intervene when necessary? If yes, then it is a Level 2 system.

Check-up question for Level 3 systems: Assuming that the driver is not performing any part of the dynamic driving task and is therefore allowed to perform specific secondary tasks, is the driver – with increased response time – still obliged to respond to a takeover request? If yes, then it is a Level 3 system.

Check-up question for level 4 systems: Assuming that the driver is not performing any part of the dynamic driving task and is not obliged to respond to a take-over request, is the system able to accomplish the dynamic driving task only in a restricted use case and operational design domain and not for every on-road journey from origin to destination? If yes, then it is a level 4 system.

Check-up question for Level 5 systems: Assuming that automation completes the dynamic driving task during any journey without being restricted to a use case or domain of operation, can the driver theoretically be removed from the vehicle? If yes, then it is a Level 5 system.

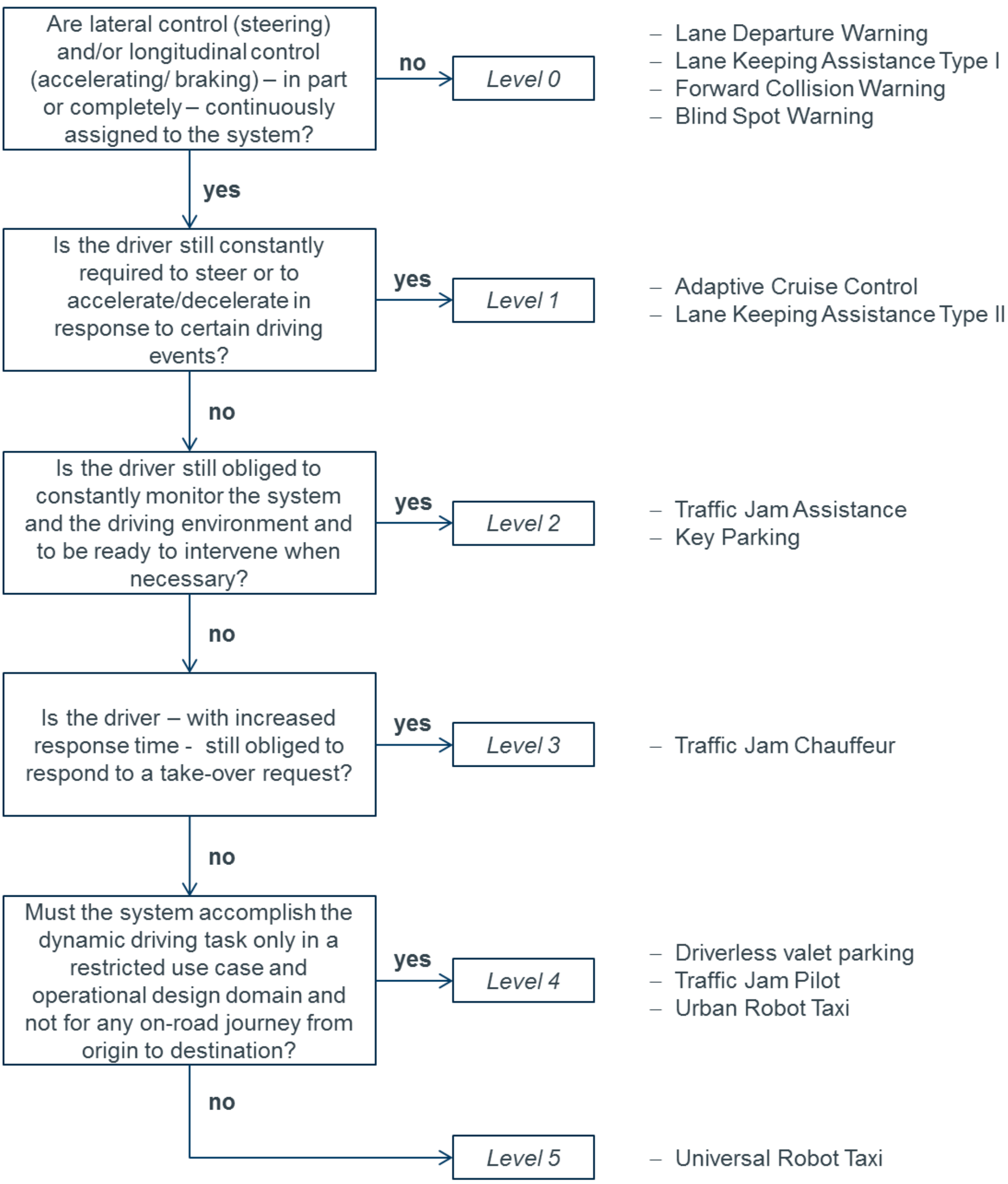

Figure 5.1: Flow chart for assignment between functions and automation levels

A 1.3 VDA

The VDA working group “Vehicle Automation” was established in October 2012. Members are (in alphabetical order) Audi, BMW, Bosch, Continental, Delphi, Daimler, Denso, Ford, Knorr Bremse, MAN, Opel (European branch of GM), Porsche, Valeo, Volkswagen and Wabco. Objective of the working group is the creation of framework conditions for the establishment of automated driving functions. Focus is on the coordination of activities concerning

a) Definitions and establishment of terminology
b) International homologation regulations: ECE regulations
c) Regulatory law: Vienna Convention of 1968, national road traffic regulations.

Based on the definitions of the BASt working group the following definitions were published by VDA as part of a position paper [4]. The position pater’s target groups are managers and politicians. As such, definitions were kept short and plain. A more refined definition that might be used as a technical standard has been provided by SAE (see above). To support international harmonization e.g. on OICA level, VDA adopted SAE terminology for the notation of automation levels in English documents.

Table 5.3: Terms and categorization of autom. driving and parking functions acc. to VDA [4]

<table>
<tr><th>Automation level</th><th>Component of control</th><th>Monitoring task</th><th colspan="2">Situation limits</th></tr>
<tr><td>Level 0
No Automation</td><td>System performs neither longitudinal nor lateral control; control remains with the driver.</td><td>Not applicable</td><td colspan="2">Not applicable</td></tr>
<tr><td>Level 1
Assisted</td><td>System performs either longitudinal or lateral control.</td><td rowspan="2">Driver must monitor the dynamic driving task and the driving environment at all times to the degree as in non-automated vehicle. Activities not related to driving are not permitted.</td><td colspan="2">System is not capable of recognizing all of its performance limits. This lies in the responsibility of the driver.</td></tr>
<tr><td>Level 2
Partial Automation</td><td rowspan="8">System performs both longitudinal and lateral control.</td><td colspan="2">Whenever the system recognizes its performance limits, driver will be requested to resume control.</td></tr>
<tr><td rowspan="2">Level 3
Conditional Automation</td><td rowspan="2">Driver does not need to monitor the dynamic driving task and the driving environment at all times. Activities not related to driving are possible to a limited degree.</td><td colspan="2">System may not transfer to minimal risk condition out of each situation. Therefore it requests the driver to resume vehicle control with sufficient time margin.</td></tr>
<tr><td colspan="2" rowspan="2">System recognizes its performance limits. Emergency situations can be accomplished by the system, provided that they can be managed similarly by a human driver during defined use case.</td></tr>
<tr><td rowspan="3">Level 4
High Automation</td><td rowspan="3">Driver is not required to monitor the system. Driver may perform activities not related to driving at all times.</td></tr>
<tr><td colspan="2">At the end of the use case the driver is requested to resume the dynamic driving task.</td></tr>
<tr><td rowspan="2">System performs the dynamic driving task in all situations automatically…</td><td>… during defined use case.</td></tr>
<tr><td rowspan="2">Level 5
Full Automation</td><td rowspan="2">No driver is required.</td><td>… during the whole journey.</td></tr>
<tr><td colspan="2">System recognizes its performance limits. Emergency situations can be accomplished by the system, provided that they can be managed similarly by a human driver during the whole journey.</td></tr>
</table>

A 1.4 BASt

BASt working group “Legal Consequences of an Increase of Vehicle Automation” was established by BASt in April 2010. Members are (in alphabetic order) BASt, BMW, Bosch, Daimler, DLR, University of Berlin, University of Braunschweig and Volkswagen. Objective of the working group is the legal assessment of automated driving functions. Its focus is on:

a) Definition of terminology
b) German regulatory law i.e. the German Road Traffic Code
c) German product liability law
d) Identification of research needs.

International homologation regulations, i.e. ECE regulations, or international regulatory law, i.e. Vienna Convention of 1968, were not considered in this working group.

BASt published the results of this working group in a report in January 2012 [1] which was also translated to English and is available on the internet. Target group of the BASt report are lawyers. Therefore a plain and universal description of the shared responsibilities between driver and system are in the focus of this definition. BASt definitions have been the basis e.g. for VDA and SAE.

Table 5.4: Terms and categorization of autom. driving and parking functions acc. to BASt [1]

Nomen-clature	Description of automation degree according to drivers' expectations	Exemplary systems
Driver Only	The driver continuously (throughout the complete trip) accomplishes longitudinal (accelerating/ braking) and lateral (steering) control.	No (driver assistance) system active that intervenes in longitudinal and lateral control.
Assisted	The driver continuously accomplishes either lateral or longitudinal control. The other/ remaining task is – within certain limits – performed by the system. • The driver must monitor the system permanently. • The driver must be prepared to take over complete control over the vehicle at any time.	Adaptive Cruise Control: - Longitudinal control with adaptive distance and speed control, Parking assistance system: - Lateral control is accomplished by the parking assistance (automatic steering into the parking space, the driver accomplishes longitudinal control).
Partial automation	The system takes over the lateral and longitudinal control (for a certain period of time and/ or in specific situations). • The driver must monitor the system permanently. • The driver must be prepared to take over the complete control of the vehicle at any time.	Motorway assistant: - Automatic longitudinal and lateral control - On motorways up to a certain top speed limit - Driver must monitor the actions constantly and respond immediately when prompted to take over
High automation	The system takes over lateral and longitudinal control for a certain period of time in specific situations. • Here, the driver need not monitor the system permanently. • If necessary, the driver will be prompted to take over control, allowing for a sufficient lead time. • All system limits are recognized by the system. The system is not capable of re-establishing the minimal risk condition from every initial state.	Motorway chauffeur: - Automatic longitudinal and lateral control - On motorways up to a certain top speed limit - Driver is not required to monitor the actions constantly. In case prompted to take over, the driver must respond within a certain lead time.
Full automation	The system takes over lateral and longitudinal control completely within the specification of the application. • The driver need not monitor the system. • Before specified limits of the application are reached, the system prompts the driver to take over control, with sufficient lead time. • In absence of driver takeover, the system will return to the minimal risk condition. • All system limits are recognized by the system. The system is capable of returning to the minimal risk condition out of every situation.	Motorway pilot: - Automatic longitudinal and lateral control - On motorways up to a certain top speed limit - Driver is not required to monitor the actions - In case the driver does not respond to a takeover request, the vehicle will brake down to a standstill.

In November 2013 Tom Gasser from BASt refined this nomenclature at a conference in Munich [9]. He added numbers to the different automation levels similar to SAE and he added a fifth level after “Full automation” called “Driverless”. In this way the BASt definitions align with VDA and SAE definitions.

A 1.5 NHTSA

NHTSA initially published levels of vehicle automation in December 2012 [10]. While this definition showed some distinct discrepancies as compared to BASt, for the first time NHTSA provided numbers for the different automation levels, which were adapted by VDA and SAE. In May 2013 NHTSA published their “Preliminary Statement of Policy Concerning Automated Vehicles” [3] which also includes a revised definition of automation level. This definition is more in line with BASt, SAE and VDA. Major difference: NHTSA does not distinguish between Level 4 and 5 (e.g. Traffic Jam Pilot and Universal Robot Taxi are in the same category). Unlike BASt and VDA, NHTSA sees e.g. ESC within the scope of its definition (see Level 1 definition). Harmonization efforts are ongoing. Furthermore, NHTSA levels are stated in normative terms and are not strictly functionally oriented, which hampers categorization of actual and future applications. This is why AdaptIVe decided not to work with the NHTSA levels, but instead to adopt the SAE levels and definitions.

NHTSA published the following short version and a detailed definition on its homepage:

Table 5.5: Terms and categorization of autom. driving and parking functions acc. to NHTSA [3]

Level 0 *No-Automation*	The driver is in complete and sole control of the primary vehicle controls - brake, steering, throttle, and motive power - at all times.
Level 1 *Function-specific Automation*	Automation at this level involves one or more specific control functions. Examples include electronic stability control or pre-charged brakes, where the vehicle automatically assists with braking to enable the driver to regain control of the vehicle or stop faster than possible by acting alone.
Level 2 *Combined Function Automation*	This level involves automation of at least two primary control functions designed to work in unison to relieve the driver of control of those functions. An example of combined functions enabling a Level 2 system is adaptive cruise control in combination with lane centering.
Level 3 *Limited Self-Driving Automation*	Vehicles at this level of automation enable the driver to cede full control of all safety-critical functions under certain traffic or environmental conditions and in those conditions to rely heavily on the vehicle to monitor for changes in those conditions requiring transition back to driver control. The driver is expected to be available for occasional control, but with sufficiently comfortable transition time. The Google car is an example of limited self-driving automation.
Level 4 *Full Self-Driving Automation*	The vehicle is designed to perform all safety-critical driving functions and monitor roadway conditions for an entire trip. Such a design anticipates that the driver will provide destination or navigation input, but is not expected to be available for control at any time during the trip. This includes both occupied and unoccupied vehicles.

A 1.6 HAVEit

The EU funded project HAVEit [11] defined levels of automation for the very first time, which were published e.g. by Flemish et al. in 2007 [12] and were taken as the starting point for BASt definitions. Major difference to BASt: HAVEit has an intermediate step between Level 0 and Level 1 called “Semi Automated” addressing ACC and LKA as separate systems and not allowing combinations of those systems. HAVEit also does not distinguish between Level 3, 4 and 5 systems; there is just a single level called “Autonomous Fully Automated”.

A 1.7 Evaluation

The following table shows an overview of the definitions of SAE, VDA, BASt and NHTSA taking SAE Levels 0–5 as a reference.

Table 5.6: Overview of terms and categorization of automated driving and parking functions

<table>
<tr><th>Level</th><th>0</th><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th></tr>
<tr><td>SAE [2] (English)</td><td rowspan="2">No Automation</td><td rowspan="2">Assisted</td><td rowspan="2">Partial Automation</td><td rowspan="2">Conditional Automation</td><td rowspan="2">High Automation</td><td rowspan="2">Full Automation</td></tr>
<tr><td>VDA [4] (English)</td></tr>
<tr><td>VDA [4] (German)</td><td rowspan="2">Driver Only</td><td rowspan="2">Assistiert</td><td rowspan="2">Teil Automatisiert</td><td rowspan="2">Hoch Automatisiert</td><td rowspan="2">Voll Automatisiert</td><td>Fahrerlos</td></tr>
<tr><td>BASt [1] (German)</td><td>-</td></tr>
<tr><td>NHTSA [3]</td><td>No Automation</td><td>Function-Specific Automation</td><td>Combined Function Automation</td><td>Limited Self-Driving Automation</td><td colspan="2">Full Self-Driving Automation</td></tr>
</table>

The following becomes obvious:

- VDA & SAE (English): Consistent content and terminology of automation levels
- VDA & BASt (German): Consistent content and terminology of automation levels except that BASt does not define Level 5
- VDA English & German: Terms are not literally translated (due to harmonization with SAE)
- NHTSA & SAE: Somewhat consistent content for Level 0–3, inconsistent in Levels 4-5 (NHTSA does not distinguish between Level 4 and 5), inconsistent terminology and classification

From this it might be concluded that harmonization between SAE, VDA and BASt concerning content and terminology of automation levels is quite extensive. Furthermore, SAE and NHTSA have a somewhat consistent understanding of Levels 0–3, even though terminology is different and NHTSA includes emergency intervention systems, such as ESC, in Level 1, while BASt, VDA, and SAE do not. Harmonization might further converge with some effort on all sides.

As mentioned above SAE offers precise definitions from an engineer’s perspective that are also well-suited for the broader “Automated Vehicle” community. Therefore AdaptIVe uses SAE definitions.

Annex 2 Definition of Exemplary Functions

Some exemplary automated driving and parking functions are briefly described in the following section. Example functions have been adopted from the VDA position paper [4], government-funded projects and literature. They are used to explain and differentiate automation levels defined in the previous section and to evaluate the suitability of the categorization defined above. A more refined functional description will be provided in deliverable D1.5.

A2.1 Cruise Control

Cruise Control (CC) is a driver assistance system which supports the driver in longitudinal vehicle speed control. It keeps a constant speed which is set by the driver. Typically there is no standardized upper speed limit. Changing the set speed will result in moderate deceleration or acceleration.

A2.2 Adaptive Cruise Control

Adaptive Cruise Control (ACC) is a driver assistance system which supports the driver in longitudinal vehicle speed control. It keeps constant time headway to the leading vehicle or, if no leading vehicle is present, maintains a constant speed. Both parameters are set by the driver. Maximum deceleration (acceleration) is limited to -3.5 m/s^2 (2 m/s^2) above 20 m/s and to -5 m/s^2 (4 m/s^2) below 5 m/s [13]. Modern ACC systems are suited for stop & go traffic as well as high speed driving up to 200 km/h depending on the implementation. Typical time headways are between 1 and 2 sec.

A2.3 Lane Keeping Assistance (Type I, II and III)

Lane Keeping Assistance (LKA) is a driver assistance system which supports the driver in lateral vehicle control.

LKA Type I systems apply a course corrective steering momentum, if the vehicle is going to leave the lane. LKA Type II systems apply course corrective steering momentum continuously to keep the vehicle near the center of the lane. For both LKA Type I and Type II systems the maximum steering momentum is limited so that the driver is always able to override the system. Some specific implementation characteristics that may vary between brands and models include the following: Typical maximum steering momentums is 3 Nm; the system supplies a steering support. The driver must have his hands on the steering wheel and must apply a steering momentum; if he doesn’t do so, a takeover request occurs and the system deactivates.

While LKA Type II systems support the driver in keeping the center of the lane, LKA Type III systems are capable of keeping the center of the lane by themselves without the help of the human driver.

Remark: Current LKA systems on the market are almost exclusively Type I or Type II systems. Therefore LKA Type III systems will not be considered in this document.

A2.4 Active Lane Change Assistance

Active Lane Change Assistance supports the driver during lane change maneuvers. It applies a course corrective steering momentum if the driver is steering to the adjacent lane if the lane that the vehicle is moving to is occupied by another vehicle.

A2.5 Combined ACC and LKA Type II

Combining ACC with LKA Type II will not result in a Level 2 system. The driver is still obliged to steer and is constantly involved in completing the dynamic driving task (see also A 1.1.2, remark 2 and 3).

A2.6 Active Traffic Light Assistance

Active Traffic Light Assistance supports the driver at maneuvers in the vicinity of traffic lights. It detects traffic light status and adopts velocity accordingly: It stops in front of a red traffic light and starts when traffic light changes to green.

A2.7 Narrowing Assistance

Narrowing Assistance supports the driver while driving on narrow urban roads. It helps the driver to keep the vehicle in the center of the road via course corrective steering momentum. When approaching an obstacle which narrows the road – e.g. parked vehicles at the roadside – it adapts the vehicles lateral position in the lane so as to avoid the obstacle. If the narrowing is impassable then the system decelerates and warns the driver.

A2.8 Construction Zone Assistance

Construction Zone Assistance supports the driver while driving in construction zones on motorways. It adjusts the velocity according to the speed limit and traffic flow. Furthermore it applies a course corrective steering momentum if the driver is steering too close to vehicles in the adjacent lane, or too close to the edge of the lane – which is defined in a construction site by e.g. guard rails, road barriers and/or traffic cones.

A2.9 Traffic Jam Assistance

Traffic Jam Assistance supports the driver with monotonous driving in traffic jams on motorways or motorway similar roads at speeds of up to 60 km/h. The system follows the leading vehicle in front at a safe distance and keeps the vehicle in the center of the lane. The driver can only activate the system if slow-driving vehicles are detected in front. The driver has to monitor the system constantly and has to intervene if required, e.g. if the vehicle is going to exit the motorway at an exit or interchange, a vehicle needs to merge into traffic, or the traffic jam situation ends. In principle the driver can take his hands from the steering wheel and need not use the foot pedals.

A2.10 Highway Assistance

Highway Assistance and Traffic Jam Assistance (refer to A2.9) are similar. Major difference: Maximum speed is up to 130 km/h. Overtaking maneuvers initiated and monitored by the driver are included.

A2.11 Overtaking Assistance

Overtaking Assistance supports the driver in overtaking maneuvers on motorways. The driver approves each single maneuver separately, e.g. by actuation of a button. The system identifies and indicates if the adjacent lane is vacant. After approval by the driver it will proceed to change lanes. The driver must monitor the system continuously and must intervene if required.

A2.12 Parking Assistance with steering

Parking Assistance with steering supports the driver in low speed parking maneuvers. The system steers the vehicle into a parking space while the driver retains control of the gas pedal, clutch and brake. The driver is located in the driver's seat and must continuously monitor the system and environment and must intervene if required e.g. by braking if a person steps into the parking space.

A2.13 Parking Assistance with steering and accelerating/braking

Parking Assistance with steering and accelerating/braking maneuvers a vehicle into a parking space with the driver located in the driver's seat: he is still obliged to monitor the system and environment and to intervene if required.

A2.14 Key Parking

Key Parking assists the driver in parking maneuvers in narrow parking spaces. When the system detects a narrow parking space, the driver steps out of the vehicle and starts the parking maneuver by pressing and holding a button on his car key or smartphone. The driver has to continuously monitor the system and has to stop the parking maneuver if required by letting go of the button, e.g. if a person steps into the parking space. If the vehicle has obtained its final parking position, the system switches off the ignition and locks the car. The inverse maneuver can be started by the driver again via car key or smartphone. The maneuver velocity is limited to 12 km/h. Maximum steering momentum is up to 10 Nm.

A2.15 Traffic Jam Chauffeur

Traffic Jam Chauffeur and Traffic Jam Assistance (see above) are similar. Major difference: The Traffic Jam Chauffeur is a Level 3 system which allows the driver to turn his attention away from his driving task in the specific scenario of a traffic jam on a motorway, although the driver must provide fallback performance if necessary. He must be in the position to resume control again with an increased lead time if a takeover request from the system occurs, so that only secondary tasks with appropriate reaction time are allowed. This would exclude e.g. sleeping or leaving the driver's seat. Due to secondary tasks, the driver may not be capable of reacting to e.g. emergency braking maneuvers of the vehicle in front which must be accomplished by the system.

A2.16 Highway Chauffeur

Highway Chauffeur and Traffic Jam Chauffeur (refer to A2.15) are similar. Major difference: Maximum speed is up to 130 km/h. Overtaking maneuvers and driving in highway junctions without driver monitoring are included.

A2.17 Overtaking Chauffeur

Overtaking Chauffeur and Overtaking Assistance (refer to A2.11) are similar. Major difference: Overtaking Chauffeur actively suggests the overtaking maneuver to the driver (e.g. via icon) who must approve (e.g. via button) but need not monitor the maneuver. Overtaking Chauffeur is a sub function of Highway Chauffeur and presumably will not be available as a stand-alone function.

A2.18 Platooning

Platooning enables small time headways between vehicles in a convoy on a motorway or motorway-similar road, thus reducing fuel consumption by slipstream driving, increasing road throughput capacities, and potentially extending allowable travel time for truck drivers. Platoon members might be passenger cars and/or trucks. Typical vehicle distances are 5 to 10 m, depending e.g. on vehicle's speed and braking capabilities. The driver of a following vehicle in the platoon is allowed to divert his attention from his driving task in the specific scenario of a platoon on a motorway. He must be in the position to resume control again with an increased lead time if a takeover request from the system occurs, thus only secondary tasks with appropriate reaction time are allowed. This would exclude e.g. sleeping. Due to small time headways and secondary tasks the driver is not capable of reacting to e.g. emergency braking maneuvers of the vehicle in front. Those must be accomplished by the system.

A2.19 Driverless Valet Parking

Driverless Valet Parking relieves the driver from parking maneuvers or finding open parking spots in parking garages. The driver delivers his vehicle to the entrance of the parking garage, steps out of his vehicle, starts the parking maneuver by pressing a button on his car key or smartphone, and leaves the entrance of the parking garage without monitoring the parking maneuver. The vehicle enters and maneuvers in the parking garage, detects and avoids obstacles, searches for and maneuvers into the parking space. Once the vehicle has obtained its final parking position, the systems switches off the ignition and locks the car. The inverse maneuver can be started by the driver again via car key or smartphone. The vehicle comes to the driver at the exit of the parking garage. The maneuver velocity is limited to 12 km/h. Maximum steering momentum is up to 10 Nm.

A2.20 Tele-Operated Driving – Urban

Tele-Operated Driving shifts the driver's working place from the vehicle to a place which is located outside of the vehicle with no direct visual contact between tele-operator and vehicle. The driver is a tele-operator who monitors the vehicle and its environment via radio transmitted sensor and video signals in real time. The system accomplishes the dynamic driving task within its system limits. If the system reaches its limits, the tele-operator must intervene, e.g. by initiating an emergency maneuver. In a use case where rental cars are automatically returned to the rental car center in an urban environment the maximum speed is limited to 60 km/h.

Remark: As indicated in Table 4.3, row 2.2.3 "Tele-operation" many other tele-operated applications can be imagined in theory. In practice, however, they have little relevance. Therefore, for simplification, only one exemplary tele-operated function is described in this section.

A2.21 Traffic Jam Pilot

Traffic Jam Pilot and Traffic Jam Chauffeur (refer to A2.15) are similar. Major difference: The Traffic Jam Pilot is a Level 4 system which allows the driver to turn his attention away from his driving task in the specific scenario of a traffic jam on a motorway with the system providing fallback performance if necessary. That is, the system must be in the position to transfer the vehicle out of each scenario into a minimal risk condition. The driver is not required to be in the position to resume control again if a takeover request from the system occurs, so that any secondary tasks are allowed without limitations. Due to secondary tasks the driver may not be capable of reacting to e.g. emergency braking maneuvers of the vehicle in front. Those must be accomplished by the system.

A2.22 Highway Pilot

Highway Pilot and Traffic Jam Pilot (refer to A2.21) are similar. Major difference: Maximum speed is up to 130 km/h. Overtaking maneuvers and driving in highway junctions without driver monitoring are included.

A2.23 Overtaking Pilot

Overtaking Pilot and Overtaking Chauffeur (refer to A2.17) are similar. Major difference: Overtaking Pilot initiates an overtaking maneuver without driver approval. Overtaking Pilot is a sub function of Highway Pilot and presumably will not be available as a stand-alone function.

A2.24 Urban Robot Taxi

An Urban Robot Taxi accomplishes the complete dynamic driving task from origin to destination in a prescribed and limited urban environment. Maximum speed may be limited to e.g. 40 km/h.

Area of operation is limited to cities or city centers. The vehicle is provided to the passenger; the passenger enters the vehicle and announces the destination; the vehicle transfers the passenger to the desired destination; the passenger steps out of the vehicle; the vehicle drives to the next passenger. In principle a working space for the driver with steering wheel, pedals and instrument cluster is not needed. Examples: Google car [14], Cybercars (see e.g. projects CitiMobil, CyberCars, CyberC).

A2.25 Automated Mining Vehicles

Automated Mining Vehicles are replacing truck drivers in mines, thus saving on wages. The operational design domain is on private property that is closed to pedestrians and vehicles other than Automated Mining Vehicles. The road is limited to predefined routes. Vehicle speed is limited to 60 km/h. Emergency maneuvers are not required due to the controlled environment.

A2.26 Automated Marshalling of Trucks

On the private property of a forwarding company a truck tractor and trailer are marshalled / combined automatically. Tractors maneuver at low speeds without drivers on a premises that is closed to pedestrians. Upon request, the marshalled truck is provided to the driver at a specific transfer point.

A2.27 Universal Robot Taxi

Universal Robot Taxi and Urban Robot Taxi (refer to A2.24) are similar. Major difference: The Universal Robot Taxi would be suited for all kind of roads – e.g. urban roads, rural roads, interstates, highways, motorways. Maximum speed may be limited to e.g. 130 km/h. Since there are no limitations concerning scenarios or environment for most of the drivers, the Universal Robot Taxi would be an equivalent replacement for today’s vehicles.

Annex 3 Functional parameter set of SP4, SP5, SP6 and exemplary functions

Table 5.7: SP4 parameter set for the classification of automated functions

		Parameters									
		1	2	3	4	5	6	7	8	9	10
		Maneuver automation	Maneuver duration	maneuver velocity	Road type	Driver location	maneuver control force	maneuver Time headway	maneuver trigger	maneuver coordination	Vehicle type
SP4 functions	Automated Park Assistant	3	short	low	11,12,13	outside	high	standard	driver	no	car
	Pholova Park Assistant	2	short	low	11,12,13	outside	high	n.a.	driver	no	car
	Automated Parking Garage Pilot	2	short	low	14	inside	high	n.a.	driver	yes	car
	Construction Site Maneuver	2	short	mid	4	inside	high	n.a.	driver	yes	car
	Minimal Risk Maneuver	EM	short	low	11,12,13	n.a.	low	standard	system	no	car

Table 5.8: SP5 parameter set for the classification of automated functions

		Parameters									
		1	2	3	4	5	6	7	8	9	10
		maneuver automation	Maneuver duration	maneuver velocity	Road type	Driver location	maneuver control force	maneuver Time headway	maneuver trigger	maneuver coordination	Vehicle type
SP5 functions	Supervised City Control: lane following and speed adaptation	2	short	mid	8-11	inside	low	standard	system	no	car
	Supervised City Control: vehicle following in lane	2	long	mid	8-11	inside	mid	standard	system	no	car
	Supervised City Control: obstacle or VRU on the road	2	short	mid	8-11	inside	high	standard	system	no	car
	City Chauffeur: lane change	3	short	mid	8-11	inside	mid	standard	system	no	car
	City Chauffeur: intersections handling	3	short	mid	8-11	inside	mid	standard	system	yes	car
	City Chauffeur: roundabouts handling	3	short	mid	8-11	inside	mid	standard	system	yes	car
	City Chauffeur: traffic lights handling	3	short	mid	8-11	inside	low	standard	system	yes	car
	City Chauffeur: lane following and speed adaptation	3	long	mid	8-11	inside	low	standard	system	no	car
	City Chauffeur: vehicle following in lane	3	long	mid	8-11	inside	mid	standard	system	no	car
	City Chauffeur: obstacle or VRU on the road	3	short	mid	8-11	inside	high	standard	system	no	car
	Minimal risk maneuver	EM	short	mid	8-11	n.a.	mid	standard	system	no	car

Table 5.9: SP6 parameter set for the classification of automated functions

		Parameters									
		1	2	3	4	5	6	7	8	9	10
		maneuver automation	Maneuver duration	maneuver velocity	Road type	Driver location	maneuver control force	maneuver Time headway	maneuver trigger	maneuver coordination	Vehicle type
SP6 functions	Lane following	3	long	high	1,2,5,6	inside	low	standard	system	no	car, truck
	Lane change (and overtaking)	3	short	high	1,2,5,6	inside	low	standard	system	no	car, truck
	Stop & go driving	3	long	mid	1,2,5,6	inside	low	standard	system	no	car, truck
	Speed / time gap adaptation at a motorway entrance ramp	3	short	high	1,2,5,6	inside	low	standard	system	no	car, truck
	Minimal risk maneuver	EM	short	high	1,2,5,6	inside	low	standard	system	no	car, truck
	Cooperative merging with speed adaptation	3	short	high	1,2,3,5,6	inside	low	standard	system	yes	car, truck
	Cooperative merging with lane change	3	short	high	1,2,3,5,6	inside	low	standard	system	yes	car
	Danger spot intervention	3	short	high	1,2,5,6	inside	low	standard	system	no	car
	Predictive automated driving	3	long	high	1,2,5,6	inside	low	standard	system	no	car
	Enter and exit of a motorway	2	short	high	3	inside	low	standard	system	no	car
	Cooperative response on emergency vehicle on duty	2	short	high	1,2,5,6	inside	low	standard	system	yes	car

Table 5.10: Exemplary functions parameter set for the classification of automated functions

		Parameters									
		1	2	3	4	5	6	7	8	9	10
		maneuver automation	Maneuver duration	maneuver velocity	Road type	Driver location	maneuver control force	maneuver Time headway	maneuver trigger	maneuver coordination	Vehicle type
Exemplary functions (see Annex 2)	Cruise Control	1	long	high	1, 5-9	inside	low	n.a.	driver	no	car, truck
	Adaptive Cruise Control	1	long	high	1, 5-9	inside	low	standard	driver	no	car, truck
	Lane Keeping Assist. Type II	1	long	high	1, 5-7	inside	low	n.a.	driver	no	car, truck
	Active Lane Change Assist.	1	short	high	1, 5-7	inside	low	n.a.	driver	no	car, truck
	Combined ACC & LKA Type II	1	long	high	1, 5-7	inside	low	standard	driver	no	car, truck
	Active Traffic Light Assist.	1	short	mid	10	inside	low	standard	driver	no	car, truck
	Narrowing Assistance	1	long	mid	8-11	inside	low	standard	driver	no	car, truck

Construction site Assistance	1	long	mid	4	inside	low	standard	driver	no	car, truck
Highway Assistance	2	long	high	1, 5-7	inside	low	standard	driver	no	car, truck
Overtaking Assistance	2	short	high	1, 5-7	inside	low	standard	driver	no	car, truck
Traffic Jam Assistance	2	long	mid	1, 5-7	inside	low	standard	driver	no	car, truck
Parking Assistance with steering	1	short	low	11-13	inside	high	n.a.	driver	no	car
Parking Assistance with steering & accel./braking	2	short	low	11-13	inside	high	n.a.	driver	no	car
Key Parking	2	short	low	11-13	outside	high	n.a.	driver	no	car
Tele Operated Driving - Urban	2	long	mid	8-12	tele	high	standard	driver	no	car
Highway Chauffeur	3	long	high	1, 5	inside	high	standard	driver	no	car, truck
Overtaking Chauffeur	3	short	high	1, 5	inside	high	standard	driver approved	no	car, truck
Traffic Jam Chauffeur	3	long	mid	1, 5	inside	high	standard	driver	no	car, truck
Platooning	3	long	high	1, 5	inside	high	small	driver	yes	car, truck
Highway Pilot	4	long	high	1, 5	inside	high	standard	driver	no	car, truck
Overtaking Pilot	4	short	high	1, 5	inside	high	standard	System	no	car, truck
Traffic Jam Pilot	4	long	mid	1, 5	inside	high	standard	driver	no	car, truck
Driverless Valet Parking	4	long	low	14	n.a.	high	standard	driver	no	car
Urban Robot Taxi	4	long	mid	8-12	n.a.	high	standard	System	no	car
Automated Mining Vehicles	4	long	mid	16	n.a.	high	standard	System	no	truck
Automated marshalling of trucks	4	long	low	17	n.a.	high	standard	System	no	truck
Universal Robot Taxi	5	long	high	1-14	n.a.	high	standard	System	no	car

Annex 4 Glossary

Table 5.11 presents a preliminary version of the AdaptIVe shared glossary concerning highly and fully automated driving functions. Relevant literature in the field of automated driving was reviewed to setup this glossary. Existing definition of terms have been extracted and summarized in a table. This initial glossary has been shared on the project server. To create a final version the Glossary will be reviewed and completed by project partners in the course of the project, resulting in an AdaptIVe consolidated glossary.

Table 5.11: Preliminary version of AdaptIVe glossary, see also D1.5

Name	Definition
Advanced Driver Assistance System (ADAS)	Systems that interact with the driver with the main purpose of supporting the *dynamic driving task* on the tracking and regulating levels based on environmental perception.
Assist	Augment the appropriate operation of the operator
Automated driving system	The hardware and software that is collectively capable of performing all aspects of the *dynamic driving task* for a vehicle (whether part time or full time). [2]
Autonomous	Acting alone or independently.
Cooperative systems	Co-operative systems improve efficiency and safety of transport systems by cooperative behavior of agents. Involved agents might be road operators, infrastructure, vehicles, their drivers and other road users. Cooperative behavior can be achieved without and with communication between agents e.g. using vehicle-to-vehicle and vehicle-to-infrastructure communication.
Dedicated lane	A dedicated lane is a lane devoted or designated for a particular use or function. The lane is assigned or allocated to a particular transport mode.
Drive / Driving	To operate a vehicle on a public or private roadway at any point at or between an origin and a destination, whether or not the vehicle is in motion. [2]
Driver	The human operator tasked with carrying out the performance of part or all of the *dynamic driving task*
Driving Environment	Conditions and surroundings intended for the legal operation of a motor vehicle
Dynamic Driving Task	All of the real-time functions required to operate a vehicle in on-road traffic, excluding the selection of destinations and waypoints (i.e. navigation or route planning) and including without limitations: [2] • Object and event detection, recognition and classification, • object and event response, • Maneuver planning, • Steering, turning, lane keeping and lane changing, • Acceleration and deceleration, • Enhancing conspicuity (lighting, signaling and gesturing, etc.).

Estimation	The process of inferring the value of a quantity of interest from indirect, inaccurate and uncertain observations
Feature	An abstraction of the raw data intended to provide a reduced data set that accurately and concisely represents the original information
Function	The task, purpose or intention of a “system”. An automated driving or parking function is capable of a single or multiple driving or paring *maneuvers*. The terms “function” and “application” are used synonymously.
Human factors (HF) Requirement	Description of an attribute, capability, characteristics, quality or performance criteria that a human-machine system needs to fulfil in order to, together with other Human Factors requirements, reach a specific goal.
HMI	Human Machine Interaction and Human Machine Interface.
Information, Warning and Intervention (IWI) Strategy	How, when and where driver information, warning and/or intervention should be presented or (in the case of intervention) performed.
Intention	The (mental) desire to act in a particular way.
Interface	The part of a system that allows another system to connect to it. Specifically, the interface defines how data is formatted and what the rules are for accepting data. Programs that pass information from one system to another are often referred to as interfaces.
Level of automation	Defines which part of the dynamic driving task is assigned to the automated system and which part of the dynamic driving task remains in the responsibility of the human driver. Described by numbers and names: [2] • Level 0: No automation • Level 1: Assisted • Level 2: Partial automation • Level 3: Conditional automation • Level 4: High automation • Level 5: Full automation
Localization	Imposing some physical order upon a set of objects, so that a given object has a greater probability of being in some particular regions of space than in others.
Maneuver	A controlled change in movement or direction of a vehicle.
Minimal Risk Condition	A low risk motor vehicle operating condition to which an *automated driving system* automatically resorts upon either a system failure or a failure of a human *driver* to respond appropriately to a request to take over the *dynamic driving task*. NOTE: A *minimal risk condition* will vary according to the type and extent of a given failure. A *minimal risk condition* could entail automatically bringing the vehicle to a stop, preferably outside of an active lane of traffic (assuming availability). [2]
Module	(1) In software, a module is a part of a program. Programs are composed of one or more independently developed modules that are not combined until the program is linked. A single module can contain one or several routines. (2) In hardware, a module is a self-contained component.

Monitor	The activities and/or automated routines that accomplish comprehensive object and event detection, recognition, classification, and response preparation, as needed to competently perform the *dynamic driving task*. NOTE: When driving vehicles that are not equipped with *automated driving systems*, human *drivers* visually sample the road scene sufficiently to competently perform the *dynamic driving task*, while also performing secondary tasks that require short periods of eyes-off-road time (e.g. adjusting cabin comfort settings, scanning road signs, tuning a radio, etc.). Thus, *monitoring* does not entail constant eyes-on-road time by the human *driver*. [2]
Multi-level storage	Also called a parking garage, parking structure, parking ramp, parking building, parking deck or indoor parking, is a building designed for car parking and where there are a number of floors or levels on which parking takes place. It is essentially a stacked car park.
Override	Ability of the human driver to stop the operation of the technical system by applying a specific command or action and hereby having dominance and final authority over the technical system.
Platooning	Vehicles traveling in close proximity to one another as a group.
Positioning	Determination of the geographical position of something
Real-time	System which has to finish the processing within a specific time interval (deadline) dedicated by its environment.
Research Question	A general question to be answered by compiling and testing related specific hypotheses.
Scenario	A sequence of situations in a specific use-case
Secondary task	A task with lower priority than the primary task in a multi-tasking situation.
Sensor	A device that detects physical parameters of the environment
Sequence of Interaction	Describes how the assistance evolves in specific situations.
Supervision	The driver's role to oversee the operation of the driving automation system and take action when necessary
System	A set of interdependent elements, which are linked by relations in a way that they can be regarded as a task-, purpose, or intention-bound unit. The extent of the relations between the elements of the system determines its structure.
Tracking	The estimation of the state of a moving object based on remote measurements. This is done using one or more sensors at fixed locations or on moving platforms.
Use case	A description of specific sequence of interaction between the user(s) and a technical system to achieve a specific goal
Validation	The confirmation by examination and provision of objective evidence that the particular requirements are sufficient for a specific intended use

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List of abbreviations and acronyms

Abbreviation	Meaning
ACC	Adaptive Cruise Control
ADAS	Advanced Driver Assistance Systems
BASt	Federal Highway Research Institute (Germany)
BSW	Blind Spot Warning
CC	Cruise Control
ECE	Economic Commission for Europe
EM	Emergency maneuver
ESC	Electronic Stability Control
FCW	Forward Collision Warning
FMEA	Failure Mode and Effects Analysis
HAVEit	Highly Automated Vehicles for Intelligent Transportation
HMI	Human Machine Interface and Human Machine Interaction
LDW	Lane Departure Warning
LKA	Lane Keeping Assistance
NHTSA	National Highway Traffic Safety Administration
OEDR	Object and Event Detection and Response
OEM	Original Equipment Manufacturer
OICA	Organisation Internationale des Constructeurs d'Automobiles
SAE	SAE International, formerly the Society of Automotive Engineers (USA)
SP	Sub Project
SUV	Sport Utility Vehicle
UNECE	United Nations Economic Commission for Europe
V2V	Vehicle to Vehicle
VDA	Association of Vehicle Manufacturers
VRU	Vulnerable road user