
**Intelligent transport systems —
Automated valet parking systems
(AVPS) —**

**Part 1:
System framework, requirements
for automated driving and for
communications interface**

*Systèmes de transport intelligents — Systèmes de parking avec
voiturier automatisé (AVPS) —*

*Partie 1: Cadre du système, exigences relatives à la conduite
automatisée et à l'interface de communication*



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ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Email: copyright@iso.org
Website: www.iso.org

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 204, *Intelligent transport systems*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

The aim of this document is to contribute to the realization of safe and reliable level 4 driverless operation of vehicles within parking facilities, and to support a fast and smooth market introduction by achieving interoperability among vehicles provided by different manufactures and within different parking facilities managed by different organizations.

An automated valet parking system (AVPS) will automatically operate unoccupied vehicles from the drop off area (where the driver and passengers leave the vehicle) to a parking destination, and will also send the vehicle to a pickup area upon the user's request.

An AVPS will not only provide enhanced user experiences, but is also expected to contribute to accident reduction, lowering energy consumption and CO₂ emissions of vehicles searching for available parking spaces, and effectively utilize land by densely parking vehicles in the available space.

An AVPS can be utilized in places such as the large-scale public parking facilities of shopping malls, airports, large apartment buildings, time-based small public parking lots, or fleet management carpools. By implementing the system in parking facilities, the service provider will gain the opportunity to add other related services such as moving electric vehicles to and from charging stations or providing access to the trunk for the delivery of goods. Rather than having fully-automated vehicles driving around and searching for space, the system allows the service provider to govern the vehicles for improved traffic management.

In order to contribute to the realization of safe and reliable level 4 driverless operation, the requirements specified in this document are based on the performance of state-of-the-art technologies that are available at the time of publication. Thus, this document will be revised in the future in accordance with relevant technology enhancement.

Within this document, specific technological solutions for the communications interface (e.g. communication method, message protocol) are intentionally left open due to differences in available and commonly-used technology (e.g. spectrum allocation) around the world. Therefore, it is recommended that the communications interface be further discussed at the national/regional level to ensure interoperability.

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Intelligent transport systems — Automated valet parking systems (AVPS) —

Part 1: System framework, requirements for automated driving and for communications interface

1 Scope

Automated valet parking systems (AVPSs) perform level 4 automated driving of individual or multiple unoccupied vehicles within a prescribed area of a parking facility. This document specifies performance requirements for the operation functions, the environmental conditions within parking facilities where automated vehicle operation is performed, and the test procedures to verify the performance requirements.

An AVPS is comprised of physically separated sub-systems distributed among vehicles, facility equipment and user domains. The functionalities of AVPSs are realized by cooperation of these sub-systems, which are, in many cases, provided by different organizations. This document defines the system architecture and the communication interfaces between the sub-systems at the logical level.

An AVPS manages its system participants (i.e. AVPS-compliant vehicles and parking facilities) and provides interfaces to other facility users and involved persons (e.g. system operators, facility managers). This document contains requirements for the management functions such as checking compatibility between vehicles and parking facilities, performing remote assistance and recovery when automated driving cannot be performed, and executing operation stop commands in response to the actions of other facility users.

AVPSs are intended for use by a service provider upon receiving authority over vehicles from individual service recipients. This document does not include parking automation technologies that are solely based on usage by an individual user. If the vehicle is put into driverless operation directly by the user, this is not considered to be part of the AVPS.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 20900, *Intelligent transport systems — Partially-automated parking systems (PAPS) — Performance requirements and test procedures*

ISO 8608, *Mechanical vibration — Road surface profiles — Reporting of measured data*

ISO 19206-2, *Road vehicles — Test devices for target vehicles, vulnerable road users and other objects, for assessment of active safety functions — Part 2: Requirements for pedestrian targets*

ISO 19206-3, *Road vehicles — Test devices for target vehicles, vulnerable road users and other objects, for assessment of active safety functions — Part 3: Requirements for passenger vehicle 3D targets*

ISO 19206-4, *Road vehicles — Test devices for target vehicles, vulnerable road users and other objects, for assessment of active safety functions — Part 4: Requirements for bicyclist targets*

ISO/SAE PAS 22736, *Taxonomy and definitions for terms related to driving automation systems for on-road motor vehicles*

IEC 61508 (all parts), *Functional safety of electrical/electronic/programmable electronic safety-related systems*

ISO 21448, *Road vehicles — Safety of the intended functionality*

ISO/SAE 21434, *Road vehicles — Cybersecurity engineering*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO/SAE PAS 22736 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <https://www.electropedia.org/>

3.1 service provider

organization that hands over or receives authority to or from users through an automated valet parking system (AVPS)

Note 1 to entry: See [5.5.2](#) for further information.

3.2 user

<of an automated valet parking system> individual service recipient that hands over or retrieves authority to or from service providers through an automated valet parking system (AVPS)

Note 1 to entry: Both the owner of a personal vehicle and a user of a car share service can be a user of an AVPS.

Note 2 to entry: Within ISO/SAE PAS 22736, the term “user” is defined as the human role specifically in relation to driving automation systems. An AVPS is a system that includes system participant management functions in addition to level 4 automated driving functions. Within this document, the term “system operator” (see [3.28](#) and [5.5.3](#)) is used as a role which performs dispatching and remote assistance in relation to the level 4 automated driving functions of an AVPS. The term “user” is assigned to the individual service recipient, and not to the dispatcher or remote assistant.

3.3 authority

rights and ability to perform certain tasks on the subject vehicle

Note 1 to entry: Within this document, authority is transferred between the user and the service provider, and does not exist among the two at the same time. One always has priority regarding the management and operation of the subject vehicle (SV).

Note 2 to entry: See [5.1.2.2](#) for further information.

3.4 subject vehicle

SV
light vehicle^[1] which is equipped with the vehicle operation sub-system of an automated valet parking system (AVPS)

3.5**parking facility**

public or private car park in which an automated valet parking system (AVPS) is available

Note 1 to entry: An AVPS does not necessarily have to be available in the entire facility in order to achieve conformance to this document. For example, it is possible for only a certain floor within a multi-story parking facility to be dedicated to an AVPS.

Note 2 to entry: Within ISO/TS 5206-1, a parking facility is defined by different elements of the place hierarchy depending on the configuration of the place hierarchy. Typically, in ISO/TS 5206-1 conformant data, a parking facility can be characterized as a "place" with associated characterizing attributes.

3.6**operation zone**

single or multiple geographical area(s) within a parking facility where automated driving can be performed by an automated valet parking system (AVPS)

Note 1 to entry: An operation zone can contain information other than the two-dimensional geographical area, such as ceiling height or floor level information.

Note 2 to entry: Within ISO/TS 5206-1, an operation zone can be defined by different elements of the place hierarchy depending on the configuration of the place hierarchy. Depending on the configuration of the parking facility, in ISO/TS 5206-1 conformant data, an operation zone can either be characterized as a "place" or as an "identified area" with associated characterizing attributes.

Note 3 to entry: Multiple areas may overlap.

3.7**drop-off area**

location within the operation zone where the user leaves the subject vehicle (SV) and hands over authority to the service provider

Note 1 to entry: The drop-off area may be for a single vehicle or a larger area (e.g. the entire operation zone).

Note 2 to entry: Within ISO/TS 5206-1, this term is defined as a "specific area" which is a sub-class of "identified area".

3.8**pick-up area**

location within the operation zone where the service provider sends the subject vehicle (SV) to the user for boarding, and hands over authority

Note 1 to entry: The pick-up area may be for a single vehicle or a larger area (e.g. the entire operation zone).

Note 2 to entry: Within ISO/TS 5206-1, this term is defined as a "specific area" which is a sub-class of "identified area".

3.9**parking spot**

area within the parking facility where a single vehicle can be parked

Note 1 to entry: Parking spots are typically delineated by line markers, curbs or other identification markings on the floor.

Note 2 to entry: Within ISO/TS 5206-1, this term is defined as a "space".

3.10**parking area**

area within the operation zone consisting of multiple parking spots

Note 1 to entry: Within ISO/TS 5206-1, this term is defined as a "specified area" with associated characterizing attributes.

3.11

destination

location within the operation zone to which the subject vehicle is transferred

Note 1 to entry: The destination is determined by the automated valet parking system (AVPS). Parking spots, service bays (e.g. location beside an electric vehicle charging station) and pick-up area are examples of a destination.

3.12

route

planned traversal of a subject vehicle (SV) from the point of origin to a destination

Note 1 to entry: When way point(s) are given, a route will be created to pass these way point(s).

3.13

path

planned sequence of way points for a subject vehicle (SV) to follow

Note 1 to entry: A path is determined based on the physical size and moving capabilities (e.g. turning radius) of the SV.

3.14

trajectory

planned path with dynamic information (e.g. time, speed, acceleration)

3.15

automated valet parking facility equipment

PFE

physical equipment installed in the parking facility for supporting automated valet parking system (AVPS)

EXAMPLE Communication devices and detection sensors.

3.16

coded marker

physical indication with a unique ID installed in the parking facility, which is detectable by the SV for the purpose of assisting localization

Note 1 to entry: The number of unique IDs may be limited depending on the area of application.

Note 2 to entry: "Marker" includes all kinds of localization indicators such as radio-based technologies and those explained in [Annex D](#).

3.17

anonymous marker

physical indication without a unique ID installed in the parking facility that is detectable by the subject vehicle (SV) for the purpose of assisting localization

3.18

designed speed

situation-specific speed for travel under given circumstances (e.g. traffic conditions, environmental conditions) which is determined by an automated valet parking system (AVPS) and which is designated to the subject vehicle (SV) by that system

Note 1 to entry: Designed speed is a variable and not a fixed value. An AVPS will operate the SV based on the designed speed, resulting in dynamic changes of the actual speed of the SV during its operation.

Note 2 to entry: Different manufacturers can provide different designed speeds under the same circumstances.

EXAMPLE An AVPS will adjust the SV's operating speed when the SV is travelling towards a corner with limited visibility due to occlusion by a wall. The exact operating speed depends on the system design in this circumstance. Therefore, most of the test procedures in this document do not specify a specific value for the speed but only refer to the designed speed.

3.19**designed distance**

situation-specific physical distance to other facility users, objects or structures, which an automated valet parking system (AVPS) intends to maintain under given circumstances while performing automated driving, and which is designated to the subject vehicle (SV) by the system

Note 1 to entry: Different manufacturers can provide different designed distances towards the same object.

3.20**pause**

braking activity performed by an automated valet parking system (AVPS) which either leads the subject vehicle (SV) to a standstill or maintains a stationary condition that occurs during automated driving and in which the SV remains ready to resume automated driving

Note 1 to entry: Situations such as coming to a standstill to give way to other traffic and coming to a standstill to avoid a collision can be considered as a pause provided the AVPS is able to continue operating the SV towards the destination after the situation that led to the pause has been cleared.

Note 2 to entry: When automated driving cannot be continued by the AVPS without human confirmation, the braking activity is described as an emergency stop as defined in [6.3](#).

3.21**sub-system**

component of an automated valet parking system (AVPS) at a logical level which includes one or more functions

Note 1 to entry: See [5.2.1](#) for details.

3.22**function**

ability of automated valet parking system (AVPS) to process inputs to the system and contribute to conversion of the inputs into appropriate outputs

3.23**reservation**

<automated valet parking service> basic agreement between the user and the service provider regarding the operation and management of the subject vehicle (SV) within a specific parking facility

Note 1 to entry: A single reservation may be valid for a certain period of time or dedicated to a single session.

Note 2 to entry: A reservation may include information such as the right to use a parking spot during a certain period of time, agreement to hand over authority or agreement for additional services (e.g. charging electric vehicle).

3.24**session**

<automated valet parking service> sequence of interactions for a given subject vehicle (SV) between a check-in (see [9.3.3.1](#)) and a check-out (see [9.3.3.2](#))

Note 1 to entry: There may be more than one session during one valid reservation period, but multiple sessions are not carried out simultaneously for one SV.

Note 2 to entry: Typically, a wireless connection is established on the operation interface (see [5.2.3](#)) during a session, leaving the possibility of suspending the connection during the sleep sub-state (see [9.3.2.3.3](#)).

Note 3 to entry: Under certain conditions, the user may have authority while a session is established. See [9.3.2.2](#) for additional information.

3.25

mission

<automated valet parking service> sequence of interactions under which the subject vehicle (SV) is being operated automatically by an automated valet parking system (AVPS) from its parked location to the destination for a particular purpose

Note 1 to entry: There may be more than one mission during one valid session period, but multiple missions are not carried out simultaneously for one SV.

3.26

scenario

<test> description of a complete traversal from the point of origin to a destination, to be performed for testing

3.27

scene

<test> description of a specific event to be performed for testing that does not include a point of origin or destination

Note 1 to entry: Test scenes may become part of a test scenario. Multiple test scenes may be implemented in a single test scenario.

3.28

system operator

role within an organization which manages vehicle operation in the parking facility, and which involves tasks which are either monitored while being performed automatically, or performed manually by individuals from a remote location.

Note 1 to entry: See [5.5.3](#) for further information.

3.29

facility manager

role within an organization which involves tasks which are to be performed by individuals and which require physical access to objects and events within the facility

Note 1 to entry: See [5.5.4](#) for further information.

4 Symbols and abbreviated terms

4.1 Symbols

Symbols and their meanings.

$V_{des,sv}$	designed speed of an SV
$V_{max,sv}$	maximum designed speed of an SV
$D_{des,fu}$	designed distance to other facility users (e.g. vulnerable road users) and dynamic non-AVPS vehicles
$D_{des,ob}$	designed distance to fixed structures or objects other than facility users (e.g. parked vehicles)
$D_{des,gap}$	designed longitudinal distance to the preceding vehicle during automated vehicle operation

4.2 Abbreviated terms

4.2.1 Terms defined in ISO/SAE PAS 22736

ADS	automated driving system
DDT	dynamic driving task
OEDR	object and event detection and response
ODD	operational design domain

4.2.2 Terms relating to names of system and sub-systems

AVPS	automated valet parking system
OB	operator backend (sub-system)
P	automated valet parking facility management (sub-system)
R	remote vehicle operation (sub-system)
U	user frontend (sub-system)
UB	user backend (sub-system)
V	on-board vehicle operation (sub-system)
VB	vehicle backend (sub-system)

4.2.3 Other terms

CRC	cyclic redundancy check
DSRC	dedicated short range communication
FV	forward vehicle
PFE	automated valet parking facility equipment (see 3.11)
SV	subject vehicle (see 3.3)
VMC	vehicle motion control
VRU	vulnerable road user
NDS	Navigation Data Standard

5 System framework

5.1 System description

5.1.1 Basic functionalities

The basic functionalities of AVPS can be described as the (automated vehicle) operation functions and the (system participants) management functions. [Table 1](#) describes these basic functionalities of AVPS.

- Performance requirements associated with the (automated vehicle) operation functions are specified in [Clause 6](#).
- General requirements associated with the (system participants) management functions are specified in [Clause 7](#).

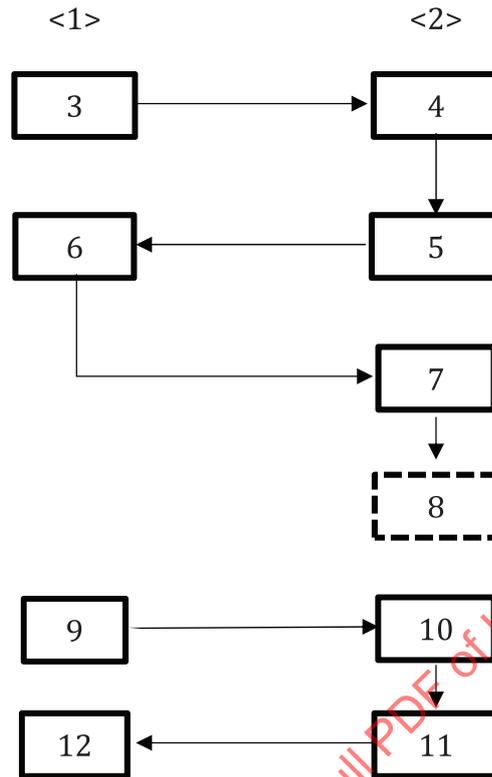
Table 1 — Basic functionalities and their description

Basic functionalities	Description
(automated vehicle) Operation functions	<ul style="list-style-type: none"> — Determines a destination and route. — Performs level 4 automated driving. — Responds to commands of the system management functionalities.
(system participants) Management functions	<ul style="list-style-type: none"> — Manages environmental conditions. — Checks the compatibility between vehicles and facilities. — Identifies the correct SV as the communication participant. — Remotely engages and disengages an SV. — Performs remote assistance^[4] when necessary. — Issues a command to stop the operation when necessary. — Reacts upon incapacitation of the automated vehicle operation. — Processes user requests.

5.1.2 Basic flow

5.1.2.1 General

[Figure 1](#) describes the basic flow of AVPS based on the user action and the system reaction. [Figure 1](#) describes the flow in which the user initially hands over authority to the service provider as a representative use case. AVPS can also be utilized for services in which the service provider initially hands over authority to the user (e.g. rental car services). Note that re-parking is an optional process and is not always required to complete the flow.

**Key**

1	user action	2	system reaction
3	requests availability	4	checks vacancy and compatibility
5	identifies SV and initiates check-in procedure	6	hands over authority
7	automated vehicle operation (entering)	8	automated vehicle operation (re-parking)
9	requests retrieval	10	automated vehicle operation (exiting)
11	initiates check-out procedure	12	receives authority

Figure 1 — Basic flow of AVPS**5.1.2.2 Considerations when the user hands over authority to the service provider**

When the user initially hands over the authority to the service provider as illustrated in [Figure 1](#), this document presupposes that an agreement exists between the user and service provider to perform the following tasks regarding the SV through AVPS, at a minimum.

- Dispatch the SV into driverless operation.
- Perform level 4 automated driving on such a dispatched vehicle.
- Turn off the SV at its parked location.

Additionally, the user may agree on certain tasks such as the following:

- Allow the facility manager to enter the vehicle and manually operate the vehicle if automated vehicle operation is not possible.
- Allow opening and closing of the trunk of the SV for package delivery service.
- Allow maintenance work.

It is assumed that the user and service provider agree on the terms and conditions when using AVPS, which would include the aspects above. However, the form and the contents of the agreement are not within the scope of this document.

The facility manager is required to manually relocate the SV in the case of incapacitation of automated vehicle operation (see [7.2.3](#)). If entering the vehicle cannot be agreed upon, alternative means shall be prepared in order to conform to the requirements of this document.

5.1.2.3 Example use cases of re-parking

Re-parking is a capability of AVPS that can be achieved by the basic functionalities. This capability allows service providers to move the SV within the operation zone without a direct action from the user.

For example, the re-parking capability could provide the following opportunities.

- Move an electric vehicle to a fixed charging spot.
- Move a parked vehicle to a car wash machine or other service bays.
- Maximize space utilization by parking vehicles close together and moving surrounding vehicles when one vehicle needs to exit.
- Reduce the time for retrieval by moving the vehicle closer to the exit near the expected arrival time (e.g. at an airport parking facility when flight arrival time information has been provided).

5.2 System configuration

5.2.1 Sub-systems

The rectangular boxes in [Figure 2](#) represent AVPS sub-systems.

- Functions allocated to each sub-system are described in [Table 2](#).
- This document specifies performance requirements for the functions allocated to the sub-systems represented by the boxes with solid lines ([Clause 6](#)). These two sub-systems perform mainly the operation functions.
- This document describes the required functions of sub-systems represented by the boxes with dotted lines. These sub-systems perform mainly the management functions ([Clause 7](#)).

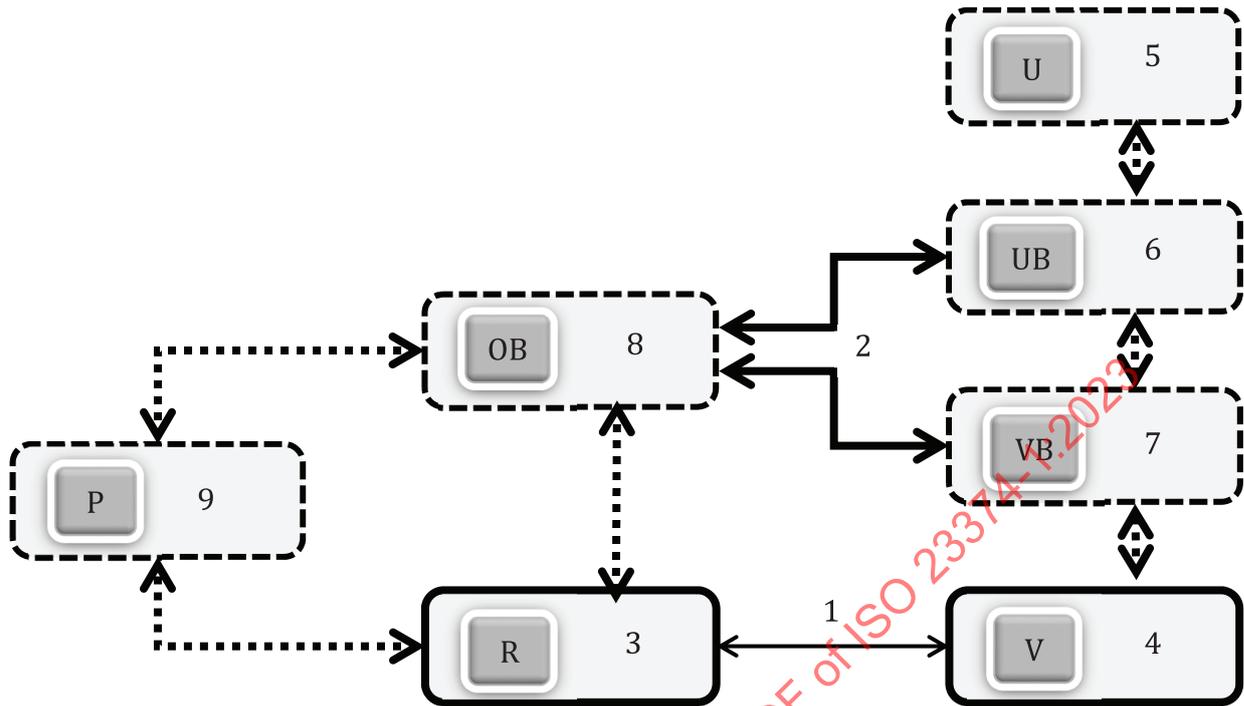
5.2.2 System architecture

[Figure 2](#) shows the logical architecture of the AVPS sub-systems. Implementation of the logical sub-systems to physical components is up to system design and is not subject to this document. In addition, a sub-system may be comprised of multiple physical components. For example, the remote vehicle operation sub-system may be comprised of sensors, control units and communication devices. The interfaces between these physical components are also not subject to this document. See [Annex G](#) for examples of system implementation to physical components.

5.2.3 Interface

The arrows in [Figure 2](#) represent the interfaces between the sub-systems.

- This document specifies the minimum set of data elements to be communicated through the operation interface (key 1) and management interfaces (key 2) ([Annex A](#)).
- This document describes the flow of information represented by the arrows with dotted lines.



Key

- 1 operation interface
- 2 management interfaces
- 3 remote vehicle operation
- 4 on-board vehicle operation
- 5 user frontend
- 6 user backend
- 7 vehicle backend
- 8 operator backend
- 9 automated valet parking facility management

Figure 2 — System architecture

5.3 Functional allocation

Table 2 shows the allocation of the main functions of AVPS to each sub-system of the architecture.

Table 2 — Functional allocation

ID	Sub-system	Role	Main functions	Remarks
R	Remote vehicle operation	Performs automated vehicle operation	— SV identification.	The functional allocation between the two vehicle operation sub-systems differs depending on the vehicle operation type (see 5.4.1 for details).
V	On-board vehicle operation		— Destination assignment.	
			— Route planning.	
			— OEDR.	
			— Localization of SV.	
			— Path determination.	
			— Trajectory calculation.	
			— Vehicle motion control.	
			— Emergency stopping.	

Table 2 (continued)

ID	Sub-system	Role	Main functions	Remarks
U	User frontend	Interface to the user	<ul style="list-style-type: none"> — Sends user requests. — Receives and updates vehicle status to user. 	
UB	User backend	Manages the system participants	<ul style="list-style-type: none"> — User request processing. 	The three backend sub-systems cooperate to respond to user requests (e.g. retrieval of vehicles).
VB	Vehicle backend		<ul style="list-style-type: none"> — Remote engagement/disengagement. 	
OB	Operator backend		<ul style="list-style-type: none"> — Manages parking facility availability. — Checks compatibility between SV and parking facility. — Dispatches SVs into driverless operation. — Performs remote assistance. 	
P	Automated valet parking facility management		<ul style="list-style-type: none"> — Manages environmental conditions. — Responds to incapacitation of the operation functions. 	

5.4 Classification

5.4.1 Vehicle operation types

5.4.1.1 General

This document classifies the automated vehicle operation functions of AVPS into three types based on its different functional allocation to the R and V sub-systems. [Table 3](#) shows functional allocation differences among the three vehicle operation types. SV identification and emergency stopping functions are excluded from [Table 3](#), as they are performed cooperatively between the R and V sub-systems and do not contribute to characterizing the types based on the functional allocation.

Refer to [Clause 6](#) for performance requirements corresponding to the functions.

Table 3 — Functional allocation for different Types

Functions	Type 1	Type 2	Type 3
Destination assignment	R & V	R	R
Route planning	V	R	R
OEDR	V (& R ^a)	R	R & V
SV localization	V	R	V
Path determination	V	R	V
Trajectory calculation	V	R or V ^b	V
Vehicle motion control	V	V	V
^a Allocation of the OEDR function to the remote vehicle operation sub-system is optional for Type 1 (refer to 8.3.1) ^b Refer to A.3.1.2 for details.			

5.4.1.2 Type 1 description

The V sub-system carries out most of the operation functions. Depending on the system design, only portions of the destination assignment function (refer to [6.4](#) for details) are allocated to the R sub-system.

5.4.1.3 Type 2 description

The R sub-system carries out most of the operation functions. Means to perform the OEDR and localization functions are established by installing PFE (e.g. detection sensors, control units) in the parking facility. OEDR by SV on-board sensors (as part of the V sub-system) is not required.

5.4.1.4 Type 3 description

The functional allocation is balanced between the two operation sub-systems. Type 3 utilizes the OEDR capabilities of the SV, and also gives sufficient control to the R sub-system by allocating the destination assignment and route-planning functions.

5.4.2 Traffic environment categories

5.4.2.1 General

Parking facilities capable of handling AVPS are categorized into mixed traffic and exclusive traffic based on the traffic environment. They have different requirements for the DDT ([6.2](#)) and environment ([Clause 8](#)).

5.4.2.2 Mixed traffic

Mixed traffic is a condition where the vehicles operated by AVPS share the same operation zone with other facility users, such as manually driven vehicles and vulnerable road users. See [8.4.1](#) for detailed information.

5.4.2.3 Exclusive traffic

Exclusive traffic is a condition where only vehicles managed by AVPS exist in the operation zone, and other facility users (e.g. vehicles not managed by AVPS, vulnerable road users) are prohibited. See [8.4.2](#) for detailed information.

5.5 Human interaction

5.5.1 General

It is expected that humans interact with AVPS under specific conditions. The following subclauses define the roles of the involved organizations and tasks expected to be performed by individuals belonging to such organizations.

The roles defined in the following subclauses can be assigned to one organization, or multiple organizations. For example, the system operator role and facility manager role can be performed by the same organization. The tasks can also be assigned separately or to the same individual.

In general, human interaction is considered to be external to AVPS. However, this document assumes that some of the requirements allocated to the P sub-system may be designed to be performed by a human as stated in [5.5.4](#).

5.5.2 Service provider

Service provider is the main organization which manages all the necessary information in order to provide services to the user through AVPS. Examples of the service provider's tasks are as follows.

- Coordinate the entities involved in AVPS and provide services to the user.
- Ensure that each sub-system fulfils the requirements stated in this document, and ensure that the cooperation of these sub-systems will conform to the system requirements defined in this document.

5.5.3 System operator

System operator interacts with AVPS through the OB sub-system. At a minimum, the following tasks shall be assigned.

- Dispatch the SV into driverless operation either manually or automatically.
- Perform remote assistance when requested by AVPS.
- Have the capability to terminate system operation when deemed necessary.

5.5.4 Facility manager

The facility manager assists the P sub-system. The requirements allocated to the P sub-system may be performed automatically or manually by the facility manager. The following are examples of the tasks which can need to be performed by a human.

- Maintain the environment in the parking facility (e.g. illuminance, floor conditions, PFE operating conditions).
- React upon incapacitation of the automated vehicle operation (e.g. reboot the system, manually transfer incapacitated vehicles).
- Check if the SV is equipped with external attachments which do not conform to the parking facilities' properties (e.g. available parking spot dimensions, ceiling height).
- Assist handover of the authority and efficient start of the automated vehicle operation (e.g. ensure that all passengers have left the SV and that other facility users are in an appropriate location when automated vehicles operation starts.).

6 Requirements for automated vehicle operation functions

6.1 General

6.1.1 Principles for performing automated vehicle operation

Safe operation of an unoccupied vehicle shall be given the highest priority among the overall objectives of AVPS.

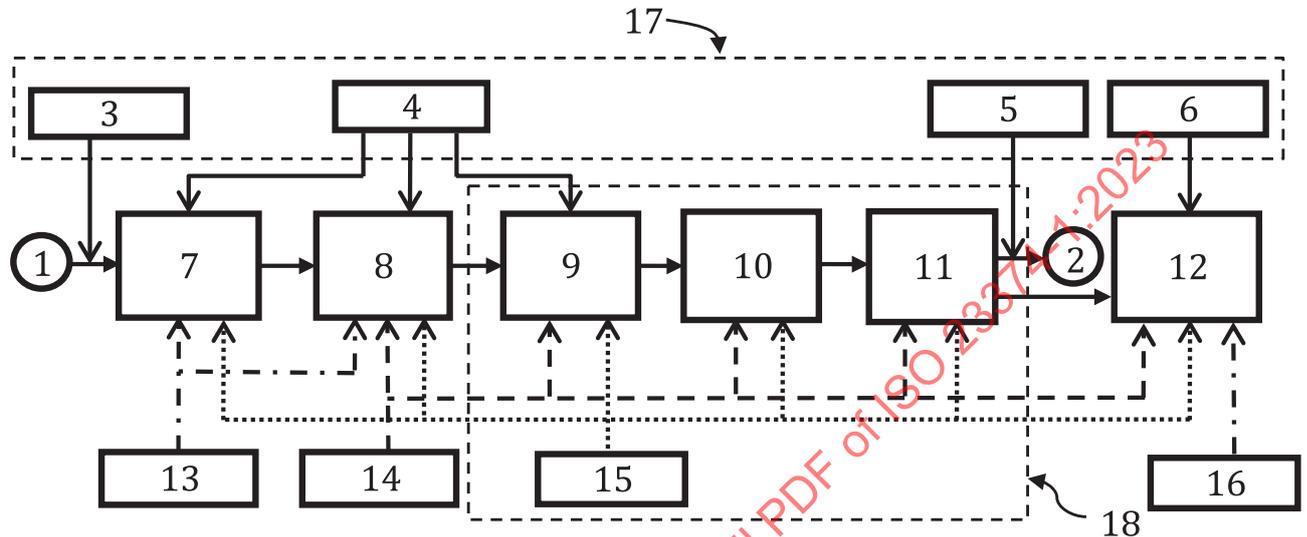
The aim for the performance of the operation functions by AVPS is to be at least equal to or better than the driving capabilities of an experienced and attentive human driver (i.e. recognizing the environment, planning the reaction, and operating the vehicle).

The following subclauses specify minimum requirements which shall be fulfilled independently of the vehicle operation types.

6.1.2 Relationship of the operation functions

Figure 3 shows the relationship of the operation functions, and also how some of the management functions influence the operation.

Requirements for path determination, trajectory calculation, VMC, and OEDR are combined as requirements for the DDT in 6.2



Key

- | | |
|---------------------------|-------------------------------|
| 1 start | 2 end |
| 3 remote engagement | 4 remote assistance |
| 5 remote disengagement | 6 operation stop command |
| 7 destination assignment | 8 route planning |
| 9 path determination | 10 trajectory calculation |
| 11 vehicle motion control | 12 emergency stopping |
| 13 map data | 14 localization |
| 15 OEDR | 16 human activity recognition |
| 17 management functions | 18 DDT |

NOTE 1 The relationships between functions expressed in arrows with broken lines are informative and the specification is up to the system design.

NOTE 2 Requirements concerning map data can be found in 8.3.3.

Figure 3 — Relationship of the operation functions

6.1.3 Operational design domain

Both R and V sub-systems shall predetermine their ODD. Automated vehicle operation is possible only when ODD conditions for both sub-systems are satisfied.

For example, SV on-board sensors and PFE used for object detection may have different operational limits. Automated vehicle operation is not possible when the environmental condition fulfils the ODD requirements of one of the sub-systems but not the other.

At a minimum, AVPS shall be capable of performing automated vehicle operation within indoor parking facilities with a paved surface, where the effect of weather is minimized. Operation in outdoor facilities is optional. Therefore, requirements for operation on rough surfaces and/or under various weather conditions are not specified in this document.

6.2 Requirements for DDT

6.2.1 General

OEDR is a primary function within the operation functions as the normal/routine operation of the SV is performed automatically without direct supervision or continuous monitoring by a human. It is crucial to verify that the performance requirements are satisfied independently of different combinations of the R and V sub-systems.

The following subclauses specify minimum requirements that are fundamental among various scenarios. System designers shall consider improving the performance beyond the minimum requirements during specific driving scenarios (e.g. increase distances to other facility users under clear traffic conditions).

It is strongly recommended that OEDR be designed in a conservative and safety-oriented manner to avoid unnecessary risk and loss of social acceptance by commanding unnecessarily aggressive VMC which can potentially be perceived as threatening by other facility users.

6.2.2 Basic performance requirements

The following requirements apply during normal operation in both mixed and exclusive traffic environments.

- The AVPS shall be capable of using braking or evasive manoeuvres in order to avoid reasonably foreseeable and preventable collisions which can cause damages to objects or to the SV.
 - The AVPS shall be capable of providing smooth braking and acceleration, and of avoiding sudden braking or acceleration of the SV under non-emergency/non-hazardous situations.
 - The AVPS shall be capable of inducing the full braking force of the SV in an attempt to avoid a collision in emergency/hazardous situations.
- The AVPS shall be capable of continuously monitoring the driving environment, other facility users, system conditions, and behaviours of the SV.
- The AVPS shall be capable of operating the SV to the assigned destination, following the planned route.
 - The AVPS shall be capable of physically maintaining the SV within the operation zone, and within the permitted boundaries if applicable.

NOTE Some Type 1 and 3 systems utilize a “permission area” transmitted from the R sub-system to the V sub-system for traffic management purposes. This can be explained as a limited, temporary operation zone that changes over time. For example, the SV can be ordered to stay within the permitted area bordering an intersection until another approaching vehicle passes.

- The AVPS shall be capable of controlling the SV in such a way that the SV observes the pre-determined traffic rules within the facility (see [8.3.3](#)).
- The AVPS shall be capable of operating the SV at its designed speed, including real-time adjustments to cope with the changing environment and conditions.
 - The achievable maximum speed induced by AVPS is 30 km/h: $V_{\max,sv} \leq 30 \text{ km/h}$
 - The operating speed shall not exceed limits defined within the parking facility (if any).
 - The achievable maximum speed shall be greater than 5 km/h: $V_{\max,sv} \geq 5 \text{ km/h}$
- The AVPS shall be capable of operating the SV on ramps up to $\pm 17\%$, independent of the structure (e.g. curve radius), and of maintaining a stationary condition on these ramps.

- The AVPS shall be capable of responding to remote assistance commands (e.g. pausing at a location or proceeding to a way point), and shall determine when to start manoeuvring within a reasonable amount of time.
 - The AVPS shall prioritize remote assistant commands to stop, unless said command is determined by the AVPS to potentially create a hazardous situation.
 - The AVPS may pause the SV until the conditions are determined suitable to respond to remote assistance commands to proceed to a certain location.
- The AVPS shall be capable of controlling the SV in order to perform all of the parking manoeuvres specified in ISO 20900, including conformance to the requirements for end position accuracy.
- The AVPS shall be capable of positioning the SV within the pick-up area so as to facilitate the smooth boarding of the user and passengers as well as the loading of goods when applicable.

6.2.3 Additional requirements for operation under a mixed traffic environment

6.2.3.1 Requirements

The following additional requirements apply when the AVPS is operated in a mixed traffic environment.

- The AVPS shall be capable of avoiding collisions with other facility users, especially with VRUs.
 - The AVPS shall be capable of controlling the SV so that the SV does not approach other facility users in the SV's direction of travel by less than 100 cm. This distance may be reduced to 40 cm when other facility users are not in the SV's direction of travel:
 - $D_{des, fu} \geq 100$ cm, when other facility users are in the direction of travel.
 - $D_{des, fu} \geq 40$ cm, when other facility users are not in the direction of travel.
 - This distance can be unachievable in reasonably unavoidable situations. Examples of such limitations are provided in 6.2.3.3.
- The AVPS shall be capable of maintaining a distance greater than 200 cm from preceding vehicles while travelling on a pathway under non-emergency/non-hazardous situations: $D_{des, gap} \geq 200$ cm. This requirement does not apply to parking manoeuvres
- The AVPS shall be capable of controlling the SV so that the SV does not block the pathway of other facility users.
 - The AVPS shall be capable of controlling the SV so that the SV does not approach objects other than facility users (e.g. walls, pillars, parked vehicles) by less than 40 cm when travelling faster than 5 km/h: $D_{des, ob} \geq 40$ cm when $V_{des, sv} \geq 5$ km/h.
- The AVPS shall determine a suitable stopping position of the SV relative to the destination so as not to disrupt the facility operation and/or interfere with other facility users. For example, when a parked vehicle is located in the area adjacent to the destination, a sufficient distance should be ensured so that the doors of the adjacent vehicle can be opened without contacting the SV.

NOTE "Other facility users" excludes AVPS-compliant vehicles in this context. It is possible to park two AVPS-compliant vehicles close together (e.g. for space saving purposes).

- The AVPS shall be able to avoid creating unnecessary traffic congestion. For example, by moving too close to vehicles that are attempting to park, or by entering an intersection when the intended direction of travel is blocked.
- The AVPS shall operate the SV in accordance with all local road and vehicle regulations, for example, using the SV's turn signals, turning on head lamps, and indicating that an ADS is engaged.

6.2.3.2 Examples of scenarios in a mixed traffic environment

The following are examples of scenarios an AVPS can potentially encounter in a mixed traffic environment, and which system designers shall consider.

- Presence of obstacles in the direction of travel which could be damaged, or which could damage the SV, when driving along the pathway or when entering the parking spot. This includes, for example, bags, trolleys, wheelchairs and especially infants and babies regardless of situation/position (e.g. sitting, lying, standing-alone or in a trolley or baby carrier).
- Presence of overhanging obstacles without direct contact to the floor, which can lead to a collision. For example, bike racks and overhanging loads such as ladders or timbers which are attached to the rear of a parked vehicle.
- Possibility of humans suddenly entering the SV's path from behind occlusions such as pillars, parked cars, etc., humans located in the driving path behind an occlusion such as a wall or barrier and not visible to the SV until the SV makes the turn around the wall or barrier, and humans overtaking a slowly moving SV and then entering the SV's driving path.
- Presence of humans in close proximity to a stationary SV, especially when humans are extremely close to or in direct contact with the SV, whose movement can potentially result in collisions and injuries.
- Presence of humans on ramps, as well as before or after ramp edges.
- Avoidance of potential blockages which are normally resolved by human drivers (e.g. where the SV and another AVPS vehicle are waiting for each other). This is especially important as the usual eye-contact and gestures of human drivers are not possible.
- Possibility of crossing, oncoming and overtaking bicyclists.

6.2.3.3 Performance limitations

Hazardous situations with moving objects (e.g. pedestrians, bicyclists, and vehicles) that are not reasonably avoidable can occur in mixed traffic conditions. Referencing the driving capability of an experienced and attentive driver should be considered as the threshold for such situations. These scenarios are covered in the test scenarios defined in [Clause 10](#).

Typical, but not exhaustive, situations where AVPS can potentially be unable to avoid collisions are as follows:

- a bicyclist or pedestrian approaches from an occluded lateral position where time to collision (TTC) is less than the time required by a human driver to stop the vehicle by applying full braking force;
- a parked vehicle suddenly drives out of a parking spot with high acceleration while the SV is already in close proximity to the parked vehicle;
- a pedestrian who deliberately tests the system's capabilities and suddenly jumps into the SV pathway directly in front of the SV.

6.3 Requirements for emergency stopping

6.3.1 General

The AVPS shall be capable of bringing the SV to a controlled stop under the situations defined in the following subclauses, at a minimum. The following requirements apply when an emergency stop is executed. The provisions of this subclause do not apply to a pause.

- The applied braking force to stop the SV depends on the driving situation. Other facility users, including vehicles approaching from behind, shall also be considered when performing an emergency stop.

- As soon as an emergency stop is initiated, the hazard lights shall be turned on, unless otherwise regulated. They may be switched off when the situation is mitigated and traffic is not obstructed.
- Human interaction is needed to resume automated vehicle operation after emergency stopping has occurred (see 7.2.3).

6.3.2 DDT fallback^[1]

The AVPS shall be capable in bringing the SV to a stable stopped condition in response to the following events.

- Occurrence of a failure in any sub-system which can or has become safety relevant (the type of failure that triggers an emergency stop is design-specific).
- Either or both R and V sub-systems are approaching ODD boundaries, or the driving environment changes such that the ODD is no longer fulfilled (e.g. blackouts, communication loss).

6.3.3 Response to operation stop commands

If an operation stop device (see 7.1.3) is activated, the AVPS initiates an operation stop command (see 9.3.3.13). The AVPS shall then bring the SV to a complete stop within the time specified in Table 4 after receiving the command.

Table 4 — Required time to stop the SV upon initiation of the operation stop command

$V_{des,sv}$ at the time of initiation	Requirement
$0 \text{ km/h} < V_{des,sv} \leq 10 \text{ km/h}$	Within 3 s
$10 \text{ km/h} < V_{des,sv} \leq 20 \text{ km/h}$	Within 4 s
$20 \text{ km/h} < V_{des,sv} \leq 30 \text{ km/h}$	Within 5 s
A maximum of 1 s is estimated (including sufficient buffer) from the time that the operation stop device was activated until the V sub-system receives the signal, giving the remaining time to actuate and bring the SV to a controlled stop.	

6.3.4 Detection of human activities

The AVPS recognizes unexpected human activities with the SV (see 6.7).

6.4 Requirements for destination assignment

6.4.1 General requirements

- The assigned destination shall be suitable in size for the SV to park, including any external attachments/loads (if applicable).
- In some cases, a destination may be assigned so that part of the vehicle or its external attachments/loads exceed the boundaries of the destination. In this case, the destination shall be assigned such that the portion of the vehicle exceeding the boundaries of the destination does not obstruct the pathway of other vehicles. For exclusive traffic environments, vehicles that exceed the boundaries of destinations should be allowed to enter the operation zone only when such a non-interfering assignment is possible.

NOTE An AVPS under exclusive traffic conditions is not required to detect irregular objects, including those protruding into the pathway for the SV.

For example, by assigning a corner location of a parking facility to oversized vehicles, so that the obstructed pathway is not used by other vehicles. As another example, if a pathway becomes obstructed, the pathway may be excluded from the drivable area (see 8.3.3.6).

- If the destination becomes unavailable during operation, an alternative destination shall be assigned.
- When a new destination is assigned via remote assistance during automated vehicle operation, this change shall be accepted accordingly by AVPS.

6.4.2 Type 1 systems

The R sub-system shall assign either a destination or a parking area consisting of multiple potential parking spots.

- If a parking area is assigned, the V sub-system shall determine a parking spot within the given parking area. While performing the DDT, the V sub-system shall search for available parking spots and report the chosen destination back to the R sub-system.
- If a single destination is assigned, the V sub-system shall adhere to the assignment.

6.4.3 Type 2 and 3 systems

The R sub-system shall assign a single destination.

6.5 Requirements for route planning

Either the V or R sub-system shall plan the route for the SV to reach the assigned destination. The following requirements shall apply.

- The route shall be created to reach the destination without violating traffic and facility-specific rules (e.g. driving the wrong way in a one-way zone).
 - If way points (intermediate destinations) are provided, the route shall be created to reach the destination via these way points.
 - For Type 1 systems, if a parking area is assigned, the V sub-system shall create a route to perform a search for available parking spot(s) in the assigned parking area.
- The most efficient route to the destination shall be created.
- The AVPS shall initiate one of the following actions if blocked areas are recognized in the planned route:
 - determine a new path within the route for the SV to avoid the blockage without changing the route, for example, to steer around a temporary construction zone;
 - plan a new route or change the destination;
 - communicate a request to the P sub-system to clear the blocked condition.
- When a new route is assigned via remote assistance, the new route shall be used accordingly.

6.6 Requirements for localization accuracy

6.6.1 Accuracy requirement relative to the digital map

AVPS shall continuously determine the position of the SV during automated vehicle operation. The following accuracy requirements shall apply.

- For Types 1 and 3, the V sub-system shall recognize the position of the SV on the digital map (see [8.3.3](#)) with an absolute accuracy of 50 cm and within $\pm 5^\circ$ for the direction. This localization is mainly needed to find the assigned destination. The measurement of distances to localization

markers, stationary objects and other facility users during automated vehicle operation is mainly performed by on-board sensors of the SV.

- For Type 2, the relative error of the position of the SV relative to objects detected by the R sub-system shall be within ± 15 cm and within $\pm 5^\circ$ for the direction. The higher accuracy requirement compared to Types 1 and 3 is needed due to the functional allocation of the complete OEDR to the R sub-system.

6.6.2 Accuracy requirement of the end position relative to the destination

The end position of the SV relative to the boundaries of the destination (e.g. lane markings, curbs, neighbouring parked vehicles) shall conform to the requirements specified in ISO 20900.

6.7 Requirements for human activity recognition

The following requirements shall apply. See [9.3.3](#) for information on the transition of the system states that can potentially be caused by the recognition results below.

- The AVPS shall be capable of recognizing the user's intent to interact with the SV (e.g. by detecting the door of the SV being unlocked with a valid key).
- The AVPS shall be capable of recognizing overriding activities while the system is operating the SV. For example, an occupant who did not leave the SV at the drop-off area may open the door, operate the steering wheel, accelerator/brake pedal, or other interfaces defined by the system designer (see [9.3.3.18](#)). These activities are considered as misuse by the user.
- The AVPS shall be capable of recognizing unexpected activities of other facility users from outside the SV. For example, other facility users can pull the door handle or try to open the trunk lid of the SV.

7 Requirements for management functions

7.1 Functions that influence the automated vehicle operation

7.1.1 General

[Figure 3](#) shows the relationship of management functions that influence the automated vehicle operation. In addition, an optional function for the situation where automated vehicle operation is simultaneously performed to multiple vehicles is defined in [7.1.6](#).

7.1.2 Remote engagement

The VB sub-system shall be capable of remotely engaging the V sub-system upon request from the OB sub-system to dispatch the SV into driverless operation. See [9.3.3.7](#) for details.

NOTE Dispatching is a system operator's task performed through the OB sub-system, while remote engagement is performed by the VB sub-system. These functions/tasks are separately defined to allow flexible system design, although in some cases they can be performed by the same organization or common hardware.

7.1.3 Operation stop

The OB sub-system shall be capable of commanding the automated vehicle operation to stop by issuing an operation stop command (see [6.3.3](#) for reaction by the operation functions).

This function also provides other facility users and facility managers with the opportunity to immediately stop the automated vehicle operation (see [8.2.5](#) and [9.3.2.7](#)).

7.1.4 Remote assistance

7.1.4.1 General requirements

The OB sub-system shall be capable of providing remote assistance when the automated vehicle operation functions cannot resolve certain situations on their own and process necessary commands to R and/or V sub-systems.

For example, two AVPS vehicles are paused facing each other at a bottleneck created by an unexpected object on the corridor. In this case, the human operator can assign a new route to one of the AVPS vehicles to resolve the situation.

This function, at a minimum, shall provide the system operator with an interface with the opportunity to submit the following commands:

- Remote assistance shall provide the system operator with the capability to change the assigned destination and planned route.
- Remote assistance shall provide the system operator with the capability, at a minimum, to command the SV to “pause”, or “permission to proceed”.
 - In addition, commands such as “slow down”, “give way”, or “reverse” may be added.

7.1.4.2 Example use case for clearance evacuation

In comparison to the operation stop command where the SV(s) performs an immediate stop, the system operator can prefer to stop the operation without blocking a certain location (e.g. emergency pathways, in front of fire extinguishers) under certain situations (e.g. earthquakes, fire). In such cases, the remote assistance function may be utilized to evacuate the SVs to a nearby preferable location.

7.1.5 Remote disengagement

The VB sub-system shall be capable of disengaging the V sub-system upon receiving a report of reaching the destination (see [9.3.3.8](#)).

The OB sub-system shall be capable of disengaging the V sub-system by triggering a transition to the suspend state (see [9.3.3.18](#)).

7.1.6 Central control

The OB sub-system may be equipped with a central control function. Central control is an optional function mainly equipped with Types 2 and 3 (and also applicable to some Type 1 systems), which coordinates operations of multiple vehicles.

By utilizing such a function, interference between AVPS vehicles can be avoided. Under an exclusive traffic environment, collisions between vehicles can be avoided, and traffic efficiency can be optimized. Under a mixed traffic environment, potential conflict between two AVPS vehicles at certain location can be prevented, and right of way can be given to one of the two vehicles.

7.2 Other management functions

7.2.1 Compatibility and occupancy check

The OB/UB/VB backend sub-systems shall be capable of checking occupancy and compatibility of parking facilities with respect to the characteristics of the SV upon receiving user requests, and communicate the necessary information to the user.

At a minimum, the following shall be confirmed when checking compatibility.

- Vehicle operation type and ODD definition between R and V sub-systems.
- SV outer dimensions and minimum turning radius relative to facility properties (e.g. ceiling height, corridor width, size of available parking spots, necessary turning circle).
- SV underbody clearance relative to the rate of change of slope angles within the parking facility.
- For Types 1 and 3, V sub-system object detection capability relative to the traffic environment category, existence of the central control function, and vehicles obstructing the pathway.

7.2.2 SV identification

The R/OB sub-systems shall be capable of identifying the (physical) SV against the V sub-system as the correct communication participant (see 8.2.3). The following list provides examples of means to perform SV identification.

- Localization proof: the V sub-system identifies the precise location of the SV in accordance with 6.6 and transmits the result to the R sub-system. A specific design is recommended when using coded markers to assist localization (see 8.2.3 and 8.3.2).
- Blink code transmission: the R sub-system sends a command to the V sub-system to activate exterior lights (e.g. by blinking the headlights). A suitable sensor installed in the parking facility will recognize the response of the SV.
- Licence plate recognition: the R sub-system will recognize the licence plate of the SV by using a camera installed in the parking facility upon arrival of the SV.

7.2.3 Response to incapacitation of the operation functions

The P sub-system shall be capable of performing the following activities when automated vehicle operation becomes incapacitated.

- Determine if the system capabilities have been recovered and automated vehicle operation may be resumed.
 - Resume automated vehicle operation if the conditions are satisfied,
 - If the conditions are not satisfied, physically access the SV and transfer the SV by means other than the automated vehicle operation. For example, by manually driving the SV or utilizing a tow truck.

7.2.4 Maintaining environmental conditions

The P sub-system shall be capable of maintaining the environmental conditions within the parking facility as defined in Clause 8. Therefore, the P sub-system should frequently check the environment within the parking facilities, especially for the conditions which cannot be detected or recovered by other sub-systems (see also 9.5). The frequency of the check depends on the characteristics of the parking facility.

For example, a parking facility located in the basement of a building is not likely to be affected by snow fall. Thus, compared to an outdoor facility, the frequency for checking the road surface conditions may be relatively low.

When environmental conditions are not satisfied, the P sub-system shall limit the operation of AVPS as needed.

The operation zone may be limited, for example, excluding areas covered with snow, which are not suitable for automated vehicle operation. The P sub-system is expected to communicate such a situation and stop accepting new reservations, retrieval request, or check-ins via AVPS.

For another example, if an object is blocking the pathway, the P sub-system is expected to remove this object.

8 Requirements for the environment within parking facilities

8.1 General

This clause defines ODD elements and PFE requirements to be established within the parking facilities in which an AVPS can operate. Different requirements apply depending on the type classification defined in [5.4](#).

8.2 Common requirements

8.2.1 Operation zone

The operation zone shall be predetermined. For example, the operation zone may be the entire facility with a mixed traffic environment, or it may be a certain floor within a multi-story facility for an exclusive traffic environment.

The boundaries of the operation zone shall be defined with a sufficient buffer between the operation zone and the area where automated vehicle operation is not allowed. Since the positional accuracy requirement is within 50 cm for Types 1 and 3, this buffer zone shall be at least 50 cm when there are no detectable physical barriers (e.g. structured walls).

8.2.2 Drop-off and pick-up area

Both drop-off and pick-up areas shall be located within the operation zone. Both areas should be large enough to provide comfortable space for boarding and exiting of the driver and passengers as well as for loading/unloading of luggage. These areas should be located in places where they do not interfere with the traffic flow. There may be more than one drop-off and more than one pick-up area within an operation zone. Drop-off and pick-up areas may share the same space (e.g. separated by time).

8.2.3 SV identification area

When the SV reaches the assigned facility with a valid reservation, the AVPS performs SV identification (see also [7.2.2](#)) in order to establish a session. SV identification may be performed at the drop-off area, anywhere inside the operation zone, or at the borders of the operation zone.

- If localization proof is used for SV identification as defined in [7.2.2](#), this document suggests placing at least three coded markers in the identification area, which conform to the description in [Annex C](#). It is recommended to have five markers in the SV's field of view (see also information in [Annex D](#)) to allow the recognition in the case that the coded markers are (temporarily) blocked by objects. It is recommended to locate this area close to the entrance of the operation zone.

8.2.4 Wireless communication

There shall be no communication blind spots within the operation zone. Sufficient bandwidth should be secured for system operation. [Subclause 9.2](#) specifies the general requirements for the communication interface.

The physical communication layer is not specified in this document and it is handled by the system design. Wireless communication may be realized by cellular network (e.g. 4G, 5G), wireless local area network (e.g. Wi-Fi, DSRC), the combination of the two, or other means suitable for the specific implementation.

8.2.5 Operation stop device

One or more operation stop device(s), which can immediately stop the automated vehicle operation (see 6.3.3 and 7.1.3), shall be installed either in the facility or in a separate location where it can be manually operated, for example by other facility users, system operators, and facility managers. A typical implementation of this device is similar to the “red button” installed on heavy machinery or at train stations.

The number of operation stop devices and areas to be equipped vary depending on the system design and size and layout of the operation zone. For example, a multi-story facility may require such a device on each floor to stop the vehicles only on that particular floor.

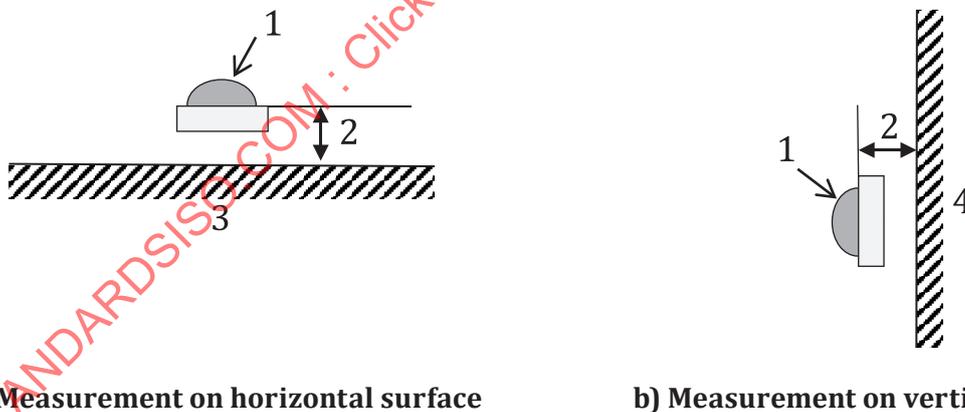
8.2.6 Lighting

The illuminance should be greater than 20 lx throughout the operation zone.

The illuminance value shall be ensured at the following segments. It may be lower at the borders of these segments.

- Along the centre line of the SV pathways.
- Along the centre line of pedestrian walkways.
- In the centre of all potential destinations.
- If localization markers as described in 8.3.2 are used, at the location where a localization marker is placed.

An illuminance meter that conforms to ISO/CIE 19476 shall be used for measurement. The illuminance meter shall be positioned less than 20 cm away from the surface of the above items to measure the illuminance in a vertical direction (90° to the surface). See Figure 4 for an illustration of the orientation of the illuminance meter.



Key

1	illuminance meter	2	< 20 cm
3	horizontal surface (e.g. ground)	4	vertical surface (e.g. pillar with a localization marker)

Figure 4 — Illuminance measurement on horizontal and vertical surfaces

Note that the illuminance requirements specified in ISO 20900 do not apply to AVPSs.

8.3 Vehicle-operation-type-dependent requirements

8.3.1 Detection capabilities of the R sub-system

8.3.1.1 General

Means to perform the OEDR and localization functions allocated to the R sub-system are typically established with detection sensors installed in the parking facility. For this reason, maintaining the necessary detection performance is classified as part of the environmental conditions.

As shown in [Table 5](#), different vehicle operation types require different detection capabilities such as detecting obstacles along the vehicle pathway, detecting the current position of the SV, or detecting the occupancy of parking spaces. These detection capabilities may be provided by the same sensor component or provided separately.

Object detection capabilities are specified based on a mixed traffic environment. Capabilities could be reduced for operation under an exclusive traffic environment.

Table 5 — Necessary detection capabilities by the R sub-system per vehicle operation types

Vehicle operation type	Object detection	Localization	Occupancy of destinations
Type 1	Optional	Not required	Optional
Type 2	Required	Required	Required
Type 3	Recommended	Not required	Required

8.3.1.2 Type 1

It is optional to provide detection capabilities to support the OEDR function for Type 1. Object detection capabilities may be provided by the R sub-system for traffic management purposes.

For example, object detection sensors installed at intersections can improve the traffic flow by providing pause/proceed commands to SVs.

8.3.1.3 Type 2

The R sub-system shall be capable of performing the OEDR and localization functions necessary for automated vehicle operation. For this reason, the detection capability of the R sub-system shall cover the entire operation zone without blind spots. The R sub-system shall detect objects, localize the SV, and detect occupancy of destinations.

8.3.1.4 Type 3

The R sub-system shall be capable of detecting available destinations within the operation zone. Object detection capability is recommended mainly for robust detection and efficient traffic management.

Guidelines for the detailed implementation are provided in [Annex H](#)

8.3.2 Localization markers

For Types 1 and 3, means to assist localization of the SV shall be provided as a part of the environment within parking facilities. (For Type 2 systems, localization is performed through detection sensors as mentioned in [8.3.1.3](#)).

In order to support the V sub-system in fulfilling the localization requirements specified in [6.6](#), a sufficient number of coded and/or anonymous markers shall be placed within the operation zone.

When installing either coded markers or the combination of coded and anonymous markers, the description provided in [Clause C.2](#) can be adopted. [Annex D](#) provides additional information for placing these markers in the operation zone.

When installing anonymous markers only, the description provided in [Clause C.3](#) can be adopted. [Clause H.1](#) provides additional information for placing anonymous markers in the operation zone.

In addition to the coded markers mentioned above, line markings described in [Annex E](#) may also support localization.

8.3.3 Digital maps

8.3.3.1 General

All AVPS vehicle operation types utilize static information from digital maps.

Type 1 and 3 vehicle operation types utilize high definition digital maps, which contain the semantic elements described in the following sub-clauses.

- For Type 1 systems, the same semantic information of a compatible map shall be used by all relevant sub-systems.
- For Type 3 systems, the high definition digital map is only used by the R sub-system, and only the information related to reaching the destination is communicated through the operation interface.

Type 2 vehicle operation type requires general information (not specific compared to Types 1 and 3 mentioned above) about the geometry of the parking facility and operation zone which may be provided by a digital map, a facility layout, or other suitable means.

8.3.3.2 Requirements for Type 1 and 3 systems

The digital map used by Type 1 and 3 systems shall contain the following semantic descriptions that are up to date in terms of the actual conditions within the parking facility. All objects defined in following sub-clauses shall carry a unique identifier within the operation zone to enable communication between the sub-systems.

NOTE 1 For example, at the time of writing, version 2.5.4 of the NDS (Navigation Data Standards)^[2] fulfils these requirements.

NOTE 2 Currently, the NDS is not the prescribed map standard. Other map standards fulfilling the requirements in [8.3.3](#) are also allowed.

The accuracy of the object location shall be within 10 cm relative to the localization markers within a radius of 30 m. The accuracy in absolute world coordinates is required to be within 1 m for linkage to map data outside the parking facility.

8.3.3.3 Road graph

A Road graph is a network of pathways through the parking facility.

A road graph shall consist of edges and nodes describing all possible traversals through the parking facility, and direction of lanes and possibilities to connect from one edge to the next in an absolute 3D space.

8.3.3.4 Geographical boundary of the parking facility

The geographical boundary of the parking facility is a polygon around the boundaries of an AVPS-conformant parking facility.

8.3.3.5 Operation zone

The operation zone is a polygon, or a series of polygons (in a multi-level facility), that is equipped with integrity protection mechanisms defining the outer boundaries for performing automated vehicle operation within the parking facility. A road graph within the operation zone shall be linked to an external road network at the boundaries of the operation zone.

8.3.3.6 Drivable area

A driveable area is a polygon representation within the operation zone suitable for vehicle operation which covers destinations (such as parking spots) and all of the necessary areas that are needed to reach destinations. At a minimum, fixed structures, such as walls and pillars shall be excluded from the drivable area.

8.3.3.7 Parking spots and service bays

Parking spots and service bays are location descriptions consisting of a geometric definition via 4 points on 3D space as well as relating attributes (e.g. charging bay, space for the handicapped), if applicable.

Parking spots and service bays shall be linked to a road graph to determine routes. Existence of a link to a lane should also imply that the destination can be reached from that direction (e.g. no physical barrier or forbidding road marking between the lane and the spot).

NOTE Parking spots and service bays can be defined as a "Space" with related attributes within ISO/TS 5206-1:—¹⁾.

8.3.3.8 Drop-off and pick-up areas

Drop-off and pick-up areas are an area description in the form of 3D coordinates and a type specifier (drop-off or pick-up).

Drop-off and pick-up areas should be linked to the road graph (see [8.2.2](#)).

8.3.3.9 Localization markers

Localization markers are coded and anonymous markers placed in the parking facility (see [8.3.2](#)).

Localization markers shall be measured in their 3-dimensional position and 3-dimension orientation, and shall carry their types and IDs in 3D in the map.

8.3.3.10 Pedestrian walkways

Areas intended for pedestrian movement. At a minimum, designated pedestrian crossings and walkways within the operation zone on the surface of the vehicle pathways shall be included when present.

This information supports the AVPS to reduce risk within mixed traffic environments.

8.3.3.11 Traffic rules

Traffic rules are pre-determined rules concerning traffic within the parking facility. At minimum, speed limits, directionality of traffic, stopping locations, and rights of way shall be included when present within the operation zone.

1) Under development. Stage at the time of publication: ISO/DTS 5206-1:2023.

8.4 Traffic environment category dependent requirements

8.4.1 Mixed traffic

For system installation, the parking facility structure shall take into consideration relevant local regulations/guidelines for pathway width, minimum curvature, ramp angle, dimensions for parking spaces, etc. See information provided in [Annex F](#) for an example of facility structure requirements in case of absence of such local regulations/guidelines.

- If speed bumps are placed in the operation zone, the maximum height shall be limited to 8,5 cm to avoid unintended detection results.
- If objects are intentionally placed to prohibit the entrance of vehicles to certain areas, the object used to represent the border shall be larger than the size of the object specified in [B.1](#).

Although this document does not require a certain surface condition to parking facilities for mixed traffic environments, it should be noted that systems which only conform to the minimum requirements defined in this document are based on operation on paved surfaces (see [6.1.3](#)).

8.4.2 Exclusive traffic

8.4.2.1 Objects in the operation zone

There shall be no objects within the operation zone which could damage the SV upon physical contact (e.g. objects larger than a golf ball, objects and debris with sharp edges).

8.4.2.2 Road surface condition

The road surface within the operation zone shall be a flat pavement with no irregular bumps/holes, which could negatively affect the automated vehicle operation.

8.4.2.3 Access control gates

Access control gates shall be installed at the border of the operation zone to allow entry of vehicles with a valid session only, and to prevent other facility users from entering the operation zone. Visible signs should be installed as necessary.

8.4.2.4 Dividing barriers

Dividing barriers shall be installed along the outer edge of the operation zone to restrict entrance of other facility users, especially humans. Visible signs should be installed as necessary.

8.4.2.5 Drop-off and pick-up areas

Means to prevent initiation of automated vehicle operation when humans (e.g. user, passenger) are present in the drop-off or pick-up areas shall be provided, for example, by surveillance or physical barriers. This is due to these areas temporarily becoming a mixed traffic environment in order to allow humans to board and exit an SV.

9 Requirements for overall system operation

9.1 General

The AVPS is a cooperative system comprised of physically separated sub-systems, in many cases provided by different organizations. For this reason, the communication interface is crucial for overall

system operation. Communication among the different organizations is the key element for establishing interoperability. As such:

- general requirements for the communication interface are specified in [9.2](#);
- the minimum set of data elements that need to be communicated within an AVPS is described based on the logical architecture shown in [Figure 2](#), and linked to the transition conditions specified in [9.3](#).

Further detailed implementation beyond what is specified in this document is up to the system design.

9.2 Requirements for the communication interface

9.2.1 General requirements

- The AVPS shall be capable of processing the following requests from the user on demand. These requests are processed independently of an active session. For example, after entering an AVPS-conformant parking facility, the user may request for availability of a compatible parking facility near the user's next destination.
 - Availability request (see [A.5.1](#)).
 - If applicable, payment requests.
- The AVPS shall be capable of processing on-demand mission requests from the user when a valid reservation or session exists. For example, the user may request an additional service while the SV is being parked.
 - At a minimum, the AVPS shall be capable of processing a retrieval request when a valid session exists (see [A.5.2](#)).
 - The AVPS may also process additional service-related requests when a valid reservation or session exists.
- A reservation shall be established before a session is created. The user is also expected to confirm the parking facility, service provider and terms and conditions of the service when a reservation is established. However, this document does not specify means to establish such reservation and user confirmation.
 - The three backend sub-systems shall be capable of performing a communication interface conformance check any time a valid reservation exists (see [A.4.1](#)).
- A session shall be created upon successful handover of the authority from the user to the service provider at the latest. The created session shall be maintained at least until successful handover of the authority from the service provider to the user, or when the service provider decides to revoke the session.
 - The AVPS shall be capable of supporting, at a minimum, event-based communication regarding the condition of the SV and status of the session and/or mission when state transition occurs between the system management states shown in [Figure 5](#) (this does not include system states within the automated vehicle operation). The information shall be communicated to the UB sub-system via the OB sub-system while a valid session exists.
- A mission shall be assigned when dispatching an SV and maintained until disengaged.
 - The operation interface shall be capable of (re)establishing a valid time synchronization for any communication on that channel while a valid mission exists.
 - The V sub-system shall be capable of providing a periodic message regarding the condition of the SV while a valid mission exists (see [A.3](#)).

9.2.2 Security goals

System designers shall perform risk analysis and implement mechanisms to avoid and protect the AVPS from security hazards. The following list provides examples of security hazards specific to AVPS.

- Vehicle theft.
 - For example, unauthorized command to unlock the SVs doors and turn on the ignition transmitted by a malicious source may lead the SV to be manually transferred outside of the facility.
- Safety hazards.
 - For example, unintended DDT relevant commands transmitted by a malicious source may lead the SV to collide with a facility user.
- Private information leakage.
 - For example, malicious attacks to the backend sub-systems may lead to leakage of private information of the customer and vehicle.
- Availability degradation or loss.
 - For example, denial of service attacks may lead to degradation or loss of the system performance.

9.2.3 Security requirements

- The AVPS shall be capable of (re)establishing secure channels among the sub-systems throughout a reservation in order to achieve the security goals.
- The AVPS shall be capable of (re)establishing mutual authentication of the management interfaces when a valid session exists in order to achieve the security goals.
- The AVPS shall be capable of (re)establishing mutual authentication of the operation interfaces when a valid mission exists in order to achieve the security goals.

9.3 System states and transition diagram

9.3.1 State transition diagram

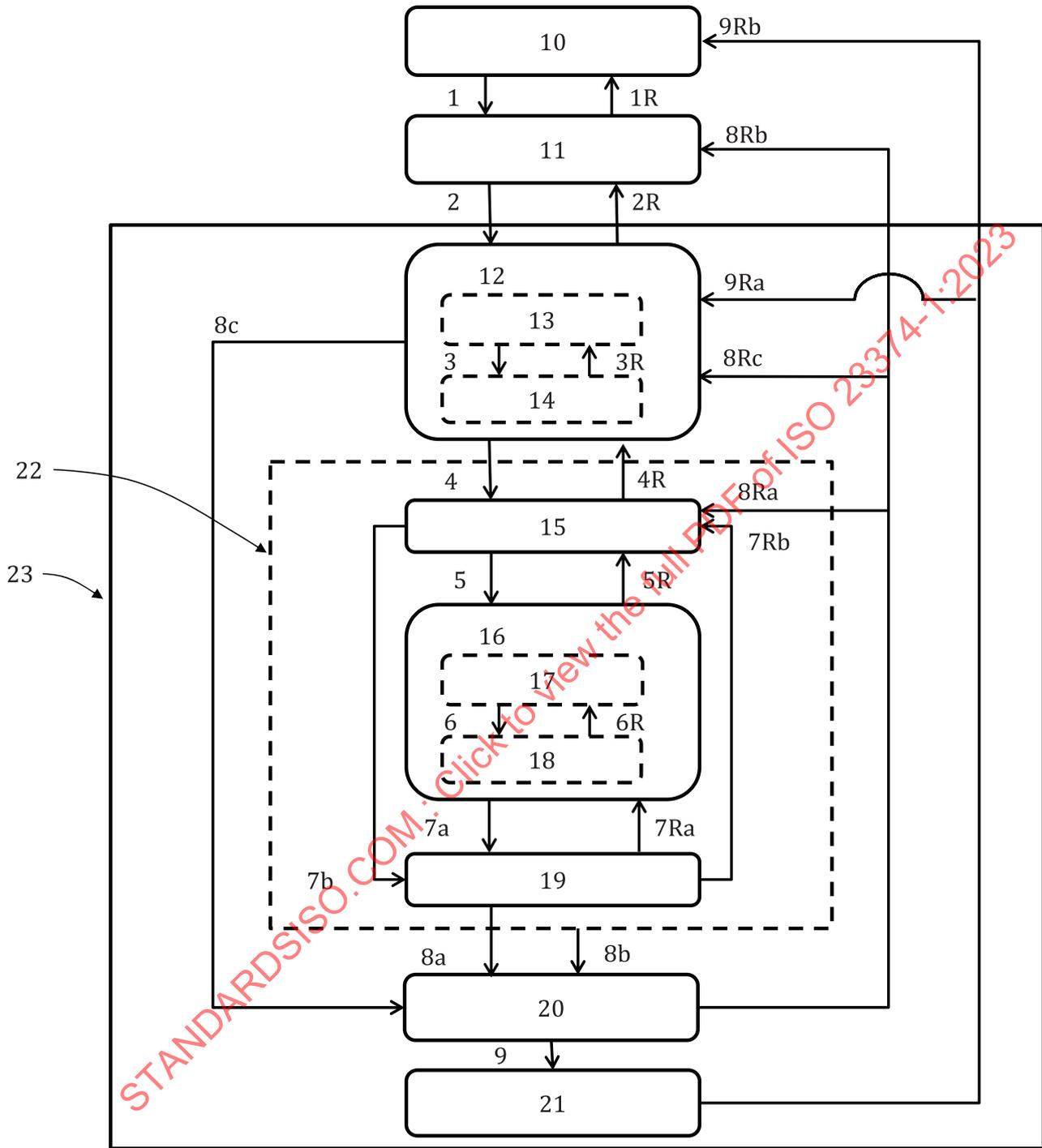
[Figure 5](#) illustrates the state transition based on the condition of a single SV. Therefore, the AVPS manages multiple states when simultaneously managing multiple SVs. The AVPS shall conform to the contents specified herein. Further implementation beyond the following specifications is up to system design.

- The inner rectangular box with a dotted line labelled “Automated vehicle operation” indicates that a mission has been assigned, and the SV is automatically operated by an AVPS through the states within the box. Performance requirements associated with these conditions are specified in [Clause 6](#).
- The outer rectangular box with a solid line labelled “System management” indicates that a session has been established and the SV is managed by an AVPS in the states within the box. Functional requirements associated with these conditions are specified in [Clause 7](#).

[Table 6](#) provides descriptions of the keys used in [Figure 5](#) and the clauses where relevant transition conditions and communication sequences are mentioned.

- Conditions described with phrases, such as, “detection of...” or “occurrence of...” trigger an immediate transition.

- Conditions described with phrases, such as “... is complete” or “... are confirmed” may be fulfilled at an earlier point in time before the transition occurs.



Key

- | | |
|----------------------|--------------------------|
| 10 inactive | 11 ready |
| 12 standby | 13 (sub-state) wait |
| 14 (sub-state) sleep | 15 depart/ arrive |
| 16 normal | 17 (sub-state) drive |
| 18 (sub-state) pause | 19 temporary error state |
| 20 suspend | 21 recovery |

Figure 5 — State transition diagram**Table 6 — Description of the keys in Figure 5**

Key	Description	Transition	Communication
1	SV identification complete	9.3.3.1	A.2.1
1R	Check-out sequence is complete	9.3.3.2	A.2.2
2	User hands over authority	9.3.3.3	A.2.3
2R	User receives authority	9.3.3.4	A.2.4
3	Sleep command	9.3.3.5	A.2.5
3R	Wake-up command	9.3.3.6	A.2.6
4	Mission assigned	9.3.3.5	A.2.7
4R	Mission accomplished	9.3.3.8	A.2.8
5	Destination and route confirmed	9.3.3.9	A.2.9
5R	Reached destination	9.3.3.10	A.2.10
6	Design specific events (e.g. object in way)	9.3.3.11	
6R	Design specific events (e.g. object cleared)	9.3.3.12	
7a	Error detected	9.3.3.13	
7b	Error detected	9.3.3.14	
7Ra	Error that caused transition 7a solved	9.3.3.15	
7Rb	Error that caused transition 7b solved	9.3.3.16	
8a	Automated vehicle operation is incapacitated	9.3.3.17	
8b	External trigger to perform an emergency stop	9.3.3.18	
8c	Transition 3 or 4 unsuccessful, human activity	9.3.3.19	
8Ra	Cause of suspend cleared	9.3.3.20	
8Rb	User receives authority.	9.3.3.21	A.2.4
8Rc	Cause of transition 8c cleared	9.3.3.22	
9	Reengagement unsuccessful	9.3.3.22	
9Ra	System capabilities are recovered	9.3.3.24	
9Rb	System capabilities cannot be recovered	9.3.3.25	A.2.2

9.3.2 Definition and requirements of system states

9.3.2.1 Inactive state

A valid session does not exist. The SV may be located within the operation zone.

9.3.2.2 Ready state

SV identification is complete, session is established, and the user has the authority.

- For Type1 systems, the user may manually operate the SV within the operation zone.
- For Type 2 and 3 systems, the SV is located within the drop-off area.

9.3.2.3 Standby state

9.3.2.3.1 General

The SV is managed by the AVPS and is waiting for further commands or user retrieval. The following requirements shall apply.

- SV maintains a stationary condition.
- Doors and windows are locked.

The standby state consists of two sub-states: “wait” and “sleep”.

9.3.2.3.2 Wait sub-state

SV shall be capable of immediate transition to the depart/arrive state.

9.3.2.3.3 Sleep sub-state

SV is in a low energy consumption condition. In this sub-state, the communication link of the operation interface may be temporarily disconnected. The following requirements shall apply in addition to [9.3.2.3.1](#).

- The operation interface can be re-established on demand.
- The estimated duration for maintaining the sleep sub-state shall be communicated from the V sub-system to the R sub-system.
- To be capable of transitioning to the wait sub-state within 3 min after issuing a wake-up command.

During this state, the SV may carry out maintenance (e.g. online updates). During such maintenance, wake-up/mission requests may not be processed.

9.3.2.4 Depart/Arrive state

The AVPS determines the destination and route, or waits for further commands after reaching the destination.

The following requirements shall apply:

- SV maintains a stationary condition.
- Position of the SV is verified by the AVPS.

The following requirements shall also apply in order to transition to the normal state.

- Performs destination assignment and route planning (refer to [6.4](#), [6.5](#) and [A.2.7](#)).
- Capable of starting performing the DDT within 10 s after receiving command, noting that actual movement of the SV is sometimes prevented by environmental conditions (e.g. objects in the direction of travel).

9.3.2.5 Normal state

9.3.2.5.1 General

The AVPS operates the SV in this state. The planned destination and route may be changed during this state. The following requirement shall apply:

- Conform to the requirements specified in [6.2](#) and [6.3](#).

The normal state consists of two sub-states, “drive” and “pause”. One example cause of the transition between these two sub-states is when an AVPS recognizes an object in the path. The AVPS will stop the SV in front of the object (transition to pause) and will resume operation when the object is no longer in the SV’s path (transition to drive).

9.3.2.5.2 Drive sub-state

SV is moving.

9.3.2.5.3 Pause sub-state

SV is stationary.

It is important to distinguish between this sub-state and other vehicle stationary conditions, such as temporary error or suspend states.

9.3.2.6 Temporary error state

The AVPS recognizes the occurrence of a temporary error. Depending on the type of the error, the AVPS may continue automated vehicle operation.

The following requirements shall apply.

- Duration of the temporary error-state shall be limited to the shortest amount of time defined by one of the sub-systems. Depending on the type of error, the defined time to transition to suspend state may vary, including immediate transition.

EXAMPLE Although the designer of the V sub-system defines 5 min as the threshold to transition to the suspend state, the owner of the parking facility prefers a maximum of 3 min to avoid congestion on a pathway. Therefore, the OB sub-system is designed to initiate a command to transition the SV to the suspend state. In this case, 3 min will apply.

- If transition occurred from normal state (7a), the AVPS may either initiate an emergency stop (see [6.3](#)), continue operation, or perform other means (e.g. degraded operation, comfort stop) to the SV depending on the type of error.
- If transition occurred from preparation state (7b), the AVPS maintains the SV in a stationary condition.

Events to be considered as temporary errors are up to system design. The following list provides typical examples of such events.

- A change in the driving environment that is not considered to be an immediate out of ODD condition but can potentially lead to an out of ODD condition after a certain period of time if the condition worsens. For example, invalid detection of a single localization marker can be determined as a temporary error if the AVPS is still able to localize the SV by detecting another marker.
- A transient loss of wireless communication connectivity.
- A sign of a system failure.

9.3.2.7 Suspend state

The AVPS becomes incapacitated to perform or continue automated vehicle operation without sufficient measures taken by the P sub-system (see [7.2.3](#)).

The following requirements shall apply.

- If the SV is moving, the AVPS shall perform an emergency stop (refer to [6.3](#)) of the SV.
- If the SV is not moving, it shall maintain a stationary condition.

- Hazard lamps of the SV shall be turned on (except when the last transition was 8c).

9.3.2.8 Recovery state

The SV or PFE is physically accessed by the P sub-system in this state. See [7.2.3](#) for examples.

- Hazard lamps of the SV may be turned off.

Recovery state duration is not limited and this state may be applied as long as necessary. For example, multiple actions can be necessary to transition to the standby state, or user retrieval can be necessary to trigger a check-out in order to complete the session.

9.3.3 Transition conditions

9.3.3.1 Transition 1, from inactive to ready

All of the following conditions are satisfied at a minimum.

- Valid reservation exists.
- Communication interface compliance check (see [A.4.1](#)) is complete.
- Check-in sequence (see [A.2.1](#)) is complete.
- SV identification (see [7.2.2](#)) is complete.

9.3.3.2 Transition 1R, from ready to inactive

The following condition is satisfied at a minimum.

- Check-out sequence (see [A.2.2](#)) is complete.

9.3.3.3 Transition 2, from ready to standby

All of the following conditions are satisfied at a minimum.

- Handover sequence (see [A.2.3](#)) is complete.
- SV is in a stationary condition, doors and windows are locked.
- The AVPS either confirms declaration by the user, or detects the following conditions:
 - there are no humans or animals in the SV;
 - there is no attachment on the SV that causes the SV to exceed the parking facility's allowable size limits;
 - SV is within the drop-off area.
- The AVPS confirms explicit user command to hand over authority to the service provider.
- R and V sub-subsystems are capable of performing automated vehicle operation.

9.3.3.4 Transition 2R, from standby to ready

Both of the following conditions are satisfied at a minimum.

- Handback sequence (see [A.2.4](#)) is complete.
- The AVPS detects user intent to receive authority.

9.3.3.5 Transition 3, from wait to sleep

Either one of the following conditions is satisfied.

- Sleep sequence (see [A.2.5](#)) is complete.
- Predefined time for the V sub-system to be in the wait sub-state has elapsed. The predefined time shall be longer than 30 s.

9.3.3.6 Transition 3R, from sleep to wait

Either one of the following conditions is satisfied:

- Wake-up sequence (see [A.2.6](#)) is complete.
- Detects valid input through SV on-board interfaces (e.g. main power train is activated with a valid key).

9.3.3.7 Transition 4, from standby to depart/arrive

The following condition is satisfied at a minimum.

- Mission assignment sequence (see [A.2.7](#)) is complete.

9.3.3.8 Transition 4R, from depart/arrive to standby

Both of the following conditions are satisfied at a minimum.

- Mission accomplished sequence (see [A.2.8](#)) is complete.
- SV is located at the intended destination or pick-up area.

9.3.3.9 Transition 5, from depart/arrive to normal

The following condition is satisfied at a minimum.

- Destination and route sequence (see [A.2.9](#)) is complete.

9.3.3.10 Transition 5R, from normal to depart/arrive

All of the following conditions are satisfied at a minimum.

- SV reached destination.
- SV is in a stationary condition.
- Destination reached sequence (see [A.2.10](#)) is complete.

9.3.3.11 Transition 6, from drive to pause

Design-specific conditions. Examples are provided in the following list.

- An obstacle is blocking the path.
- Approaching a facility-defined stop location (e.g. at intersections)

9.3.3.12 Transition 6R, from pause to drive

Design-specific conditions. Examples are provided in the following list.

- Obstacle previously blocking the path no longer exists.

- Intersection is clear to proceed.

9.3.3.13 Transition 7a, from normal to temporary error

The following condition is satisfied at a minimum.

- Error is detected.

9.3.3.14 Transition 7b, from depart/arrive to temporary error

At least one of the following conditions is satisfied.

- Error is detected.
- Transition 5 (see [9.3.3.9](#)) unsuccessful.

9.3.3.15 Transition 7Ra, from temporary error to normal

Both of the following conditions are satisfied.

- Cause of transition 7a is no longer valid.
- Previous state was normal state.

9.3.3.16 Transition 7Rb, from temporary error to preparation

Both of the following conditions are satisfied.

- Cause of transition 7b is no longer valid.
- Previous state was preparation state.

9.3.3.17 Transition 8a, from temporary error to suspend

At least one of the following conditions is satisfied.

- Shortest amount of time defined by one of the sub-systems to transition to suspend state has elapsed.
- OB sub-system commands transition.

9.3.3.18 Transition 8b, from automated vehicle operation to suspend

At least one of the following conditions is satisfied.

- Operation stop command (see [7.1.3](#)) is initiated.
- Overriding activity (see [6.7](#), second bullet point) is detected.
- Unexpected activities of other facility users (see [6.7](#), third bullet point) are detected.
- OB sub-system commands a transition to the suspend state.
- Other system designer-defined conditions (e.g. collision has occurred, bonnet or trunk opened).

9.3.3.19 Transition 8c, from standby to suspend

At least one of the following conditions is satisfied.

- Transition 4 (see [9.3.3.7](#)) unsuccessful.

- Overriding activity (see [6.7](#), second bullet point) is detected.
- Unexpected activities of other facility users (see [6.7](#), third bullet point) are detected.

9.3.3.20 Transition 8Ra, from suspend to depart/ arrive

The P sub-system has confirmed that the cause of suspend is resolved and current mission can be resumed.

9.3.3.21 Transition 8Rb, from suspend to ready

All of the following conditions are satisfied.

- The user's intent to receive authority (see [6.7](#), first bullet point) is detected.
- In case a valid mission exists, the mission shall be terminated (see [A.2.8](#)).
- Handback sequence (see [A.2.4](#)) is complete.

9.3.3.22 Transition 8Rc, from suspend to standby

The P sub-system has confirmed that the cause of suspend is resolved. If a valid mission exists, the mission shall be terminated (see [A.2.8](#)).

9.3.3.23 Transition 9, from suspend to recovery

The P sub-system makes a decision regarding physical access to the SV (see [7.2.3](#)). If a valid mission exists, the mission shall be terminated (see [A.2.8](#)).

9.3.3.24 Transition 9Ra, from recovery to standby

The P sub-system has confirmed that the cause of suspend is no longer valid, estimates that automated vehicle operation is possible, and attempts to determine if a new mission can be assigned.

All of the following conditions are satisfied at a minimum.

- SV is in a stationary condition, doors and windows are locked.
- P-sub system confirms the following conditions:
 - there are no humans or animals in the SV;
 - there is no attachment on the SV that causes the SV to exceed the parking facility's allowable size limits;
 - SV is within the operation zone.
- P-sub system communicates readiness of the state transition to standby.
- R and V sub-subsystems are capable of performing automated vehicle operation.

9.3.3.25 Transition 9Rb, from recovery to inactive

The following conditions are satisfied.

- A system failure in one or more of the sub-systems cannot be recovered.
- Check-out has been triggered/completed
- OB sub-system revokes system authority.

9.4 Suspend condition codes

In general, when the automated vehicle operation becomes suspended (see 9.3.2.7), the change in state shall be communicated within the AVPS. When the suspend condition is determined to conform to one of the conditions shown in Table 7, the suspend code shall be communicated to the P sub-system accompanied with a time stamp and location information.

The suspend conditions are transmitted with a combination of two or more layers. The first layer is classified by a fault or failure and determines if the suspend condition is reported from the R or V sub-system. This information assists the P sub-system in identifying the location.

The second layer provides additional information of either the cause of the fault, or possible reaction by the P sub-system upon failure of the V sub-system. This information benefits in determining the reaction (see 7.2.3).

Sub-system designers or related organizations may add further categories beyond layer 2 and may also add symbols in layers 1 and 2 that cannot be classified into the provided categories. Such additional categories shall be provided to the relevant organizations (e.g. facility manager, system operator).

The P sub-system is expected to take prompt action upon receiving the suspend condition codes.

The suspend condition codes in Table 7 focus only on situations that occur after mission assignment. Therefore, faults and failures which occur before mission assignment or when a mission is being assigned are not included. It is recommended to prepare alternative means for the AVPS to recognize unsuccessful session establishment or mission assignments.

Table 7 — Suspend condition categories and codes

Layer 1		Layer 2		Example/description
A	SV or V sub-system fault	01	Low fuel/battery	
		02	Internal overriding activity	Steering wheel
		03	External human activity	Door handle, trunk
		04	Uneven road surface	Pothole, ice
		05	Perception disturbance	Dirt on sensor head
		06	Marker detection unsuccessful	
		07	No signal from R sub-system	
		08	No signal from VB sub-system	
		09	Mission time-out	
		10	Invalid destination	Occupied
		11	Invalid route	Blocked
		12	Collision detected	
		13	Unavoidable obstacle in pathway	
		14	Unsuitable road surface	
		15	Invalid map data	
		16	User confirmation time-out	
		17	Retrieval time-out	
		18	User intervention	Remote key operation
			(other)	

Table 7 (continued)

Layer 1		Layer 2		Example/description
B	PFE or R sub-system fault	01	Unexpected SV movement	
		02	SV out of drop-off area	
		03	SV out of destination	
		04	Collision	
		05	Obstacle	
		06	Unsuitable road surface	
		07	Perception disturbance	
		08	No signal from V sub-system	
		09	No signal from OB sub-system	
		10	No signal from P sub-system	
			(other)	
C	SV or V sub-system failure	01	SV is manually drivable	
		02	SV is not manually drivable, but may be transferred.	
		03	SV is not manually drivable, and shall not be transferred.	
D	PFE or R sub-system failure			
	(other)			

9.5 Object and event detection data reporting

The object and event detection data reporting mechanism is one possible way to assist the P sub-system to maintain the environment within parking facilities by collecting data detected by R or V sub-systems which did not lead to the suspend state. Examples of such objects and events, which should be communicated to the P sub-system with a time stamp and location information, are shown in [Table 8](#). The thresholds to determine whether or not the object or event is reported are not specified in this document and are left up to the sub-system designer or related organization.

Table 8 — Example of object and events

	Object and event	Description/examples
1	Low illuminance	e.g. below 30 lx
2	Obstacle on road surface	
3	Abnormal road surface	Potholes, icy
4	Abnormal localization marker	Dirty, position changed
5	Map data unmatched	
6	Strong deceleration	
7	Intermittent communication	e.g. error in periodic communication
	(other)	

9.6 Data recording

The AVPS shall record and store the following data at a minimum,

- Video image of the surroundings of the SV while automated vehicle operation is being performed. This may be achieved using a vehicle on-board camera or camera installed in the facility, and these cameras may also serve different purposes.

- Data log of the following events:
 - change in system states;
 - communication within the system;
 - suspend condition codes.

The granularity of the data (e.g. resolution of the video image) and its storage duration should be determined by the relevant stakeholders in the area of system implementation, as certain countries or regions can have specific requirements on privacy and ownership of such data.

9.7 Information to the user

The AVPS shall provide the user with the following information.

- Authority has been handed over between the user and service provider.
- Estimated time of arrival in response to a retrieval request.

The system may provide the user with the following information.

- Location of the parked SV.
- Suspend conditions.
- Mission assignment status.

9.8 Development process and management

Service providers should ensure that the sub-systems conform to the requirements specified in the following documents.

- Conformance of the R sub-system to the respective part(s) of the IEC 61508 series.
 - When communication is used to fulfil safety scenarios, countermeasures for failures of the communication process shall be considered according to the IEC 61508 series.
- Conformance of the V sub-system to the respective part(s) of ISO 26262 series (Functional safety).
- Conformance of the R and V sub-systems to ISO 21448 and ISO/SAE 21434.
- Conformance of the OB/UB/VB sub-systems to the respective part(s) of ISO/IEC 27000 family.

10 Test scenarios for automated vehicle operation

10.1 General

10.1.1 Purpose

This clause provides basic test scenarios which shall be successfully completed using any AVPS that is deemed conformant to this document. The test scenarios are categorized based on their applicable traffic environment (refer to [5.4.2](#)).

This document is not intended to provide an exhaustive list of test scenarios. Thus, the relevant stakeholders (e.g. service provider, local authority, certification body, manufacturers, and their suppliers) should consider which additional tests, if any, are required, and/or if a given test should be repeated using modified settings within the specified range (e.g. position of a static object, movement of a dynamic object).

Conformance testing of communication that does not involve the operation interface (e.g. compatibility and occupancy checks) is not included in this document. It is recommended to be tested separately, as it does not require any physical setups that are defined in this clause.

10.1.2 Test sites

Testing may be performed in any parking facility that satisfies the specific requirements for each scenario or scene. For example, testing for ramps may be performed in a different parking facility if the facility used for basic operations testing does not have a ramp.

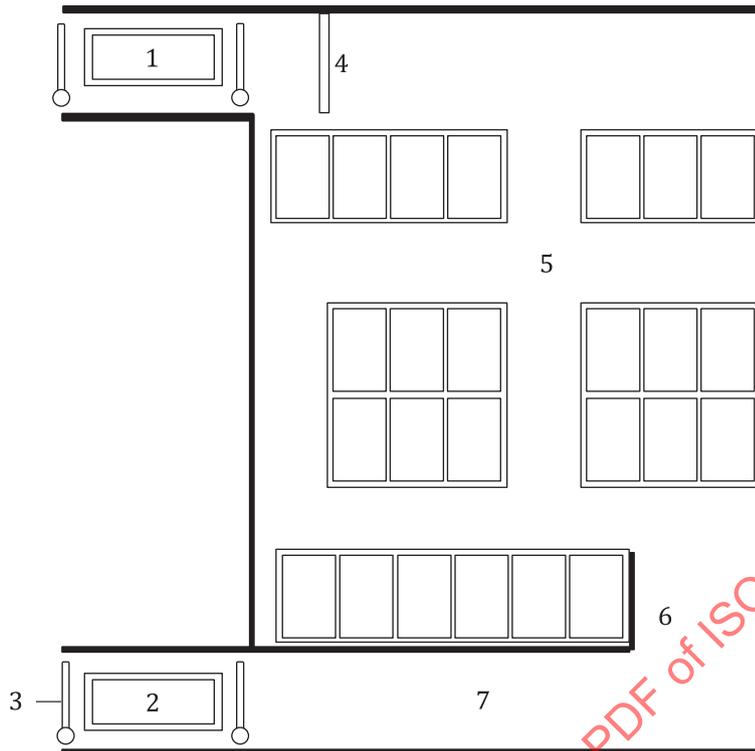
10.1.3 Environmental conditions

Testing shall be performed in parking facilities which satisfy the environmental conditions specified in [Clause 8](#).

In order to confirm conformance to the minimum requirements specified in this document, all tests shall be conducted on a dry (no visible moisture on the surface), uniform, solid paved surface and with a consistent slope below 1,5 %. Testing shall be conducted on a smooth road surface, no rougher than road class A as defined in ISO 8608.

10.1.4 Example test setups

[Figure 6](#) shows an overview of a test setup as an example. The example test setups for all scenarios/scenes illustrated are based on vehicles driving on the right side of the vehicle pathway, and the illustrations of the surrounding environment are representative. They may be adjusted for the available test sites provided they meet the minimum required elements.



Key

- | | | | |
|---|--------------|---|-----------------|
| 1 | pick-up area | 2 | drop-off area |
| 3 | gate | 4 | stop location |
| 5 | intersection | 6 | occluded corner |
| 7 | ramp | | |

NOTE The implementation of pick-up and drop-off areas are flexible in design (see 8.2.2).

Figure 6 — Example overview of a test setup

10.1.5 Values of each figure

Values included in the keys to the figure may have the following suffixes.

- Where marked “typical”, changing the value is not critical for the test results.
- Where a dynamically changing value is marked “tolerance (with a %)", when performing a test (e.g. speed of a test target), the test shall be conducted with the specified value, but the observed value while conducting the test may vary within the tolerance and still be considered as a successful test.
- Where a static value as the precondition of a test (e.g. location of a test target) is marked with a “range”, testing shall be performed by selecting a point within the specified range (see also 10.1.6).

Even though the illustrations of the test scenarios/scenes are provided as representative examples, values provided within keys indicating tolerances shall apply.

10.1.6 Test targets

Typical dimensions of static test targets to be used for the testing are provided in Annex B. At the time of publication of this document, the specifications of an infant test target were still under consideration, with the intention of adding them to the ISO 19206 series. When the relevant document becomes available, its requirements concerning an infant test target shall be considered applicable.

The size of the test targets specified in [Clauses B.1](#) and [B.2](#) represent the size of the smallest object that the AVPS shall be capable of avoiding. In particular, under the mixed traffic environment, accidents involving humans (or living animals) shall be avoided. Since the current state-of-the-art technologies have limitations in object recognition and identification, the test scenes are defined based on distinguishing objects by their physical sizes.

When testing any of the object avoidance scenarios, the defined test target shall be used at least once. The test may be repeated by replacing the test target with a real-world object (e.g. shopping cart, construction sign, baby stroller) with a larger size in all dimensions. The position and velocity of the test target shall be kept within the specified range.

Care is needed when testing systems with object detection sensors installed in the parking facility. Static test objects shall be placed at a point in time between when the SV starts its travel, and before the SV approaches the test location. The AVPS may re-route and operate the SV towards a different destination upon detecting the object in its original route. In this case, the SV may not approach the location in which the object was placed, but the test is considered successful. Proactive human intervention during any of the tests is prohibited. Remote assistance is only permitted when requested by the AVPS, and the SV is at a stopped, stationary condition.

10.1.7 Observing designed values at a preparation run

Some of the test scenes require a preparation run in order to observe the designed values (i.e. designed speed, designed distance and designed gap). The behaviour of the SV under a given condition and the factors that influence these design values are design-dependant.

For example, with design speed it is likely that Type 1 and 3 compliant vehicles will travel at different speeds under the same condition, whereas for design distance, one AVPS-compliant vehicle will potentially travel in the centre of the pathway, whereas another vehicle will potentially travel with a constant distance to the border on one side of the pathway.

For this reason, the test operator should take extra care in order not to change the operating conditions between the preparation run and the actual verification test, and perform them at short intervals between the two runs. The test is considered successful only when the observed designed values are reproduced within the specified tolerances defined in each test case description.

EXAMPLE The timing of the movement of the FV cross cutting the path of the SV in test scene 32 (see [10.6.2](#)) changes in relation to the designed speed of the SV ([Table 11](#) specifies these values). The observed designed speed for a preparation run without the object movement could be 1,8 m/s. In this case, the test would be determined to be conducted with a distance of 3,2 m. However, the SV could actually be travelling at 2,2 m/s when testing, with the object moving due to a change in the operating conditions that was not recognized by the test operator. In this case, the result does not satisfy the objective of verifying the system performance. Such a test result is not be considered as a pass or fail, but only an unsuccessful test.

10.1.8 Means to limit the designed values

Some of the test scenes require the designed values to be within a certain range in order to achieve the objective of the test. For example, test scene 1 (see [10.3.1](#)) requires the designed speed to be below 3 km/h. As another example, test scene 14 (see [10.4.4](#)) requires the designed distance towards the wall to be greater than 60 cm.

It is possible, under certain conditions, to limit the designed speed below a certain value. One example is to place a forward vehicle for the SV to follow, then reducing the forward vehicle's speed (assuming that the SV will not overtake or change the route). Another example is to apply a speed limit through either the R or OB sub-system, if the system is designed to be capable of doing so.

It is possible, under certain conditions, to influence the designed distance (i.e. to force the SV to travel at a certain lateral position within the pathway). One example is to place a physical barrier on the side(s) of the SV so that the width of the pathway is limited. Another example is to adjust the logical permission area (see [6.2.2](#), NOTE) if the system is designed to be capable of doing so.

These means are mainly needed when testing Type 1 and 3 systems.

10.1.9 Common pass criteria

Requirements specified in [Clause 6](#) shall be satisfied.

The requirement for operating the SV at as speed above 5 km/h shall be confirmed during at least one of the tests shown in [Table 9](#).

10.1.10 List of test scenarios and scenes

The test scenes may be performed together with other test scenarios/scenes, as necessary. For example, the object avoidance scenes may be performed together with the basic operation scenarios.

[Table 9](#) shows the list of test scenarios and scenes defined herein.

Table 9 — List of test scenarios and scenes

Basic scenarios		Applicable traffic environment category ^a	Clause
A	Entering	Common	10.2.1
B	Re-parking	Common	10.2.2
C	Exiting	Common	10.2.3
Basic scenes		Applicable traffic environment category	Clause
01	Climbing a ramp at slow speed	Common	10.3.1
02	Ramp down	Common	10.3.2
03	Operation on spiral ramps (up/down)	Common ^b	10.3.3
04	Out of drop-off area	Common	10.3.4
05	SV identification	Common	10.3.5
06	Out of operation zone	Common	10.3.6
Traffic rules and behaviours		Applicable traffic environment category	Clause
11	Stopping location	Common	10.4.1
12	Intersection passing	Common ^c	10.4.2
13	Blocked intersection	Common ^c	10.4.3
14	Give way in two-way traffic	Common ^c	10.4.4
15	Vehicle in front is reversing towards SV	Common ^c	10.4.5
Static objects		Applicable traffic environment category	Clause
21	Smallest object in direction of travel (forward/ reverse)	Common	10.5.1
22	Overhanging object	Common ^d	10.5.2

^a "Common" refers to both exclusive and mixed traffic environments

^b Testing shall not be performed for systems not designed to operate on two-way spiral ramps as illustrated in [Figure 12](#).

^c Testing shall not be performed for systems designed to operate under exclusive traffic environment only, and if the R-sub system is equipped with the central control function (see [7.1.6](#)).

^d Testing shall not be performed for systems designed to effectively avoid such situations (i.e. exclusive traffic environment only, and either does not allow entry of oversized vehicles or designed to assign destinations such that oversized vehicles exceeding the boundaries of the assigned destination do not obstruct the pathway of other vehicles)

Table 9 (continued)

Basic scenarios		Applicable traffic environment category ^a	Clause
23	Infant in parking spot (reverse/forward)	Mixed	10.5.3
24	Infant lying near ramp (up/down)	Mixed	10.5.4
25	Infant lying behind a curve	Mixed	10.5.5
26	Infant standing in front of parked vehicle (reverse/ forward)	Mixed	10.5.6
27	Infant standing beside parked vehicle	Mixed	10.5.7
28	Infant lying partly underneath parked vehicle	Mixed	10.5.8
Dynamic objects		Applicable traffic environment category	Clause
31	Forward vehicle braking hard	Common	10.6.1
32	Parked vehicle rushing out	Common ^c	10.6.2
33	Cross-cutting child	Mixed	10.6.3
34	Irregular movement of adult	Mixed	10.6.4
35	Bicyclist approaching	Mixed	10.6.5
Emergency stopping		Applicable traffic environment category	Clause
41	Operation stop command	Common	10.7.1
42	Communication failure	Common	10.7.2
^a "Common" refers to both exclusive and mixed traffic environments ^b Testing shall not be performed for systems not designed to operate on two-way spiral ramps as illustrated in Figure 12 . ^c Testing shall not be performed for systems designed to operate under exclusive traffic environment only, and if the R-sub system is equipped with the central control function (see 7.1.6). ^d Testing shall not be performed for systems designed to effectively avoid such situations (i.e. exclusive traffic environment only, and either does not allow entry of oversized vehicles or designed to assign destinations such that oversized vehicles exceeding the boundaries of the assigned destination do not obstruct the pathway of other vehicles)			

10.2 Basic scenarios

10.2.1 Scenario A: Entering

10.2.1.1 Category

Applicable to both mixed and exclusive traffic environments.

10.2.1.2 Objective

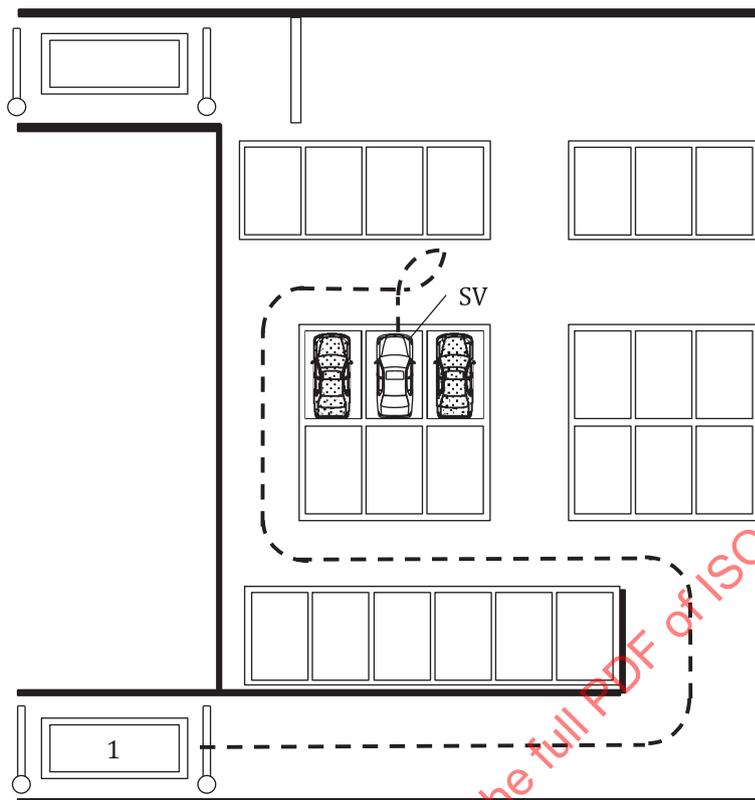
Verification of the basic automated vehicle operation and reverse parking manoeuvre. Also serves as the basis for adding additional test scenes.

10.2.1.3 Test setup

The test setup shall consist of, at a minimum, the following elements. [Figure 7](#) illustrates an example test set up.

- Drop-off area compliant to the operation type being tested.
- The route from the drop-off area to the destination has more than three curves (typically 90 ° each), consisting of both directions (left turn/right turn), and the travel distance is greater than 50 m.

— Parking spot as a destination.



Key

SV subject vehicle

1 drop-off area

Figure 7 — Example test setup for Scenario A

10.2.1.4 Test procedure

- 1) SV is located at the drop-off area and in standby state.
- 2) A parking spot is assigned as the destination.
- 3) AVPS operates the SV at its designed speed.
- 4) AVPS performs reverse parking into the assigned parking spot.
- 5) SV reaches the destination and transitions to standby state.

10.2.1.5 Pass criteria

Requirements specified in [6.2](#) are satisfied.

10.2.2 Scenario B: Re-parking

10.2.2.1 Category

Applicable to both mixed and exclusive traffic environments.

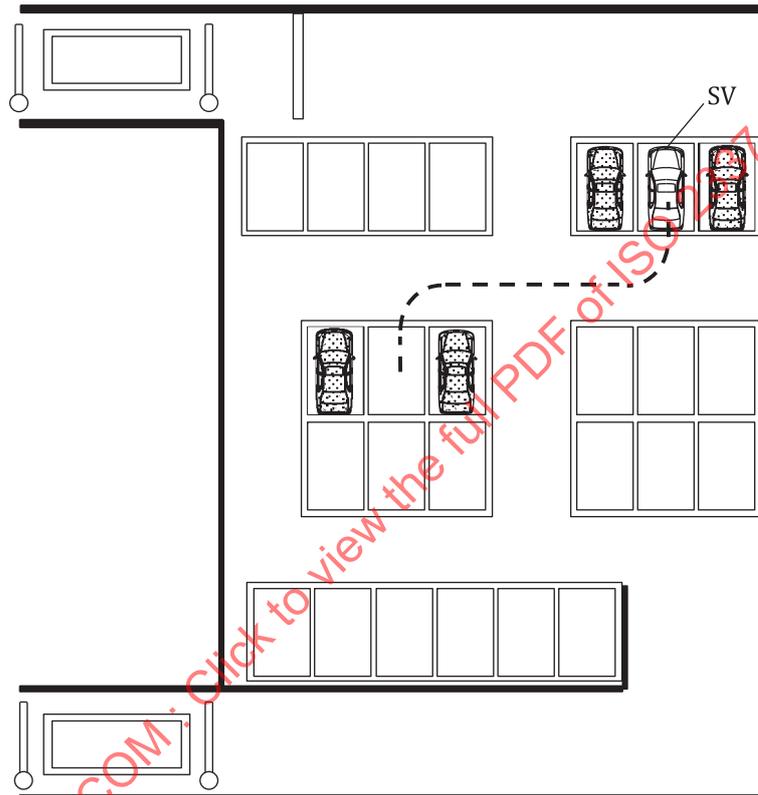
10.2.2.2 Objective

Verification of the re-parking capability and forward parking manoeuvre. Also serves as the basis for adding additional test scenes.

10.2.2.3 Test setup

The test setup shall consist of, at a minimum, the following elements. [Figure 8](#) illustrates an example test setup.

- Parking spot as a destination.



Key

SV subject vehicle

Figure 8 — Example test setup for Scenario B

10.2.2.4 Test procedure

- 1) SV is located in a parking spot and in standby state.
- 2) Another parking spot is assigned as the destination.
- 3) AVPS operates the SV at its designed speed.
- 4) AVPS performs forward parking into the assigned parking spot.
- 5) SV reaches the destination and transitions to standby state.

10.2.2.5 Pass criteria

Requirements specified in [6.2](#) are satisfied.

10.2.3 Scenario C: Exiting

10.2.3.1 Category

Applicable to both mixed and exclusive traffic environments.

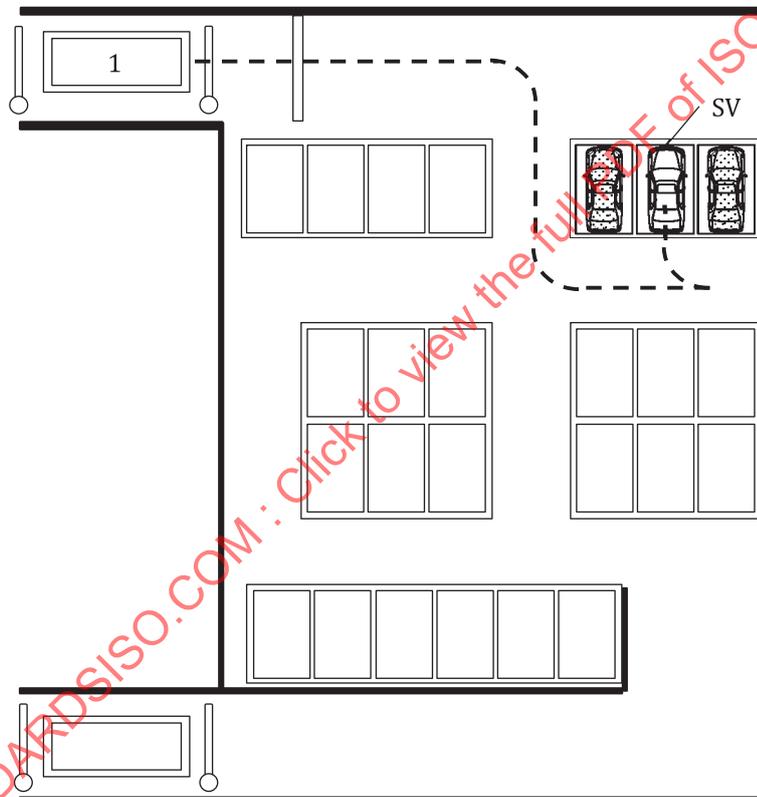
10.2.3.2 Objective

Verification of the basic automated vehicle operation, reverse exiting manoeuvre, and positioning of the SV within the pick-up area. Also serves as the basis for adding additional test scenes.

10.2.3.3 Test setup

The test setup shall consist of, at a minimum, the following elements. [Figure 9](#) illustrates an example test setup.

- Pick-up area as a destination



Key

SV subject vehicle

1 pick-up area

Figure 9 — Example test setup for Scenario C

10.2.3.4 Test procedure

- 1) SV is located in a parking spot and in standby state.
- 2) Pick-up area is assigned as the destination.
- 3) AVPS performs reverse exiting from the parking spot.
- 4) AVPS operates the SV at its designed speed.

5) SV reaches the destination and transitions to standby state.

10.2.3.5 Pass criteria

Requirements specified in [6.2](#) are satisfied.

10.3 Basic scenes

10.3.1 Scene 01: Climbing a ramp at slow speed

10.3.1.1 Category

Applicable to both mixed and exclusive traffic environments.

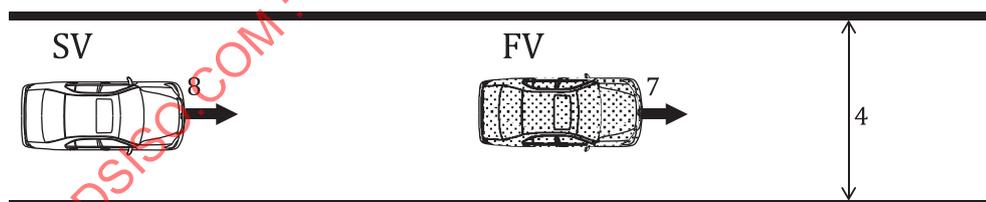
10.3.1.2 Objective

Verification of slow operation and maintaining a stationary condition on a ramp.

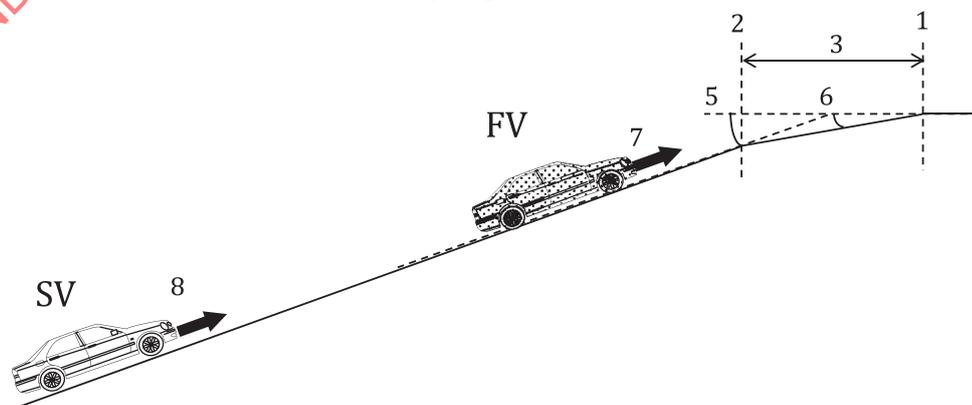
10.3.1.3 Test setup

The test setup shall consist of, at a minimum, the following elements. [Figure 10](#) illustrates an example test setup. For this test, values represented by key elements 3 and 6 shall be determined considering the underbody clearance of the SV (see [7.2.1](#)).

- Ramp, taking into consideration local guidelines for parking facilities regarding length, width and angle. The angle shall be equal to or greater than 15 %.
- Means to force the SV to travel under 3 km/h and to pause on the ramp.
- For example, such means may be a manually driven forward vehicle (FV) or a predetermined speed regulation of the facility.



a) Top view



b) Side view

Key

SV	subject vehicle	FV	forward vehicle
1, 2	section points	3	length of slope transition section: 3,5 m typical
4	width of ramp: 3,5 m typical	5	first slope angle: > 15 %
6	slope transition section angle: 7,5 % typical	7	travelling direction of FV, speed: 3 km/h acceptable tolerance: ±5 %
8	travelling direction of SV, speed: $V_{des,sv}$		

Figure 10 — Example test setup for Scene 01

10.3.1.4 Test procedure

- 1) AVPS operates the SV on a ramp upwards below 3 km/h
- 2) SV is paused on the ramp for more than 1 min.
- 3) SV's travel is resumed and reaches the end of the ramp.
- 4) If the ramp is not long enough to combine the verification of slow operation (1) and pausing (2)/ resuming (3) in one run, the two objectives may be verified by two separate runs.

10.3.1.5 Pass criteria

- SV does not reverse more than 20 cm down the ramp when pausing and resuming.
- SV underbody/bumper does not contact the surface of the ramp (due to over speed approach).
- 3 km/h or less is maintained when following the FV.

10.3.2 Scene 02: Ramp down

10.3.2.1 Category

Applicable to both mixed and exclusive traffic environments.

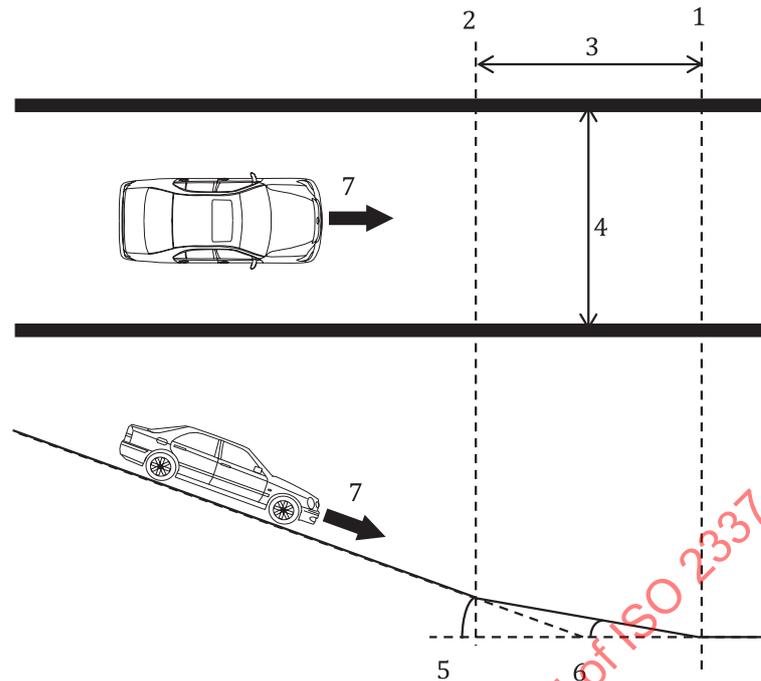
10.3.2.2 Objective

Verification of maintaining a constant speed on a downward ramp.

10.3.2.3 Test setup

The test setup shall consist of, at a minimum, the following elements. [Figure 11](#) illustrates an example test setup. For this test, the values for key elements 3 and 6 shall be determined considering the underbody clearance of the SV (see [7.2.1](#)).

- Straight and flat approach towards a downward ramp.
- Ramp, taking into consideration local guidelines for parking facilities regarding length, width and angle. The angle shall be equal to or greater than 15 %.

**Key**

- | | | | |
|------|---|---|---|
| 1, 2 | section points | 3 | length of slope transition section, 3,5 m typical |
| 4 | width of ramp: 3,5 m typical | 5 | first slope angle: > 15 % |
| 6 | slope transition section angle: 7,5 % typical | 7 | travelling direction of SV, speed: $V_{des,sv}$ |

Figure 11 — Example test setup for Scene 02**10.3.2.4 Test procedure**

- 1) AVPS operates the SV at its designed speed on a straight and flat corridor toward a downward ramp.
- 2) AVPS operates the SV on the ramp travelling downwards.
- 3) SV reaches end of the ramp.

10.3.2.5 Pass criteria

- SV does not accelerate and maintains a constant speed when traversing the ramp (excluding both ends of the ramp where the SV may decelerate).
- SV does not exceed the facility's upper speed limit.
- When traversing down the ramp the SV maintains a constant speed within a tolerance of ± 2 km/h.
- SV may decelerate near the slope transition section to avoid underbody/bumper contacting the surface of the ramp (due to over-speed approach).

10.3.3 Scene 03: Operation on spiral ramps (up/down)**10.3.3.1 Category**

Applicable to both mixed and exclusive traffic environments. However, testing is only required for systems designed to operate on two-way spiral ramps.

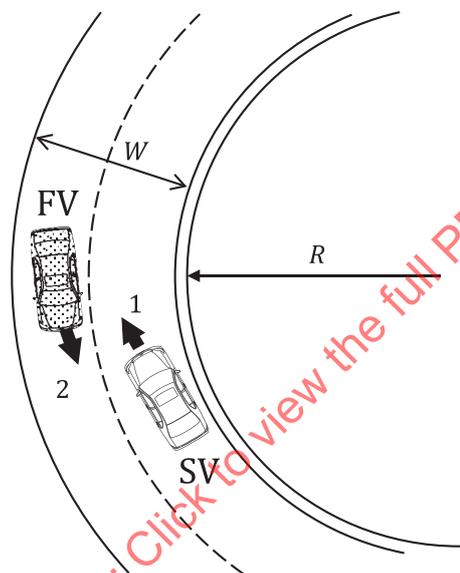
10.3.3.2 Objective

Verification of continuous operation on a curved road with on-coming traffic with limited visibility.

10.3.3.3 Test setup

The test setup shall consist of, at a minimum, the following elements. [Figure 12](#) illustrates an example test setup.

- Spiral ramp with length, width, and angle according to the values in [Figure 12](#).
- FV (either manually operated or operated by AVPS) travelling within the oncoming lane.
- If a two-way spiral ramp as illustrated in [Figure 12](#) is not available, testing may be performed on a flat surface. In this case, occlusion of the FV shall be considered as a way to reproduce the ramp angle as far as possible.



Key

SV	subject vehicle	FV	forward vehicle
W	width of ramp: 7,0 m range of $\pm 1,0$ m	R	radius: 6,5 m range of $\pm 1,0$ m
1	travelling direction of SV, speed: $V_{des,sv}$	2	travelling direction of FV, speed: 7 km/h, acceptable tolerance: ± 10 %

NOTE 1 Slope angle 13,5 %, range of $\pm 3,5$ %

NOTE 2 This figure shows only one run of the test procedure. SV and FV are exchanged on the second run.

Figure 12 — Example test setup for Scene 03

10.3.3.4 Test procedure

Test consists of two runs.

- 1) AVPS operates the SV at its designed speed on a ramp travelling downwards.
- 2) AVPS operates the SV at its designed speed on a ramp travelling upwards.

On both runs, the FV does not cross the lane boundaries.

10.3.3.5 Pass criteria

- SV does not cross the lane boundaries of its own lane of travel.
- Under mixed traffic conditions, SV does not pause to avoid collision with the FV.

10.3.4 Scene 04: Out of drop-off area

10.3.4.1 Category

Applicable to both mixed and exclusive traffic environments.

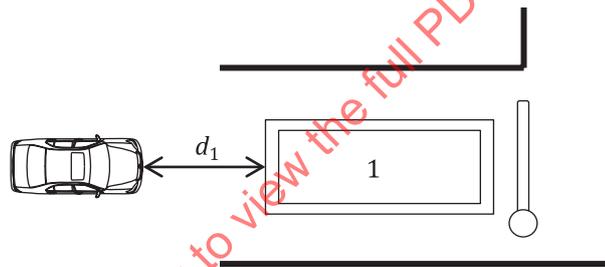
10.3.4.2 Objective

Verify that authority handover does not occur outside the drop-off area.

10.3.4.3 Test setup

The test setup shall consist of, at a minimum, the following elements. [Figure 13](#) illustrates an example test setup.

- Drop-off area conformant to the operation type being tested.



Key

d_1 distance between SV and drop-off area: 1,0 m range of $\pm 0,5$ m 1 drop-off area

Figure 13 — Example test setup for Scene 04

10.3.4.4 Test procedure

- 1) Driver attempts to initiate transition 2 (refer to [9.3.3.3](#)) when the SV is outside the drop-off area.

10.3.4.5 Pass criteria

AVPS does not engage the SV.

10.3.5 Scene 05: SV identification

10.3.5.1 Category

Applicable to both mixed and exclusive traffic environments.

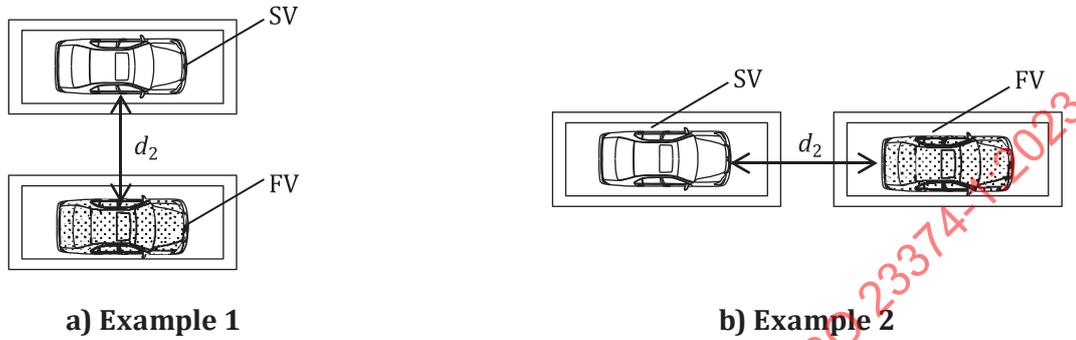
10.3.5.2 Objective

Verification of the SV identification function.

10.3.5.3 Test setup

The test setup shall consist of, at a minimum, the following elements. [Figure 14](#) illustrates an example test setup.

- Drop-off area for 2 vehicles conformant to the operation type being tested.
- Stationary FV, conformant to AVPS and similar to SV (preferably same type and same colour).



Key

- SV subject vehicle
- FV forward vehicle
- d_2 distance between SV and FV: 1,5 m range of $\pm 0,5$ m

Figure 14 — Example test setup for Scene 05

10.3.5.4 Test procedure

- 1) Both SV and FV are in the drop-off area and in ready state.
- 2) Driver of SV initiates transition 2 (see [9.3.3.3](#)).

10.3.5.5 Pass criteria

- Authority for SV is handed over to the service provider.
- Authority for FV is not handed over to the service provider.

10.3.6 Scene 06: Out of operation zone

10.3.6.1 Category

Applicable to both mixed and exclusive traffic environments.

10.3.6.2 Objective

Verify that automated vehicle operation is not possible outside the operation zone.

10.3.6.3 Test setup

The test setup shall consist of, at a minimum, the following elements.

- SV located outside the border of the operation zone.

10.3.6.4 Test procedure

- 1) SV is in standby state within the operation zone.
- 2) Test performer manually transfers the vehicle outside of the operation zone, or if possible, adjusts the operation zone so that SV is out of the operation zone.
- 3) AVPS attempts to perform remote engagement.

10.3.6.5 Pass criteria

SV is not engaged.

10.4 Traffic rules and behaviours

10.4.1 Scene 11: Stopping location

10.4.1.1 Category

Applicable to both mixed and exclusive traffic environments.

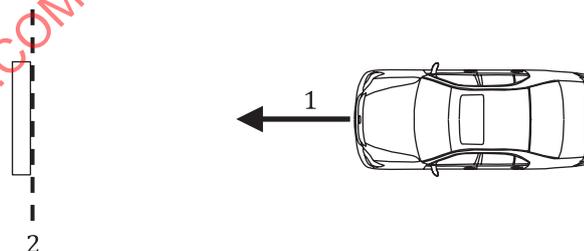
10.4.1.2 Objective

Verify that AVPS stops the SV in front of a stopping location.

10.4.1.3 Test setup

The test setup shall consist of, at a minimum, the following elements. [Figure 15](#) illustrates an example test setup.

- Stop location predefined by the parking facility.
- The stop location may be identified by a command from the OB sub-system or embedded in the digital map as a semantic element.



Key

- 1 travelling direction of SV, speed: $V_{des,sv}$ 2 stop location

NOTE The stop location indicator (white line) is representative and not required for testing.

Figure 15 — Example test setup for Scene 11

10.4.1.4 Test procedure

- 1) AVPS operates the SV at its designed speed in the forward direction towards a stop location.

10.4.1.5 Pass criteria

- SV pauses in front of the stop location.

- SV resumes operation when conditions are clear (e.g. the intersection is free of traffic)

10.4.2 Scene 12: Intersection passing

10.4.2.1 Category

Applicable to both mixed and exclusive traffic environments. However, this test shall not be performed in exclusive traffic conditions if the R sub-system is equipped with the central control function (see 7.1.6).

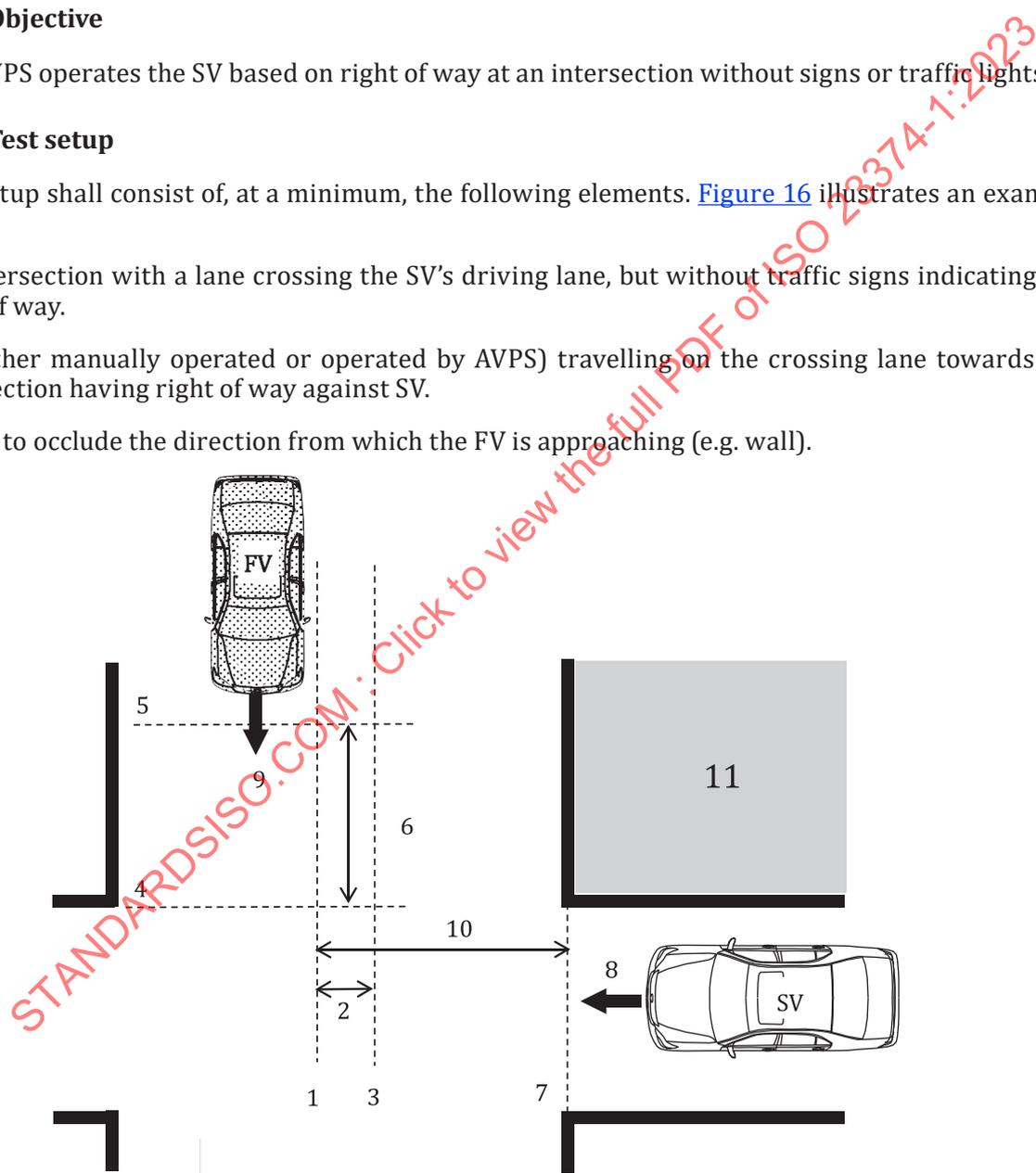
10.4.2.2 Objective

Verify if AVPS operates the SV based on right of way at an intersection without signs or traffic lights.

10.4.2.3 Test setup

The test setup shall consist of, at a minimum, the following elements. Figure 16 illustrates an example test setup.

- An intersection with a lane crossing the SV’s driving lane, but without traffic signs indicating the right of way.
- FV (either manually operated or operated by AVPS) travelling on the crossing lane towards the intersection having right of way against SV.
- Means to occlude the direction from which the FV is approaching (e.g. wall).



Key

- | | | | |
|----|--------------------------------|----|--|
| SV | subject vehicle | FV | forward vehicle |
| 1 | outermost edge of FV (SV side) | 2 | distance between key elements 1 and 3: 1,0 m, acceptable tolerance: ±3 % |
| 3 | SV stop location limit | 4 | border of the pathway of the FV and intersection |
| 5 | FV reference position | 6 | distance between key elements 4 and 5: 10 m ± 0,5 m |

7	border of the pathway of the SV and intersection	8	travelling direction of SV, speed: $V_{des,sv}$
9	travelling direction of FV, speed: 10 km/h, acceptable tolerance: $\pm 3\%$	10	distance from key elements 1 to 7: 3 m, acceptable tolerance: $\pm 0,2$ m
11	occluded		

Figure 16 — Example test setup for Scene 12

10.4.2.4 Test procedure

- 1) Perform a preparation run without the approaching FV to observe the value for key element 8.
- 2) AVPS operates the SV to the forward direction at its designed speed within $\pm 10\%$ tolerance compared to the value observed at the preparation run, towards an intersection with a crossing pathway.
- 3) FV travels with constant speed (key element 9) and reaches key element 5 when the SV reaches key element 7 of [Figure 16](#).

10.4.2.5 Pass criteria

- SV does not exceed key element 3 of [Figure 16](#).
- SV restarts after FV has passed the intersection.

10.4.3 Scene 13: Blocked intersection

10.4.3.1 Category

Applicable to both mixed and exclusive traffic environments. However, this test shall not be performed in exclusive traffic conditions if the R sub-system is equipped with the central control function (see [7.1.6](#))

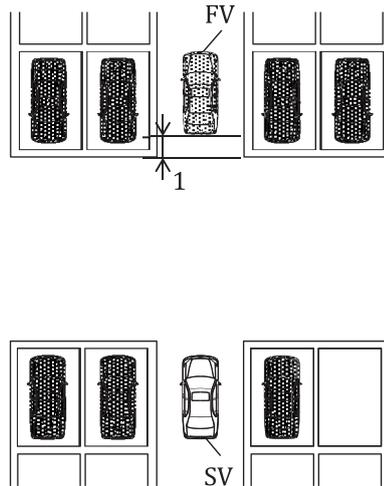
10.4.3.2 Objective

Verify if AVPS recognizes a blocked traffic condition at an intersection and operates the SV appropriately. It is not intended to verify re-routing capability.

10.4.3.3 Test setup

The test setup shall consist of, at a minimum, the following elements. [Figure 17](#) illustrates an example test setup.

- Destination of the SV can be reached only by proceeding straight across the intersection.
- An intersection with a lane crossing the SV's driving lane, but without traffic signs or map data indicating the right of way.
- Stationary FV blocking the intended pathway of the SV on the other side of the intersection.



Key

SV subject vehicle

FV forward vehicle

1 distance between rear end of FV and front border of parking spot: 1,0 m, range $\pm 0,5$ m

Figure 17 — Example test setup for Scene 13

10.4.3.4 Test procedure

- 1) AVPS operates the SV to the forward direction at its designed speed towards an intersection with a crossing lane.
- 2) A stationary FV on the other side of the intersection does not leave enough space for the SV.

10.4.3.5 Pass criteria

The SV does not enter the intersection.

10.4.4 Scene 14: Give way in two-way traffic

10.4.4.1 Category

Applicable to both mixed and exclusive traffic environments. However, this test shall not be performed in exclusive traffic conditions if the R sub-system is equipped with the central control function (see [7.1.6](#))

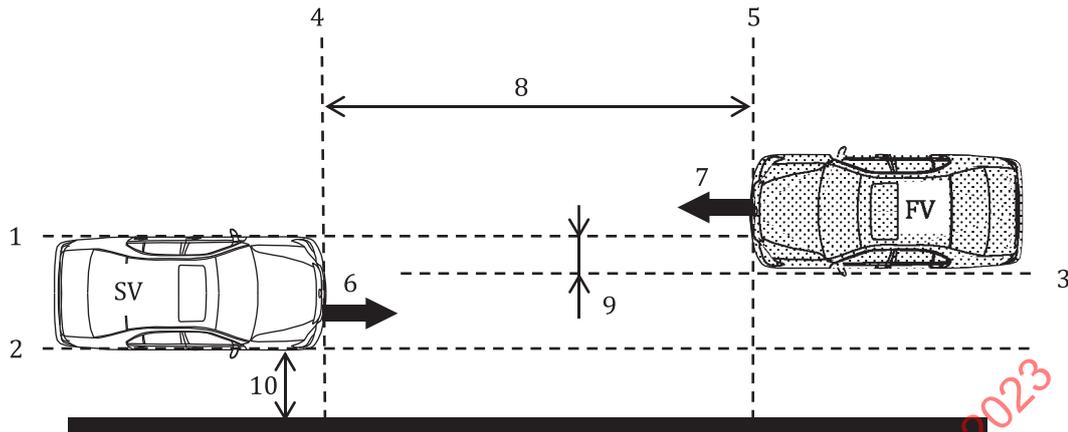
10.4.4.2 Objective

Verify if AVPS is able to operate the SV on a narrow corridor with two-way traffic.

10.4.4.3 Test setup

The test setup shall consist of, at a minimum, the following elements. [Figure 18](#) illustrates an example test setup.

- Corridor with a wall on one side but with sufficient width for two-way traffic.
- Either a manually operated FV or test target conformant to ISO 19206-3 that approaches the SV with an overlap.
- Means to force the SV to travel within the defined distance from the wall.



Key

- | | | | |
|----|---|----|--|
| SV | subject vehicle | FV | forward vehicle |
| 1 | outermost edge of SV (left side) | 2 | outermost edge of SV (right side) |
| 3 | outermost edge of FV (left side) | 4 | outermost edge of SV (front side) |
| 5 | outermost edge of FV (front side) | 6 | travelling direction of SV, speed: $V_{des,sv}$ |
| 7 | travelling direction of FV, initial speed: 10 km/h, acceptable tolerance: $\pm 10\%$ | 8 | initial distance between key elements 4 and 5: $> 15\text{ m}$ |
| 9 | distance between key elements 1 and 3 (initial overlap): 30 cm acceptable tolerance: $\pm 20\%$ | 10 | distance from wall to key element 2: $> 60\text{ cm}$ |

Figure 18 — Example test setup for Scene 14

10.4.4.4 Test procedure

- 1) Perform a preparation run without the approaching FV to observe key element 10 and determine the lateral position of the FV such that the value of key element 9 is satisfied.
- 2) AVPS operates the SV in the forward direction at its designed speed on a two-way corridor with a wall on the near side.
- 3) Oncoming traffic (FV) approaches with an overlap (key element 9), but does not steer to give way in the other direction.

10.4.4.5 Pass criteria

- In all cases, SV steers towards the wall to give way but does not touch the wall.
- SV may brake and pause after steering towards the wall. The movement of the FV shall be stopped when observing that the SV has paused. If the SV is not able to proceed between the FV and the wall after the FV has stopped, the FV shall steer towards the open space and complete the passing manoeuvre.
- After the SV and the FV pass each other, the SV manoeuvres towards the centre of the corridor.

10.4.5 Scene 15: Vehicle in front is reversing towards SV

10.4.5.1 Category

Applicable to both mixed and exclusive traffic environments. However, this test shall not be performed in exclusive traffic conditions if the R sub-system is equipped with the central control function (see 7.1.6).

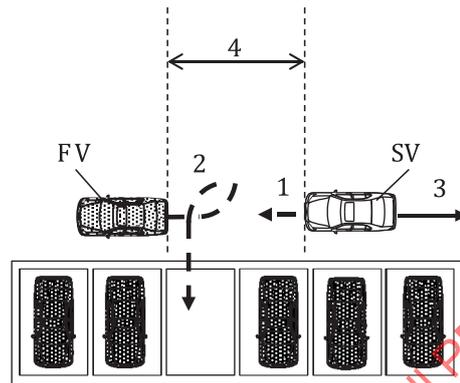
10.4.5.2 Objective

Verify if AVPS is able to operate the SV to give way to a reverse parking FV.

10.4.5.3 Test setup

The test setup shall consist of, at a minimum, the following elements. [Figure 19](#) illustrates an example test setup.

- FV (manually operated).
- Parking area with at least one free parking spot.



Key

- | | | | |
|----|---|----|---|
| SV | subject vehicle | FV | forward vehicle |
| 1 | SV's initial direction of travel, speed: $V_{des,sv}$ | 2 | FV's direction of travel, reversing speed: $3 \leq \text{km/h}$ |
| 3 | SV's expected direction of travel when FV starts its reversing manoeuvre, speed: $V_{des,sv}$ | 4 | $D_{des,gap}$ |

Figure 19 — Example test setup for Scene 15

10.4.5.4 Test procedure

- 1) AVPS operates the SV in the forward direction at designed speed, following a FV with a gap, $D_{des,gap}$.
- 2) FV passes a vacant parking spot, stops, and then begins to reverse towards SV.
- 3) There is nothing behind the SV that limits the possibility to reverse.

10.4.5.5 Pass criteria

- SV reverses to give space for FV.
- SV should provide comfortable distance for the FV reverse. This distance shall be greater than 2 m.

10.5 Static object avoidance

10.5.1 Scene 21: Smallest object in the direction of travel (forward/reverse)

10.5.1.1 Category

Applicable to both mixed and exclusive traffic environments.

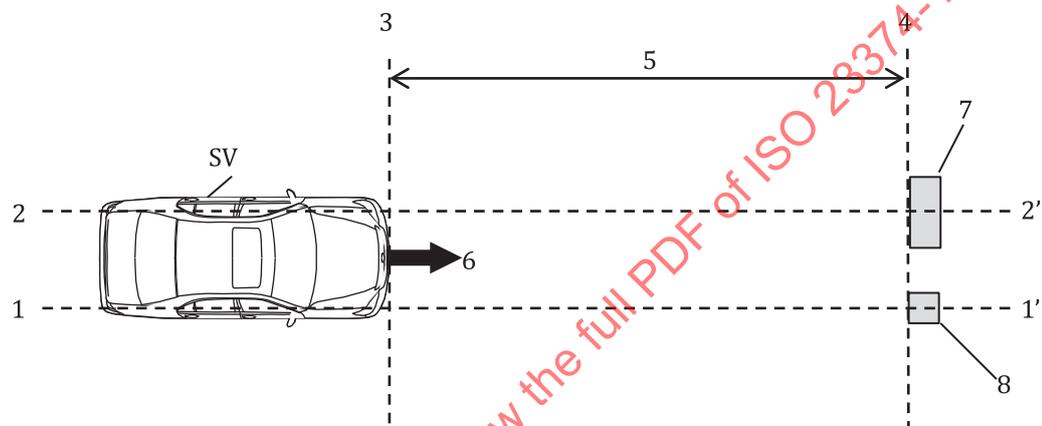
10.5.1.2 Objective

Verify collision avoidance against required smallest object size.

10.5.1.3 Test setup

The test setup shall consist of, at a minimum, the following elements. [Figure 20](#) illustrates an example test setup.

- Static object (choose object according to traffic environment category; use only one object: cube for mixed traffic and timber for exclusive traffic):
 - Mixed traffic: cube (see [Clause B.1](#) for details)
 - Exclusive traffic: timber (see [Clause B.2](#) for details)



Key

SV	subject vehicle	1, 1'	extension of the SV's centre of the right tyre
2, 2'	extension of the SV's centre of the left tyre	3	front outermost edge of the SV
4	front outermost edge of the object	5	initial distance between C and D: 5 m typical
6	SV's direction of travel, speed, $V_{des,sv}$	7	timber
8	cube		

NOTE This figure shows a forward-maneuvring case. The same conditions apply when testing reverse manoeuvring but with the SV facing the opposite direction.

Figure 20 — Example test setup for Scene 21

10.5.1.4 Test procedure

Two tests shall be performed, one with the SV with a forward manoeuvre, and one with the SV with a reverse manoeuvre.

- 1) The static object is placed on the road surface at the extension of the front tyre for the forward manoeuvring test, and respectively the rear tyre for the reverse manoeuvring test, of the SV.
- 2) AVPS operates the SV towards the direction where the static object is placed at designed speed.

10.5.1.5 Pass criteria

- SV either steers around the object without physical contact, or pauses in front and informs the P sub-system for both forward and reverse cases.

10.5.2 Scene 22: Overhanging object

10.5.2.1 Category

Applicable to both mixed and exclusive traffic environments. However, this test shall not be performed for systems designed to effectively avoid such situations (i.e. designed to operate under an exclusive traffic environment only, and either does not allow entry of oversized vehicles or is designed to assign destinations such that oversized vehicles exceeding the boundaries of the assigned destination do not obstruct the pathway of other vehicles.)

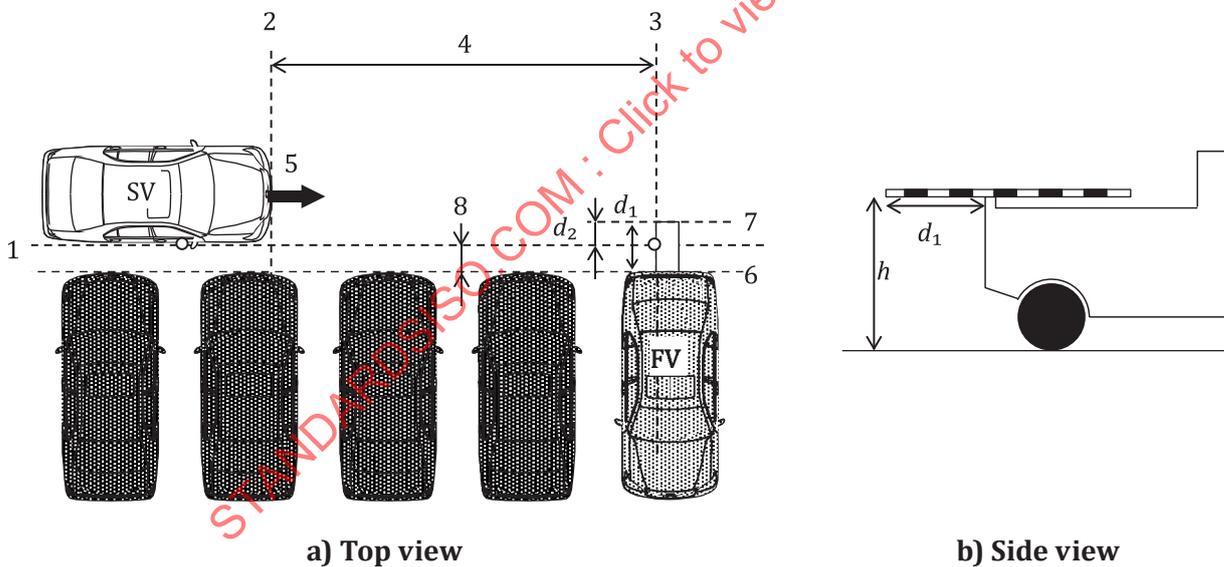
10.5.2.2 Objective

Verify if AVPS operates the SV to steer around an overhanging object protruding from a parked vehicle. This test scene is not intended to verify if the SV simply pauses in front of the object.

10.5.2.3 Test setup

The test setup shall consist of, at a minimum, the following elements. [Figure 21](#) illustrates an example test setup.

- Stationary FV parked in a parking spot.
- Row of parked vehicles beside the FV towards the approaching SV with the front edge aligned.
- Timber (see [Clause B.2](#) for details) protruding from the FV in a way that will cause a collision with the SV.
- Corridor with sufficient width for SV to steer around the protruding object.



Key

- | | | | |
|-------|--|-------|---|
| SV | subject vehicle | FV | forward vehicle |
| 1 | outermost edge of SV (right side) | 2 | outermost edge of SV (front side) |
| 3 | outermost edge of object (front side) | 4 | distance between key elements 2 and 3: 5 m typical |
| 5 | SV's direction of travel, speed: $V_{des,sv}$ | 6 | outermost edge of FV (rear side) |
| 7 | outermost edge of object | 8 | distance between key elements 1 and 6: $D_{des,ob}$ |
| d_1 | length between key elements 7 and 6:
value of key element 8 + d_2 | d_2 | length between key elements 1 and 7 (initial overlap):
40 cm range ± 10 cm |

h height of the protruding object: 80 cm range
±40 cm

Figure 21 — Example test setup for Scene 22

10.5.2.4 Test procedure

- 1) Perform a preparation run without the protruding object to determine value d_1 by observing the value of key element 8.
- 2) AVPS operates the SV to the forward direction at designed speed, and within ±10 % tolerance of the value of key element 8 compared to the first preparation run.
- 3) SV approaches the FV with a protruding object where an overlap value d_2 exists.

10.5.2.5 Pass criteria

SV steers around the object without physical contact to the object.

10.5.3 Scene 23: Infant in parking spot (reverse/forward)

10.5.3.1 Category

Applicable to mixed traffic environments only.

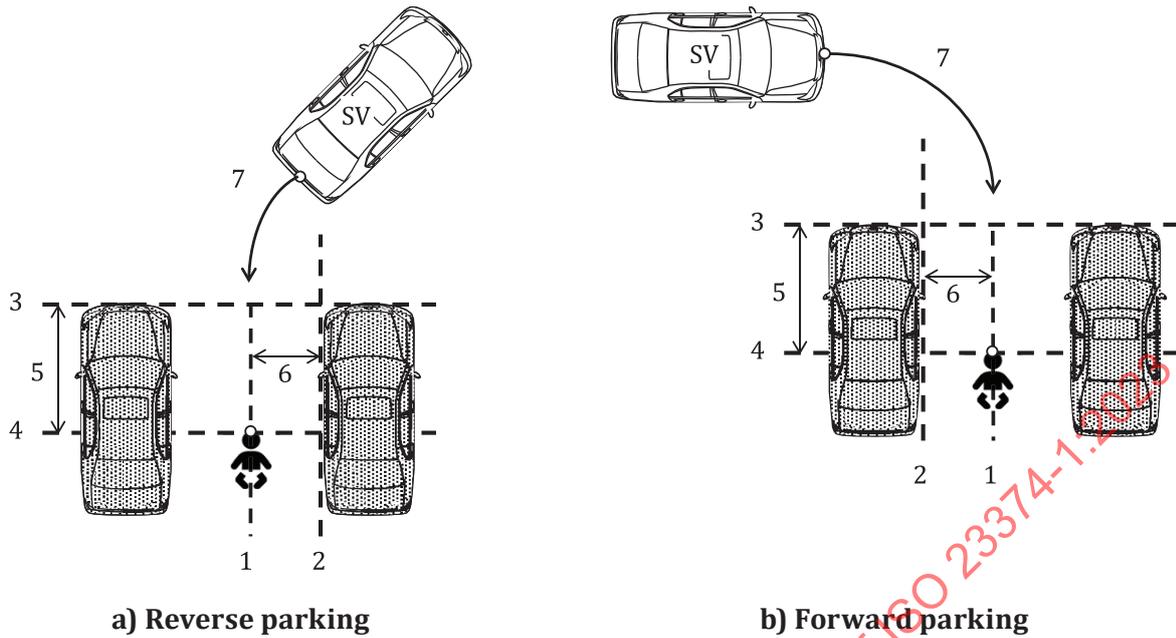
10.5.3.2 Objective

Verify if AVPS is capable of operating the SV to avoid collisions with infants present in the parking spot, which is considered to be one of the worst and most difficult case for AVPS. The plausibility and liability of the situation are not criteria.

10.5.3.3 Test setup

The test setup shall consist of, at a minimum, the following elements. [Figure 22](#) illustrates an example test setup.

- Parking spot as the destination.
- Two parked FVs on both sides of the destination.
- Infant test target (see [Clause B.3](#) for details)



Key

- | | | | |
|----|--|---|---|
| SV | subject vehicle | 1 | centre of the test target |
| 2 | outermost edge of FV (inner side) | 3 | outermost edge of FV (front side) |
| 4 | outermost edge of object (front side) | 5 | distance between key elements 3 and 4:
2,5 m range $\pm 1,5$ m |
| 6 | distance between key elements 1 and 2: 1,3 m | 7 | SV's planned direction of travel, speed: $V_{des,sv}$ |
| | | | range $\pm 0,9$ m |

Figure 22 — Example test setup for Scene 23

10.5.3.4 Test procedure

- 1) SV intends to perform (reverse and forward) parking into a vacant parking spot with bordering vehicles on both sides, and an infant test target is placed lying with any orientation on the surface of the vacant parking spot.

10.5.3.5 Pass criteria

SV pauses with more than 100 cm distance from the test target.

10.5.4 Scene 24: Infant lying near ramp (up/down)

10.5.4.1 Category

Applicable to mixed traffic environments only.

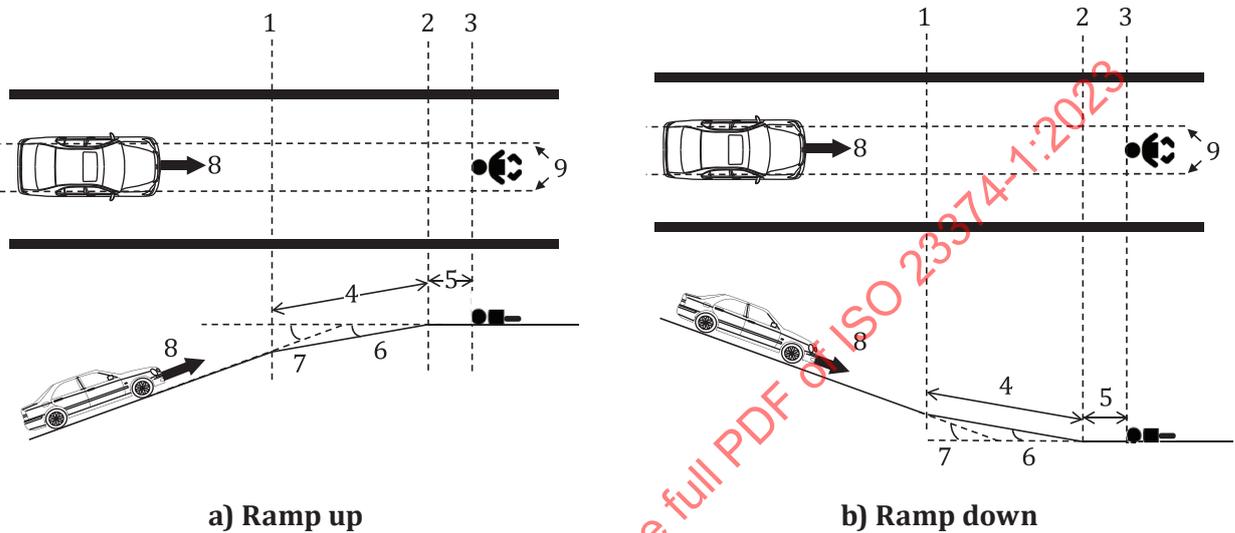
10.5.4.2 Objective

Verify if AVPS is capable of operating the SV to avoid collisions with infants present at an occluded area of the road surface, which is considered to be one of the worst and most difficult case for AVPS. The plausibility and liability of the situation are not criteria. Compared to scene 23, the occlusion behind the edge of the ramp creates a hazardous situation.

10.5.4.3 Test setup

The test setup shall consist of, at a minimum, the following elements. Figure 23 illustrates an example test setup.

- Infant test target (see Clause B.3)
- Ramp, taking into consideration local guidelines for parking facilities regarding length, width and angle. The angle shall be equal to or greater than 15 %.



Key

- | | | | |
|------|---|---|--|
| 1, 2 | section points | 6 | slope transition section angle: 7,5 % typical |
| 3 | outermost edge of test target | 7 | slope angle: > 15 % |
| 4 | length of slope transition section: 3,5 m typical | 8 | SV's direction of travel, speed: $V_{des,sv}$ |
| 5 | distance between ramp edge to test object: 0,8 m | 9 | observed trajectory of the front tyres of the SV |
| | range $\pm 0,3$ m | | |

Figure 23 — Example test setup for Scene 24

10.5.4.4 Test procedure

- 1) Perform a preparation run without the test target placed on the corridor and observe the trajectory of the SV.
- 2) AVPS operates the SV to the forward direction at designed speed on a ramp (up and down).
- 3) Place the test target lying with any orientation on the road surface behind the tip of the ramp so that the portion of the head is between the two lines of key element 9. The exact position and orientation of the test target is flexible, but it is recommended to perform the test with the test target positioned close to the centre of the two lines of key element 9, as it is possible that the exact trajectory will not be reproduced.

10.5.4.5 Pass criteria

SV pauses with more than 40 cm clearance from the object for ramp up, and 100 cm for ramp down.

NOTE The ramp-up scene creates an occlusion from the view of the SV, thus the required clearance distance is relaxed.

10.5.5 Scene 25: Infant behind a curve

10.5.5.1 Category

Applicable to mixed traffic environments only.

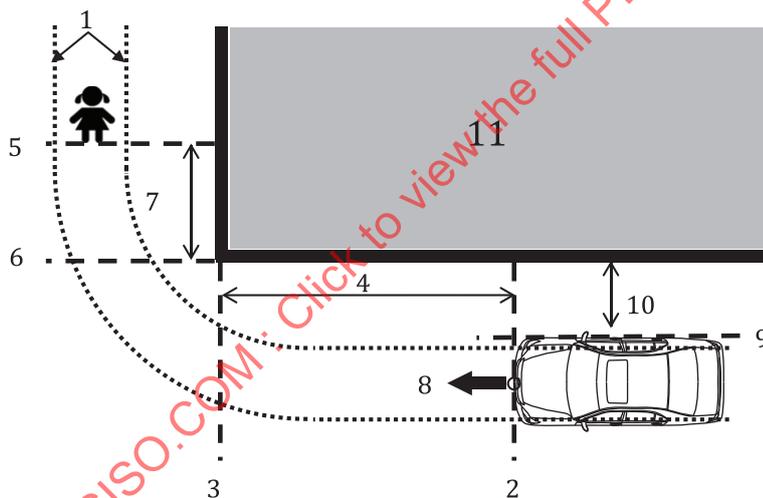
10.5.5.2 Objective

Verify if AVPS is capable of operating the SV to avoid collisions with infants present at an occluded area of the road surface, which is considered to be one of the worst and most difficult case for AVPS. The plausibility and liability of the situation are not criteria. Compared to scene 24, the object is not in the travelling direction of the SV.

10.5.5.3 Test setup

The test setup shall consist of, at a minimum, the following elements. [Figure 24](#) illustrates an example test setup.

- Infant test target (see [Clause B.3](#)).
- Corridor consisting of a corner with occlusion.
- Means to force the SV to travel within the defined distance from the wall.



Key

- | | | | |
|----|--|----|--|
| 1 | observed trajectory of the front tyres of the SV | 2 | outermost edge of SV (front side) |
| 3 | extension of the occluded corner | 4 | distance between key elements 2 and 3: 5 m typical |
| 5 | outermost edge of test target (corner side) | 6 | extension of the occluded corner |
| 7 | distance between key elements 6 and 5:
3,0 m range ±0,5 m | 8 | SV's direction of travel, speed: $V_{des,sv}$ |
| 9 | outermost edge of SV (wall side) | 10 | distance between key element 9 and wall: 2 m ± 0,5 m
when the SV is parallel to the wall (exclude when turning) |
| 11 | occluded | | |

Figure 24 — Example test setup for Scene 25

10.5.5.4 Test procedure

- 1) Perform a preparation run without the test target placed on the corridor and observe the trajectory of the SV. The distance of the SV towards the wall shall be kept within limits (key element 10) including both before the turn and after the turn.

- 2) AVPS operates the SV to the forward direction at designed speed, along the corridor with an occluded corner.
- 3) Place the test target behind the corner so that the portion of the head is between the two lines of key element 1. The exact position and orientation of the test target is flexible, but it is recommended to perform the test with the test target positioned close to the centre of the trajectory, as it is possible that the exact trajectory will not be reproduced.

10.5.5.5 Pass criteria

SV does not arrive closer than 40 cm to the test target.

10.5.6 Scene 26: Infant in front of parked vehicle (forward/reverse)

10.5.6.1 Category

Applicable to mixed traffic environments only.

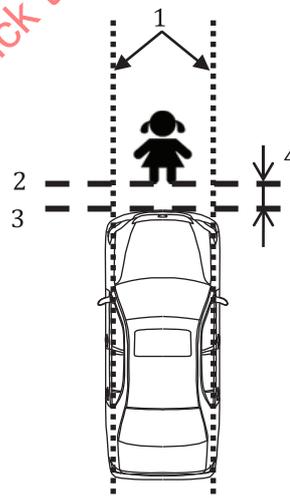
10.5.6.2 Objective

Verify if AVPS is capable of understanding the environment after wake-up and before starting movement and reacting properly.

10.5.6.3 Test setup

The test setup shall consist of, at a minimum, the following elements. [Figure 25](#) illustrates an example test setup. The figure shows the forward manoeuvring case. The same conditions apply when testing reverse manoeuvring, but with the SV facing the opposite direction.

- Infant test target (see [Clause B.3](#)).



Key

- | | | | |
|---|--|---|--|
| 1 | extent of the centre of the SV's tyres | 2 | outermost edge of object (SV side) |
| 3 | outermost edge of SV (object side) | 4 | distance between key elements 2 and 3: 0,3 m range ± 0,2 m |

Figure 25 — Example test setup for Scene 26

10.5.6.4 Test procedure

- 1) SV is stationary at sleep state.

- 2) Place the test target standing in the SV's intended direction of travel so that the portion of the head is between the two lines of key element 1.
- 3) AVPS assigns SV a new mission and starts its process to transition SV to normal state.

10.5.6.5 Pass criteria

Collision does not occur.

10.5.7 Scene 27: Infant beside parked vehicle

10.5.7.1 Category

Applicable to mixed traffic environments only.

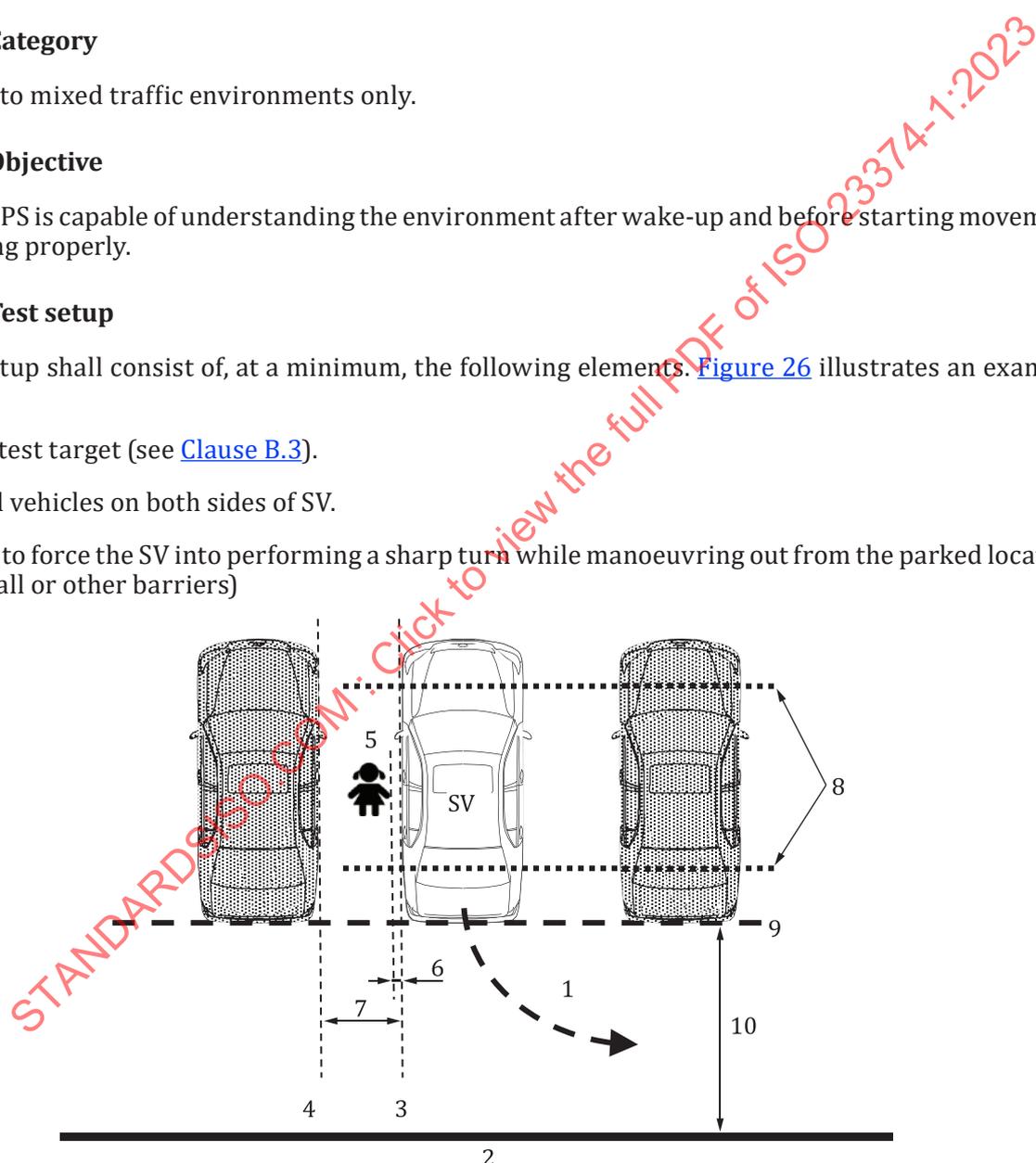
10.5.7.2 Objective

Verify if AVPS is capable of understanding the environment after wake-up and before starting movement and reacting properly.

10.5.7.3 Test setup

The test setup shall consist of, at a minimum, the following elements. [Figure 26](#) illustrates an example test setup.

- Infant test target (see [Clause B.3](#)).
- Parked vehicles on both sides of SV.
- Means to force the SV into performing a sharp turn while manoeuvring out from the parked location (e.g. wall or other barriers)



Key

SV	subject vehicle	1	SV's intended direction of travel
2	wall or other barrier	3	outermost edge of SV (test target side)
4	outermost edge of bordering vehicle	5	outermost edge of test target (SV side)
6	distance between key elements 3 and 5: 20 cm	7	distance between key elements 3 and 4: 80 cm
7	range ±5 cm		range ±10 cm

- | | | | |
|----|--|---|----------------------------------|
| 8 | SV's wheelbase | 9 | outermost edge of SV (rear side) |
| 10 | distance between key elements 2 and 9: 6 m typical | | |

Figure 26 — Example test setup for Scene 27

10.5.7.4 Test procedure

It is recommended to perform a preparation run to confirm that the SV will turn while manoeuvring out from the parked location, and to observe the trajectory to determine the position of the test target.

- 1) SV is stationary at sleep state.
- 2) Place the test target either standing or sitting beside the SV so that the portion of the head is between the two lines of key element 8. The position of the test target shall be determined such that a collision would occur if the SV manoeuvred out from the parked location.
- 3) AVPS assigns SV a new mission and starts the process to transition the SV to the normal state in such a way that the SV will perform reverse manoeuvring in the direction of key element 1.

10.5.7.5 Pass criteria

There is no physical contact between the test object and the SV.

10.5.8 Scene 28: Infant lying partly underneath parked vehicle

10.5.8.1 Category

Applicable to mixed traffic environments only.

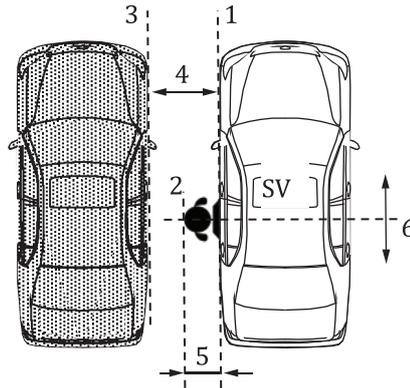
10.5.8.2 Objective

Verify if AVPS is capable of understanding the environment after wake-up and before starting movement and reacting properly. Scene 28 is a supplement to scene 27, where the infant can potentially stumble and fall underneath the SV. The plausibility and liability of the situation are not criteria.

10.5.8.3 Test setup

The test setup shall consist of, at a minimum, the following elements. [Figure 27](#) illustrates an example test setup.

- Infant test target (see [Clause B.3](#)).



Key

- | | | | |
|----|--|---|---|
| SV | subject vehicle | 1 | outermost edge of SV (object side) |
| 2 | outermost edge of object (far side) | 3 | outermost edge of bordering vehicle (SV side) |
| 4 | distance between key elements 1 and 3: 80 cm
range ±10 cm | 5 | distance between key elements 1 and 2: 40 cm
range ±5 cm (more than 50 % of the length of the test target) |
| 6 | centre of the test target: middle between the front and rear axle of the SV range ±50 cm | | |

Figure 27 — Example test setup for Scene 28

10.5.8.4 Test procedure

- 1) SV is stationary at sleep state.
- 2) Place the test target lying with the lower part of its body underneath the SV.
- 3) AVPS assigns SV a new mission and starts its process to transition SV to normal state.

10.5.8.5 Pass criteria

There is no physical contact between the test object and SV.

10.6 Dynamic object avoidance

10.6.1 Scene 31: Forward vehicle braking hard

10.6.1.1 Category

Applicable to both mixed and exclusive traffic environments.

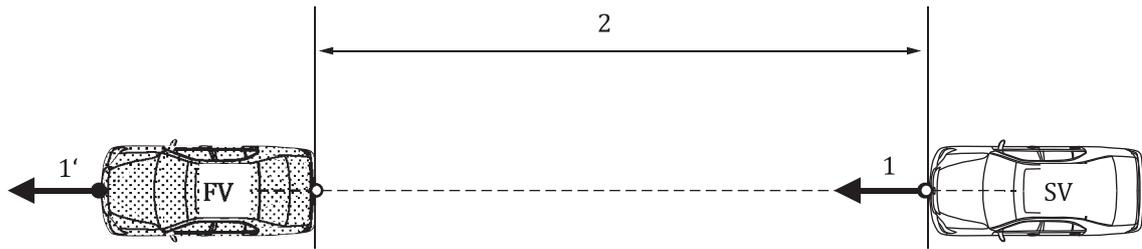
10.6.1.2 Objective

Verify if AVPS is capable of avoiding a collision when an FV performs full braking.

10.6.1.3 Test setup

The test setup shall consist of, at a minimum, the following elements. [Figure 28](#) illustrates an example test setup.

- FV (either manually operated or operated by AVPS) that brakes in front of the SV.

**Key**

SV subject vehicle

FV forward vehicle

1 SV's direction of travel, speed: $V_{des,sv}$ 1' FV's direction of travel and speed: equivalent to key element 1, acceptable tolerance $+0/-0.1$ m/s2 distance between SV and FV: $D_{des,gap}$ **Figure 28 — Example test setup for Scene 31****10.6.1.4 Test procedure**

- 1) Perform a preparation run without the FV and observe the value for key element 1.
- 2) FV travels in the same direction and at the same speed as the observed design speed of the SV.
- 3) AVPS operates the SV to the forward direction at designed speed and with designed gap to the FV.
- 4) FV performs an emergency stop with a peak deceleration greater than 6 m/s^2 and comes to an immediate stop.

10.6.1.5 Pass criteria

Collision does not occur.

10.6.2 Scene 32: Parked vehicle rushing out**10.6.2.1 Category**

Applicable to both mixed and exclusive traffic environments. However, this test shall not be performed in exclusive traffic conditions if the R sub-system is equipped with the central control function (see [7.1.6](#)).

10.6.2.2 Objective

Verify if AVPS is capable of avoiding a collision when a parked vehicle suddenly pulls out in front of the SV. The test covers the reaction capabilities at speeds when the SV is driving close to a parked vehicle and with an increased distance, assuming different speeds of the SV are observed.

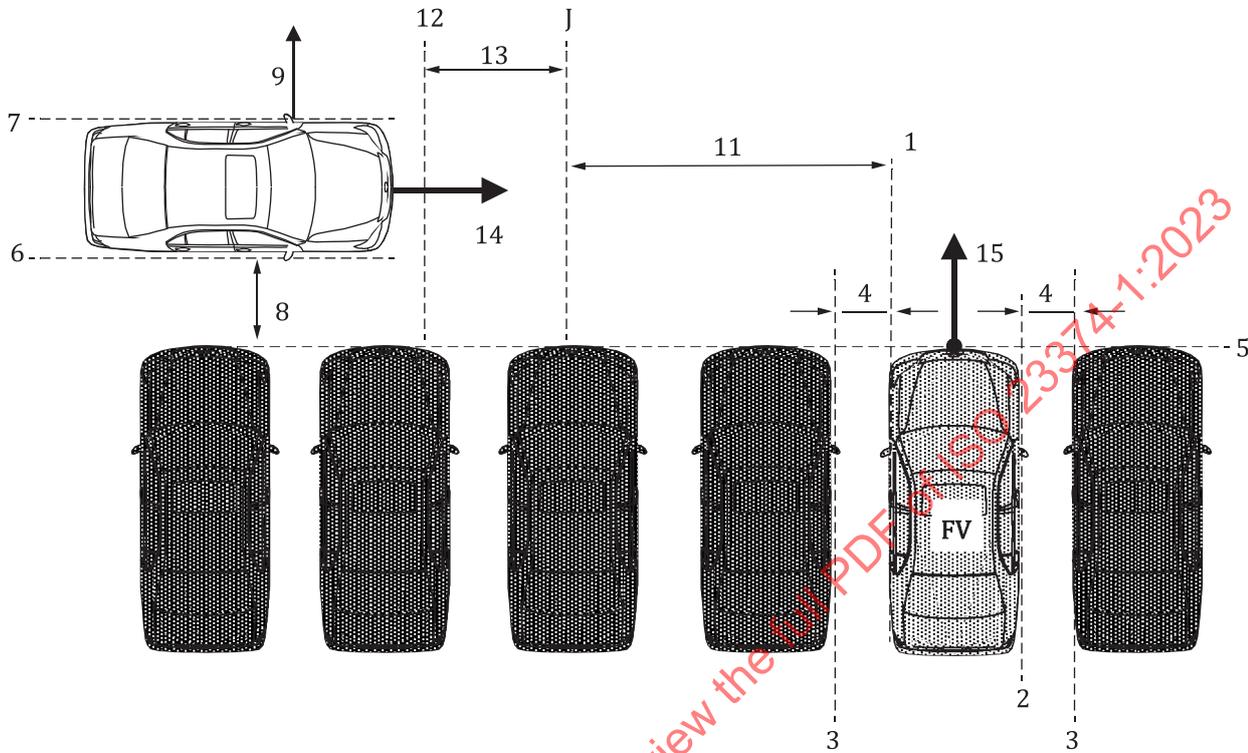
The distance indicated by key element 11 in [Figure 29](#) changes in relation to the designed speed of the SV, assuming that a collision could not be avoided even by an experienced and attentive driver, when a parked vehicle suddenly pulls out with a distance shorter than that indicated in key element 11.

10.6.2.3 Test setup

The test setup shall consist of, at a minimum, the following elements. [Figure 29](#) illustrates an example test setup.

- Either a 3D vehicle target conformant to ISO 19206-3, or a manually operated FV.
- Two bordering vehicles parked on either side of the FV.

- A row of parked vehicles on one side of the FV towards the approaching SV with the front edge aligned. The number of parked vehicles in the row is subject to the designed speed of the SV.
- Means to force the SV to travel within the defined distance towards the parked vehicles (see [Table 10](#)).



Key

- 1 outermost edge of FV (SV near side)
- 2 outermost edge of FV (SV far side)
- 3 outermost edge of FV (front side)
- 4 outermost edge of bordering vehicles (FV side)
- 4 distance between A/B and C: $80\text{ cm} \pm 10\text{ cm}$
- 5 outermost edge of FV (front side)
- 6 outermost edge of SV (FV side)
- 7 outermost edge of SV (opposite side)
- 8 distance between E and F: see [Table 10](#)
- 9 free space on opposite side: see [Table 10](#)
- 10 SV's position when FV's manoeuvre begins
- 11 distance between key elements 1 and 10: see [Table 11](#)
- 12 reference line
- 13 distance between key elements 10 and 12: 5 m
- 14 SV's direction of travel, speed $V_{des,sv}$
- 15 FV's direction of travel at the following speed profile:
 - Constant acceleration of $1,5\text{ m/s}^2$ for 1 s (acceptable tolerance: $\pm 0,1\text{ m/s}^2$)
 - Maintain constant speed after the above 1 s elapse
 - May come to a stop when either a collision with an object or structure on the open side is imminent, or the body of the FV has blocked the SV's path

Figure 29 — Example test setup for Scene 32

Table 10 — Values of key elements 8 and 9

Test	Key element 8	Key element 9
1 (close to parked vehicles)	60 cm (acceptable tolerance $\pm 20\text{ cm}$)	Not specified
2 (far from parked vehicles)	200 cm (acceptable tolerance $\pm 20\text{ cm}$)	200 cm (acceptable tolerance $\pm 20\text{ cm}$)

Table 11 — Specification of distance represented by key element 11

Observed designed speed during preparation run	Distance (key element 11)
$0,5 \text{ m/s} < V_{\text{des,sv}} \leq 1,5 \text{ m/s}$	2,5 m
$1,5 \text{ m/s} < V_{\text{des,sv}} \leq 2 \text{ m/s}$	3,2 m
$2 \text{ m/s} < V_{\text{des,sv}} \leq 3 \text{ m/s}$	4,7 m
$3 \text{ m/s} < V_{\text{des,sv}} \leq 4 \text{ m/s}$	6,4 m
$4 \text{ m/s} < V_{\text{des,sv}} \leq 5 \text{ m/s}$	8,2 m
$5 \text{ m/s} < V_{\text{des,sv}} \leq 6 \text{ m/s}$	10,2 m
$6 \text{ m/s} < V_{\text{des,sv}} \leq 7 \text{ m/s}$	12,2 m
$7 \text{ m/s} < V_{\text{des,sv}} \leq 8,3 \text{ m/s}$	15,0 m

10.6.2.4 Test procedure

Two tests shall be performed with the SV travelling at different distances towards the row of parked vehicles as shown in [Table 10](#). Both tests require a preparation run to observe the designed speed under the given condition, but without the FV movement. The distance represented by key element 11 is determined in accordance with the values shown in [Table 11](#).

- 1) AVPS operates the SV to the forward direction at designed speed on a corridor with parked vehicles. The designed speed shall be within $\pm 10\%$ tolerance compared to the observed speed during the preparation run, at least within the boundaries of key element 13.
- 2) When the SV reaches key element 10 of [Figure 29](#), the stationary FV starts to move in the forward direction as specified in key element 15.

10.6.2.5 Pass criteria

Collision does not occur.

10.6.3 Scene 33: Cross-cutting child

10.6.3.1 Category

Applicable to mixed traffic environment only.

10.6.3.2 Objective

Verify if AVPS is capable of avoiding a collision when a child rushes out in front of the SV from an occluded position. The test covers reaction capabilities at speeds when the SV is driving close to the occlusion, and when the SV is driving with an increased distance, assuming different speeds are observed.

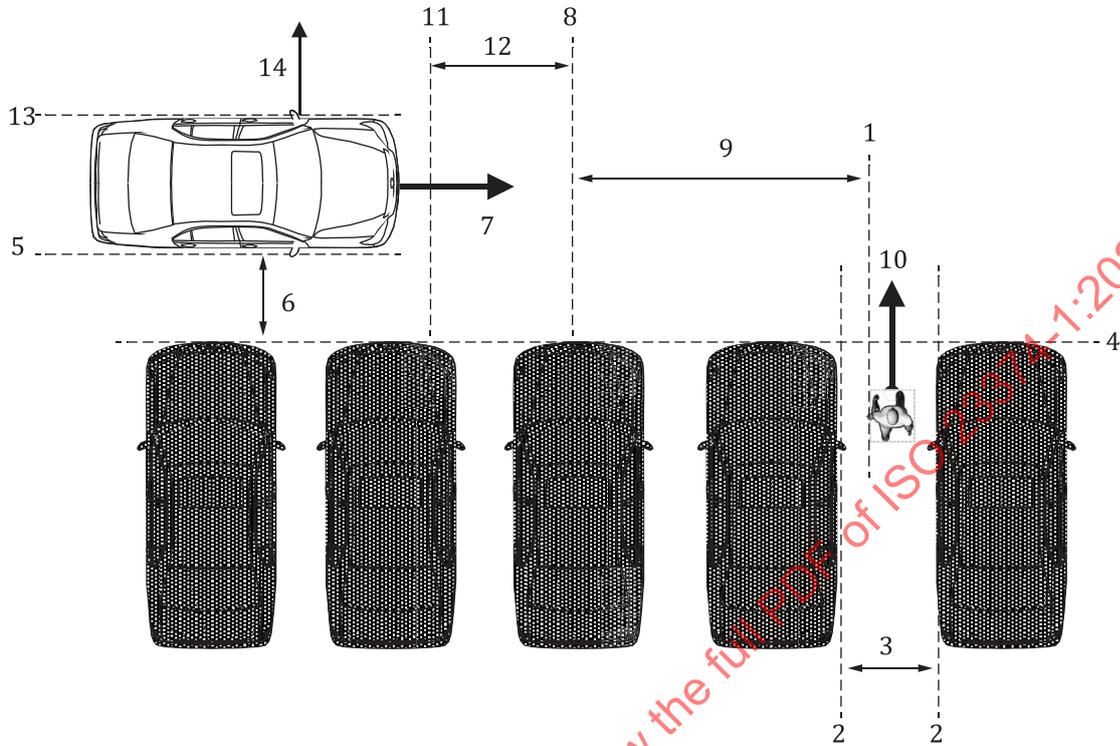
The distance represented by key element 9 in [Figure 30](#) changes in relation to the designed speed of the SV, assuming that a collision could not be avoided even by an experienced and attentive driver when the child rushes out with a distance shorter than that expressed in key element 9.

10.6.3.3 Test setup

The test setup shall consist of, at a minimum, the following elements. [Figure 30](#) illustrates an example test setup.

- Child pedestrian test target in accordance with ISO 19206-2, cross-cutting the SV's intended path. Leg articulation shall be activated.
- Two or more parked vehicles with a height taller than the test target at every point of the chassis except the bumper (height of the test target is 1,2 m).

- A row of parked vehicles on one side of the FV towards the approaching SV with the front edge aligned. The number of parked vehicles in the row is subject to the designed speed of the SV.
- Means to force the SV to travel within the defined distance towards the parked vehicles.



Key

- | | | | |
|---|---|----|---|
| 1 | outermost edge of test target (SV side) | 8 | SV's position when test target reaches line 4 |
| 2 | outermost edge of bordering vehicles (inner side) | 9 | distance between key elements 1 and 8: see Table 13 |
| 3 | distance between key element 2: 80 cm ± 10 cm | 10 | test target's direction of travel, speed: 5 km/h ^a |
| 4 | outermost edge of parked vehicles (front side) | 11 | reference line |
| 5 | outermost edge of SV (parked vehicle side) | 12 | distance between key elements 8 and 11: 5 m |
| 6 | distance between key elements 4 and 5: see Table 12 | 13 | outermost edge of SV (opposite side) |
| 7 | SV's direction of travel, speed: $V_{des,sv}$ | 14 | free space on opposite side: see Table 12 |

^a The value shall be reached when the test target reaches line 4, and maintained within a tolerance of ±3 % after that point. The test target may come to a stop before colliding with an object or structure on the open opposite side.

Figure 30 — Example test setup for Scene 33

Table 12 — Values of key elements 6 and 14

Test	Key element 6	Key element 14
1 (close to parked vehicles)	60 cm (acceptable tolerance ±20 cm)	Not specified
2 (far from parked vehicles)	200 cm (acceptable tolerance ±20 cm)	200 cm (acceptable tolerance ±20 cm)

Table 13 — Specification of distance represented by key element 9

Observed designed speed during preparation run	Distance (key element 9)
$0,5 \text{ m/s} < V_{\text{des,sv}} \leq 1,5 \text{ m/s}$	2,1 m
$1,5 \text{ m/s} < V_{\text{des,sv}} \leq 2 \text{ m/s}$	2,6 m
$2 \text{ m/s} < V_{\text{des,sv}} \leq 3 \text{ m/s}$	3,9 m
$3 \text{ m/s} < V_{\text{des,sv}} \leq 4 \text{ m/s}$	5,3 m
$4 \text{ m/s} < V_{\text{des,sv}} \leq 5 \text{ m/s}$	7,0 m
$5 \text{ m/s} < V_{\text{des,sv}} \leq 6 \text{ m/s}$	8,7 m
$6 \text{ m/s} < V_{\text{des,sv}} \leq 7 \text{ m/s}$	10,5 m
$7 \text{ m/s} < V_{\text{des,sv}} \leq 8,3 \text{ m/s}$	13,2 m

10.6.3.4 Test procedure

Two tests shall be performed with the SV travelling at different distances towards the row of parked vehicles as shown in [Table 12](#). Both tests require a preparation run to observe the designed speed under the given condition, but without the test target movement. The distance represented by key element 9 is determined in accordance with the values shown in [Table 13](#).

- 1) AVPS operates the SV to the forward direction at designed speed on a corridor with parked vehicles. The designed speed shall be within $\pm 10\%$ tolerance compared to the observed speed during the preparation run, at least within the boundaries of key element 12.
- 2) Test target starts to move in the forward direction and reaches key element 4 when the SV reaches key element 8, both of [Figure 30](#). The test target continues to move crossing the SV's directing of travel.

10.6.3.5 Pass criteria

Collision does not occur.

10.6.4 Scene 34: Irregular movement of an adult

10.6.4.1 Category

Applicable to mixed traffic environments only.

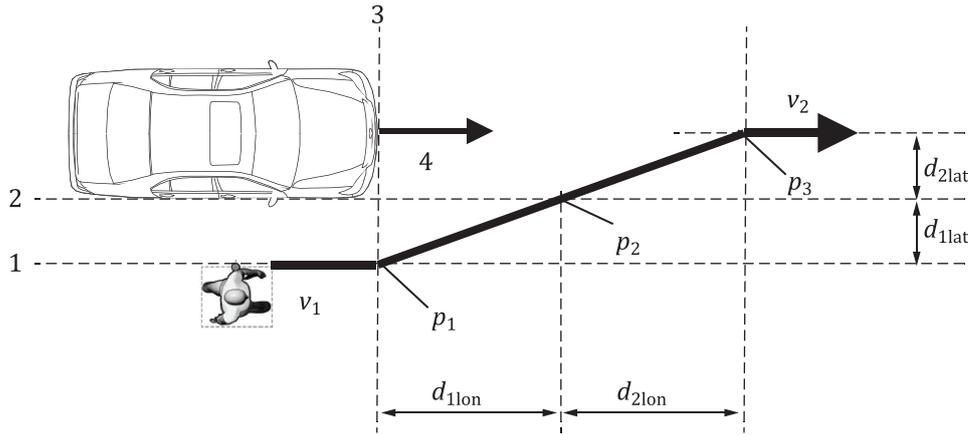
10.6.4.2 Objective

Verify if AVPS is capable of avoiding a collision when an adult is approaching from behind and crossing in front of the SV.

10.6.4.3 Test setup

The test setup shall consist of, at a minimum, the following elements. [Figure 31](#) illustrates an example test setup.

- Adult pedestrian test target in accordance with ISO 19206-2 with leg articulation, and capable of flexible manoeuvring.
- Means to force the SV to travel at the defined speed and distance.



Key

1	outermost edge of test target (SV side shoulder)	d_{1lat}	lateral distance between key element 2 and test target: 0,5 m ± 0,1 m
2	outermost edge of SV (near side)	d_{2lat}	lateral distance between p_2 and p_3 : 1 m ± 0,1 m
3	outermost edge of SV (front side)	d_{1lon}	longitudinal distance between p_1 and p_2 : 2,5 m ± 0,2 m
4	SV's direction of travel, speed 3 km/h	d_{2lon}	longitudinal distance between p_2 and p_3 : 2,5 m ± 0,2 m
	acceptable tolerance: ±5 %	v_1	initial speed of test target until reaching p_2 : 5 km/h acceptable tolerance: ±5 %
p_1	waypoint of test target when reaching key element 3	v_2	speed of test target when reaching p_3 : 3 km/h, acceptable tolerance: ±5 %
p_2	waypoint of test target when reaching key element 2		
p_3	waypoint of test target		

Figure 31 — Example test setup for Scene 34

10.6.4.4 Test procedure

- 1) AVPS operates the SV to the forward direction at the defined speed (key element 5).
- 2) Test target travels parallel to the SV at a constant speed of v_1 until it reaches key p_1 . The test target should travel on a physical pedestrian sidewalk or outside of the SV's logical drivable area.
- 3) Test target starts to cut across the SV's pathway from p_1 .
- 4) Test target continuously decelerates starting at p_2 , and reaches the speed of v_2 by the time it reaches p_3 .
- 5) The test target continues to travel in the same direction of the SV's direction of travel at the speed of v_2 after reaching p_3 .

10.6.4.5 Pass criteria

- AVPS adjusts the speed of the SV such that it does not come closer than 2 m to the test target at the time when the test target reaches p_3 .

If the SV maintains its speed, the distance between the SV and test target at p_2 will become (0,9 – 1,1) m, requiring the AVPS to decelerate the SV in order to achieve the distance required in the pass criteria.

10.6.5 Scene 35: Bicyclist approaching

10.6.5.1 Category

Applicable to mixed traffic environments only.

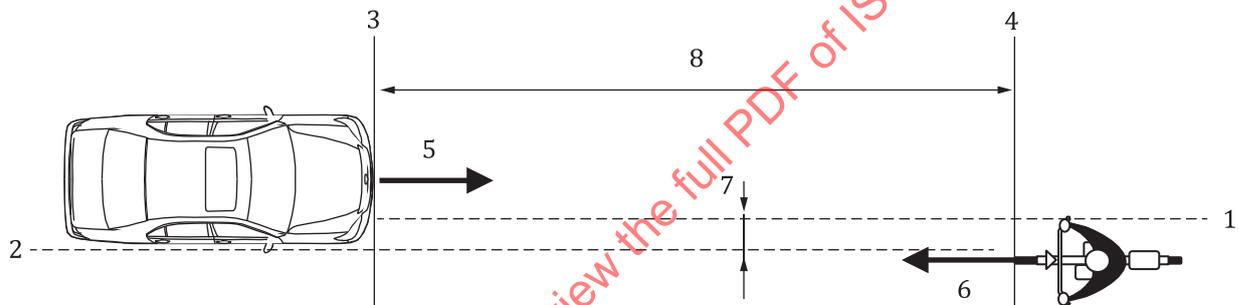
10.6.5.2 Objective

Verify if AVPS is capable of avoiding a collision when a relatively fast-moving bicycle is approaching.

10.6.5.3 Test setup

The test setup shall consist of, at a minimum, the following elements. [Figure 32](#) illustrates an example test setup.

- Adult bicyclist test target in accordance with ISO 19206-4 approaching the SV with an overlap.
- Corridor with sufficient open space for an evasive manoeuvre (towards the left with respect to the SV's direction of travel in the example shown in [Figure 32](#)).



Key

- | | | | |
|---|---|---|--|
| 1 | outermost edge of target (SV side) | 2 | outermost edge of SV (object side) |
| 3 | outermost edge of SV (front side) | 4 | outermost edge of target (front side) |
| 5 | SV's direction of travel: $V_{des,sv}$ | 6 | target's direction of travelling, initial speed: 10 km/h
tolerance: $\pm 3\%$ |
| 7 | distance between key elements 1 and 2
(overlap): $30\text{ cm} \pm 10\text{ cm}$ | 8 | initial distance between key elements 3 and 4 $> 15\text{ m}$ |

Figure 32 — Example test setup for Scene 35

10.6.5.4 Test procedure

It is recommended to perform a preparation run without the bicyclist test target to determine the lateral position of the test target such that the value for key element 8 is satisfied.

- 1) AVPS operates the SV to the forward direction at designed speed.
- 2) Test target is travelling towards the SV at a constant speed with an overlap with the SV.

10.6.5.5 Pass criteria

- SV avoids a collision by either performing a lateral evasion manoeuvre towards the open space, or pauses before the distance represented by key element 9 (see [Figure 30](#)) becomes less than 5 m.

The test target should be stopped after the distance becomes less than 5 m to avoid unnecessary collision with the SV.

10.7 Emergency stopping

10.7.1 Scene 41: Operation stop command

10.7.1.1 Category

Applicable to both mixed and exclusive traffic environments.

10.7.1.2 Objective

Verify the operation stop device, operation stop command, and emergency stopping function.

10.7.1.3 Test setup

The test setup shall consist of, at a minimum, the following elements.

- Operation stop device (see [8.2.5](#)).

10.7.1.4 Test procedure

- 1) AVPS operates the SV to the forward direction at designed speed.
- 2) Operation stop device is activated.

10.7.1.5 Pass criteria

SV comes to a complete stop within the required times stated in [Table 4](#) after the operation stop device was activated.

10.7.2 Scene 42: Communication failure

10.7.2.1 Category

Applicable to both mixed and exclusive traffic environments.

10.7.2.2 Objective

Verify the response upon communication failure.

10.7.2.3 Test setup

The test setup shall consist of, at a minimum, the following elements.

- Means to deactivate the communication device of the R sub-system.

10.7.2.4 Test procedure

- 1) AVPS operates the SV to the forward direction at designed speed.
- 2) The R sub-system is deactivated, and failure occurs to the operation interface.

10.7.2.5 Pass criteria

SV performs an emergency stop and comes to a complete stop according to the required times in [Table 4](#).

Annex A (normative)

Communication sequences

A.1 General

The communication sequences presented in [Figures A.2 to A.14](#) define the sequential flow of messages composed of the minimum set of data elements defined in [Tables A.1 to A.13](#) and [Tables A.23 to A.26](#). Different sequences for one transition can be communicated in arbitrary order.

The messages and data elements are defined on a logical level with their respective units. This way, interoperability of the solutions in the field can be achieved without specifying a byte-level message format and protocol, enabling different carrier technologies in different markets while minimizing the functional impact of low-level technology choices on the overall system.

[Figure A.1](#) shows the legend to be used for understanding the communication sequence charts shown in [Figures A.2 to A.14](#).

Arrows connecting the sub-systems represent a message. The minimum set of data elements to be communicated within each message is indicated with solid lines and provided in the “Relevant message” column of corresponding tables. Messages represented by broken lines describe the flow of data. Numbers within brackets of the “Relevant message” column of each table indicate that the respective data element is expected to be communicated between the sub-systems. These solid and broken line representations are identical to those shown in [Figure 2](#).

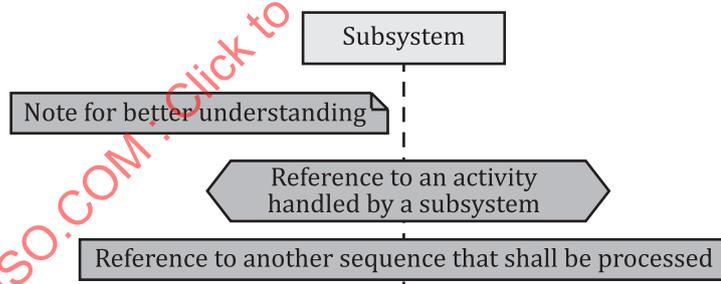
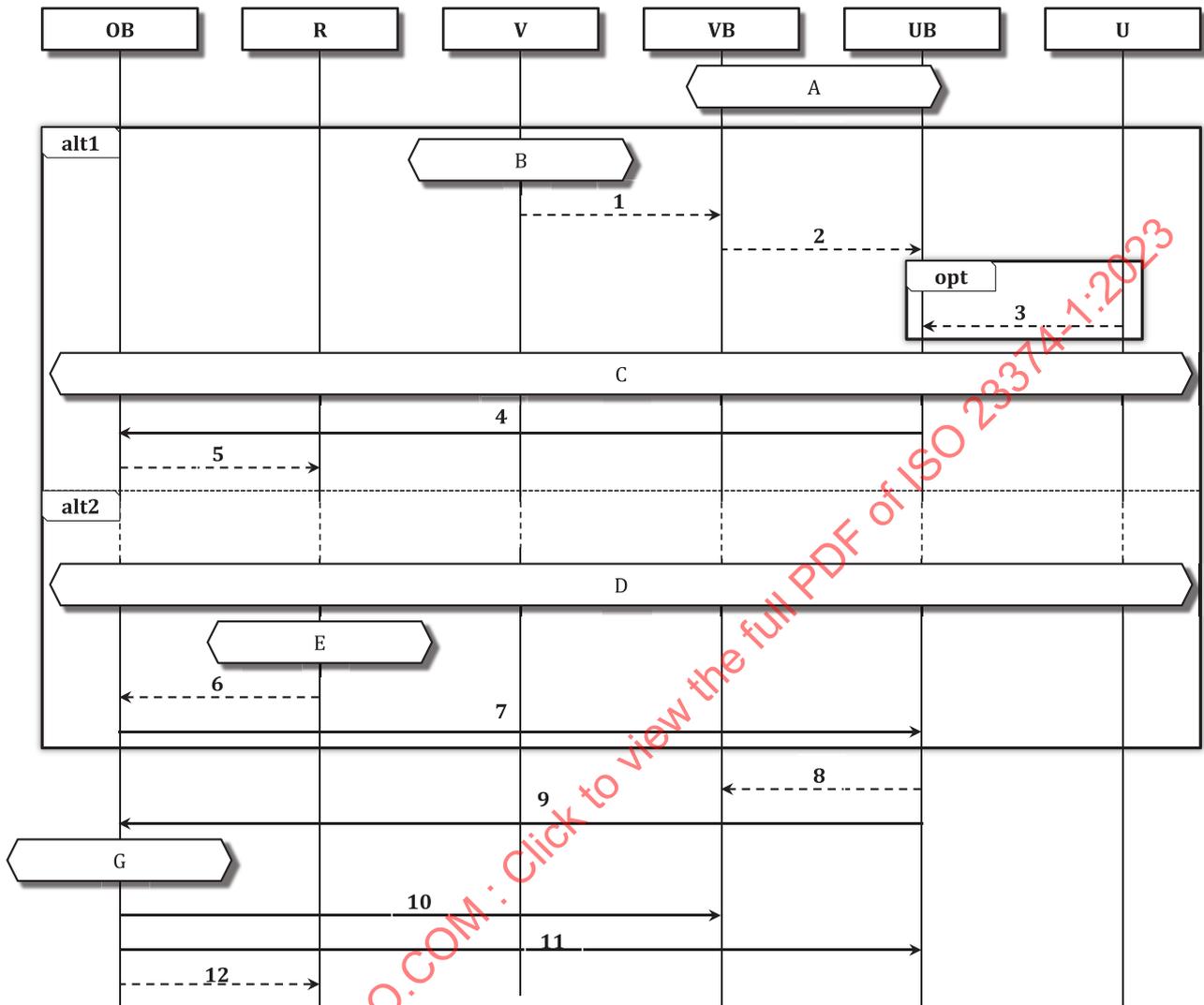


Figure A.1 — Legend

A.2 Communication sequences which trigger a state transition

A.2.1 Check-in sequence



Key

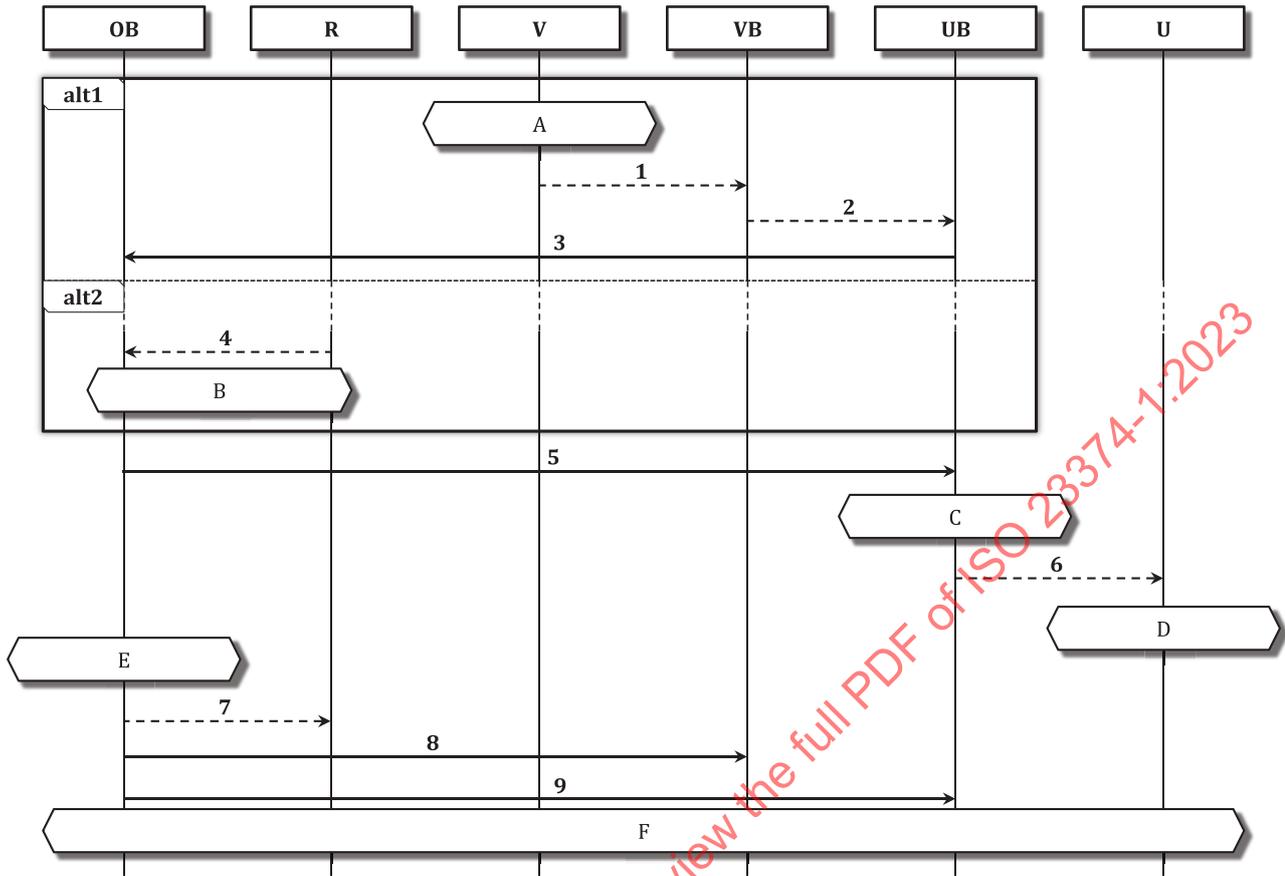
- | | |
|---|--|
| OB Operator_Backend | R Remote_Vehicle_Operation |
| V Onboard_Vehicle_Operation | VB Vehicle_Backend |
| UB User_Backend | U User_Frontend |
| A User is known and associated with SV | B Recognizes SV arrival at reserved parking facility |
| C AVPS confirms reservation | D AVPS confirms reservation |
| E Recognizes SV arrival at reserved parking facility | G Create Session_ID |
| 1 SV reached parking facility (FACILITY_ID) | 2 SV reached parking facility (SV_ID, FACILITY_ID, OEM_ID) |
| 3 User confirms arrival | 4 SV reached parking facility (SV_ID) |
| 5 SV reached parking facility (SV_ID) | 6 SV reached parking facility (SV_ID) |
| 7 SV reached parking facility (SV_ID) | 8 Reservation Data (Reservation_ID, OEM_ID, SV_ID...) |
| 9 Reservation Data (Reservation_ID, OEM_ID, SV_ID...) | 10 Communicate Session_ID (Session_ID) |

11 Communicate Session_ID (Session_ID)

12 Communicate Session_ID (Session_ID)
(Used AVP protocol version, [Type1 Used vehicle
map version])**Figure A.2 — Check-in sequence****Table A.1 — Description of data elements of [Figure A.2](#)**

Data element	Unit	Value range	Description	Relevant message
Reservation_ID	UID	large enough to identify single session for the legally required storage time in a market	Unique reservation identifier created by AVP_Backend after successful reservation of one SV	9 (8)
OEM_ID	UID	3 Bytes alphanumeric – I, O and Q excluded	Unique manufacturer identifier based on the world manufacturer identifier (WMI) (ISO 3780)	9 (2, 8)
SV_ID	fixed length hash	>= 128 bits	Salted hash based on unique vehicle identifier (VIN)	4, 6, 7, 9 (2, 5, 6, 8)
Facility_ID	UID	Unique to a market	Unique facility identifier created by OB sub-system	9 (1, 2, 8)
AVP_Session_ID	UID	large enough to identify single session for the legally required storage time in a market	Unique identifier for management of one SV from the time of check-in until check-out	10, 11 (12)
AVP_Timestamp	Unix Time	64 bits	Synchronized point in time	all

A.2.2 Check-out sequence



Key

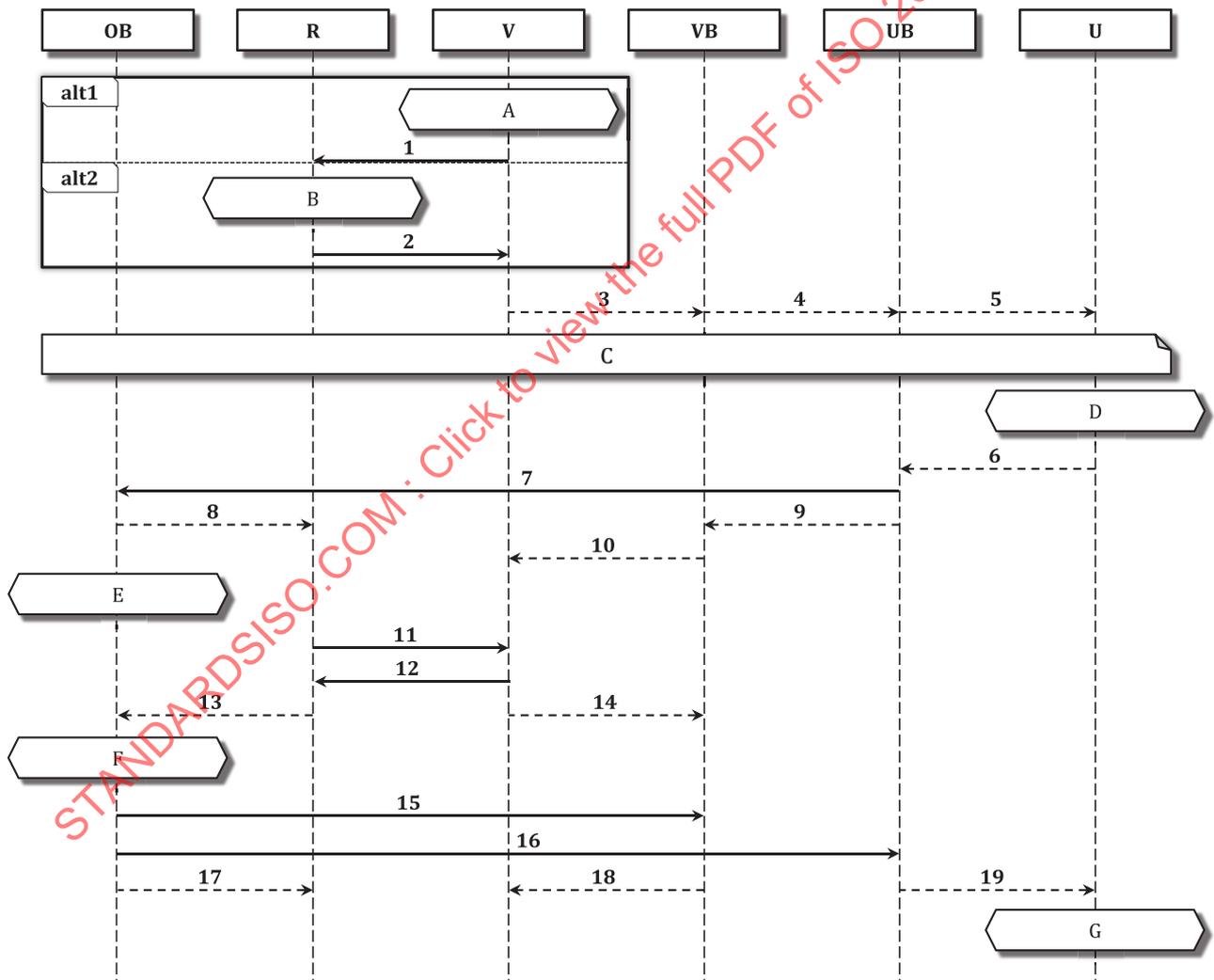
- | | |
|--|---|
| OB Operator_Backend | R Remote_Vehicle_Operation |
| V Onboard_Vehicle_Operation | VB Vehicle_Backend |
| UB User_Backend | U User_Frontend |
| A Recognizes SV has left parking facility | B Recognizes SV has left parking facility or is deactivated (failed recovery) |
| C Process checkout | D Display check-out result |
| E Revoke Session_ID | F Update Reservation |
| 1 SV left parking facility | 2 SV left parking facility |
| 3 SV left parking facility | 4 SV left parking facility |
| 5 Check-out report (Session_ID, Provided_Services) | 6 Check-out result (e.g. duration, Provided_Services) |
| 7 Close session (Session_ID) | 8 Close session (Session_ID) |
| 9 Close session (Session_ID) | |

Figure A.3 — Check-out sequence

Table A.2 — Data elements of Figure A.3

Data element	Unit	Value range	Description	Relevant message
AVP_Session_ID	UID	large enough to identify single session for the legally required storage time in a market	Unique identifier for management of one SV from the time of check-in until check-out	5, 8, 9 (7)
Services_Provided	List of Service Objects	no recommendation	List of information objects containing name, duration and price of services provided during session	5 (6)
AVP_Timestamp	Unix Time	64 bits	Synchronized point in time	all

A.2.3 Handover sequence



Key

- OB Operator_Backend
- R Remote_Vehicle_Operation
- V Onboard_Vehicle_Operation
- VB Vehicle_Backend
- UB User_Backend
- U User_Frontend
- A Recognizes SV arrival at drop-off area
- B Local sub-system recognizes SV arrival at drop-off area
- C User leaves SV
- D Receives user command to handover authority

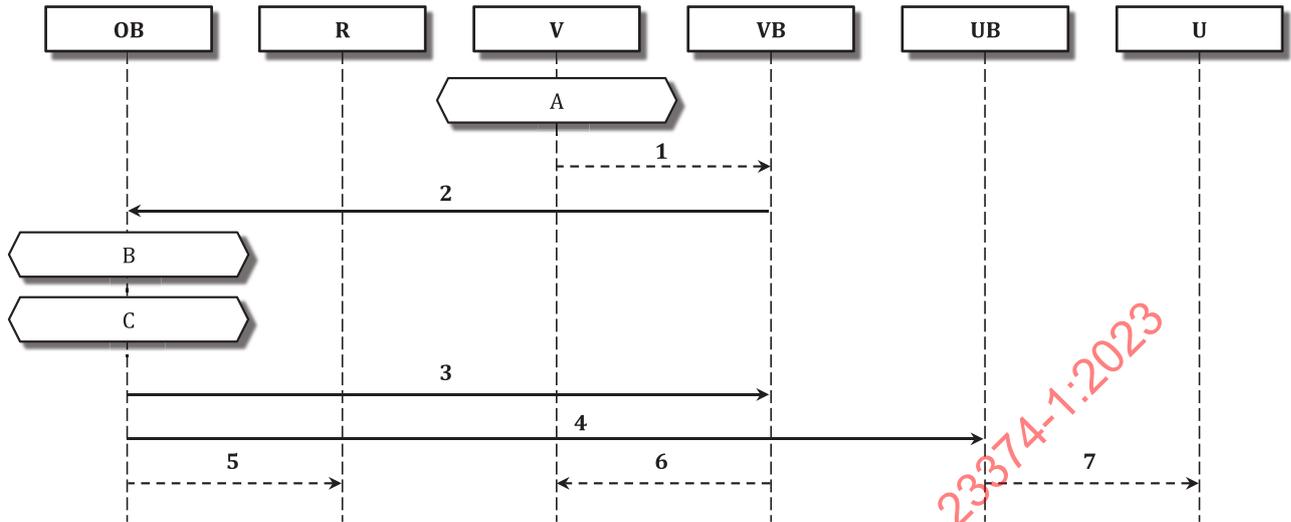
- | | | | |
|----|--|----|----------------------------|
| E | Record handover by user | F | Determine system authority |
| G | Inform handover result (successful or error) | | |
| 1 | SV in drop-off area | 2 | SV in drop-off area |
| 3 | Notify readiness | 4 | Notify readiness |
| 5 | Notify readiness | 6 | Handover request |
| 7 | Handover request | 8 | Handover request |
| 9 | Handover request | 10 | Handover request |
| 11 | R-System L4Check results | 12 | V-System L4Check results |
| 13 | R-System L4Check results | 14 | R-System L4Check results |
| 15 | System authority (result) | 16 | System authority (result) |
| 17 | System authority (result) | 18 | System authority (result) |
| 19 | System authority (result) | | |

Figure A.4 — Handover sequence

Table A.3 — Data elements of Figure A.3

Data element	Unit	Value range	Description	Relevant message
Dropoff_ID	UID	No recommendation	Identifier for drop-off zone, unique for one facility	1, 2
Infrastructure_L4_Status	Enum	1) OK 2) NOK 3) Unknown	Result from AVP Operator specific L4 test	11 (13, 14)
SV_L4_status	Enum	1) OK 2) NOK 3) Unknown	Result from OEM specific L4 test	12 (13, 14)
AVP_System_Authority	Enum	1) Established 2) Revoked 3) Unknown	Result of system authority transition to infrastructure as determined by AVP_Backend	7 (6, 8, 9, 10)
AVP_Timestamp	Unix Time	64 bits	Synchronized point in time	all

A.2.4 Handback sequence



Key

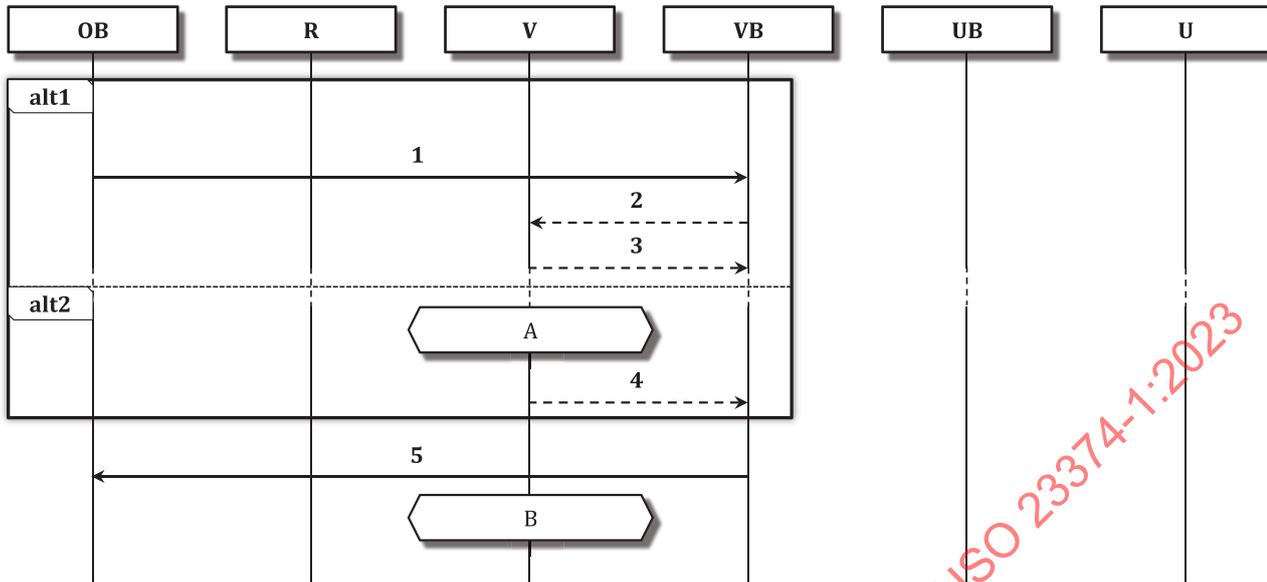
- OB Operator_Backend
- R Remote_Vehicle_Operation
- V Onboard_Vehicle_Operation
- VB Vehicle_Backend
- UB User_Backend
- U User_Frontend
- A Recognizes user intent to regain authority (see 6.7)
- B Record user in vehicle
- C Revoke system authority
- 1 User intent
- 2 User intent
- 3 System authority (revoked)
- 4 System authority (revoked)
- 5 System authority (revoked)
- 6 System authority (revoked)
- 7 System authority (revoked)

Figure A.5 — Handback sequence

Table A.4 — Data elements of Figure A.5

Data element	Unit	Value range	Description	Relevant message
User_Presence_Status	Enum	1) Present 2) Not present	Result of vehicle user presence test	2 (1)
AVP_System_Authority	Enum	1) Established 2) Revoked 3) Unknown	Result of system authority transition to infrastructure as determined by AVP_Backend	3, 4 (5, 6, 7)
AVP_Timestamp	Unix Time	64 bits	Synchronized point in time	All

A.2.5 Sleep sequence



Key

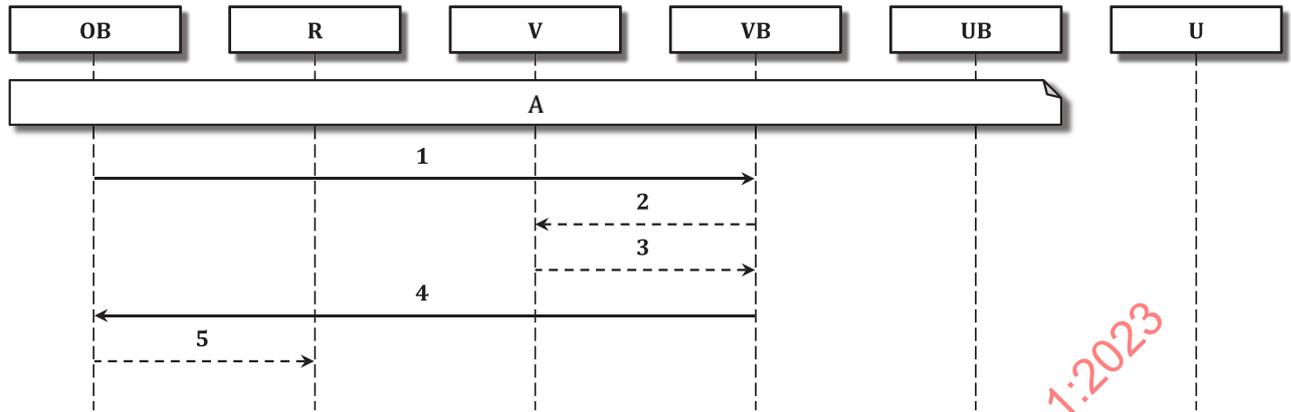
- OB Operator_Backend
- R Remote_Vehicle_Operation
- V Onboard_Vehicle_Operation
- VB Vehicle_Backend
- UB User_Backend
- U User_Frontend
- A Wait duration exceeded
- B Transition to sleep sub-state
- 1 Request sleep
- 2 Negotiate minimal power consumption
- 3 Engaging sleep
- 4 Engaging sleep
- 5 Sleep engaged (SV_Latest_Wake-up)

Figure A.6 — Sleep sequence

Table A.5 — Data elements of Figure A.6

Data element	Unit	Value range	Description	Relevant message
Mission_ID	UID	no recommendation	Unique mission identifier created by AVP_Backend for a disengagement request	1, 5
SV_Latest_Wake-Up	Unix Time	64 bits	Time of latest possible successful wake-up for SV as determined by Vehicle_backend ("maximum sleep time")	5
AVP_Timestamp	Unix Time	64 bits	Synchronized point in time	all

A.2.6 Wake-up sequence



Key

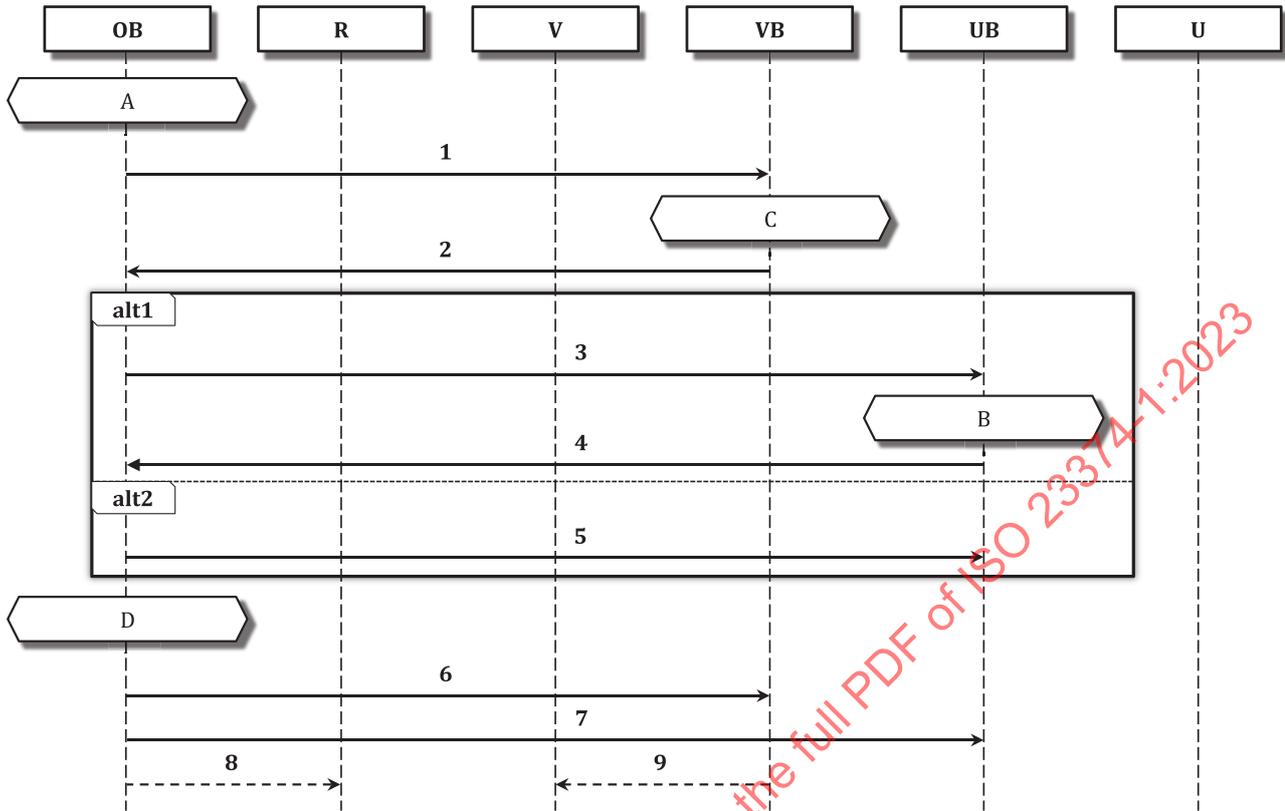
- OB Operator_Backend
- R Remote_Vehicle_Operation
- V Onboard_Vehicle_Operation
- VB Vehicle_Backend
- UB User_Backend
- U User_Frontend
- A Mission confirmed by system
- 1 Request wake up (Mission_ID)
- 2 Wake up command (Mission_ID)
- 3 Result wake up (Mission_ID, Wake_Up_Result)
- 4 Result wake up (Mission_ID, Wake_Up_Result)
- 5 SV in standby state (SV_ID)

Figure A.7 — Wake-up sequence

Table A.6 — Data elements of Figure A.7

Data element	Unit	Value range	Description	Relevant message
Mission_ID	UID	no recommendation	Unique mission identifier within a session created by OB sub-system for an engagement request	1, 4 (2, 3)
SV_ID	Hashed UID	≥ 128 bit	Salted hash based on unique vehicle identifier (VIN).	(5)
Wake-Up_Result	Enum	1) Successful 2) Denied	Response to requested wake-up as determined by VB sub-system; in case of Denied, additional error code and reason has to be provided	4 (3)
AVP_Timestamp	Unix Time	64 bits	Synchronized point in time	all

A.2.7 Mission assignment sequence



Key

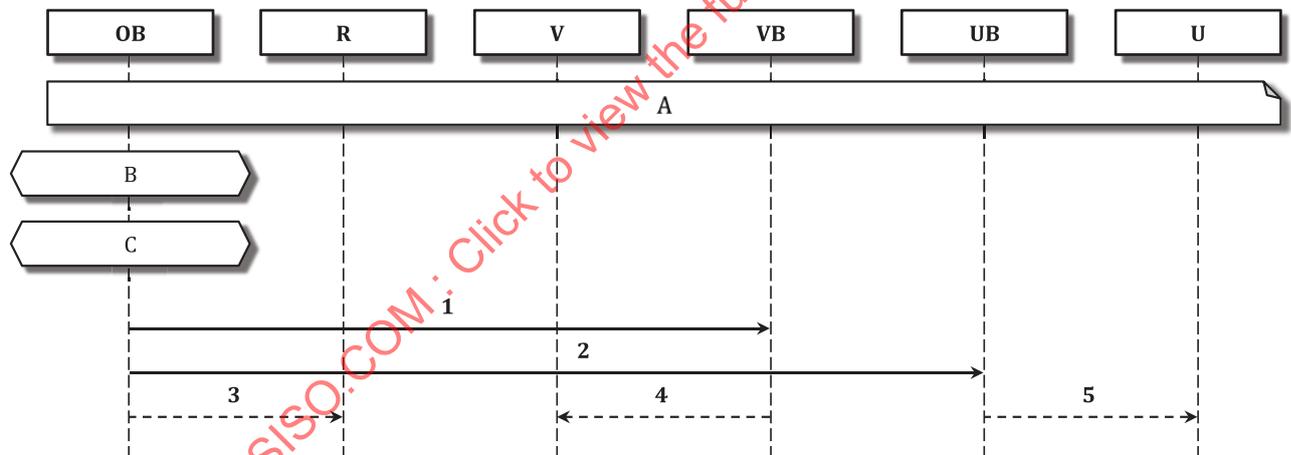
- | | |
|---|---|
| OB Operator_Backend | R Remote_Vehicle_Operation |
| V Onboard_Vehicle_Operation | VB Vehicle_Backend |
| UB User_Backend | U User_Frontend |
| A Create_Mission_ID | B Determination_if_purpose_suits_interests_of_user |
| C Determination_if_purpose_is_ok_for_SV_and_OEM | D Record_or_revoke_Mission_ID_dependent_on_determination_of_UB_and_VB |
| 1 Mission_request_(Mission_ID, Purpose, Session_ID) | 2 Mission_OEM_determination_(Mission_ID, Session_ID) |
| 3 Mission_request_(Mission_ID, Purpose, Session_ID) | 4 Mission_UB_determination_(Mission_ID, Session_ID) |
| 5 Mission_information_(Mission_ID, Purpose, Session_ID) | 6 Mission_determination_(Mission_ID, Purpose, Session_ID) |
| 7 Mission_determination_(Mission_ID, Purpose, Session_ID) | 8 Mission_determination_(Mission_ID) |
| 9 Mission_determination_(Mission_ID) | |

Figure A.8 — Mission assignment

Table A.7 — Data elements of Figure A.8

Data element	Unit	Value range	Description	Relevant message
AVP_Session_ID	UID	large enough to identify single session for the legally required storage time in a market	Unique identifier for management of one SV from the time of check-in until check-out	1, 2, 3, 4, 5, 6, 7
Mission_ID	UID	no recommendation	Unique mission identifier created by OB sub-system for an engagement request	1, 2, 3, 4, 5, 6, 7 (8, 9)
Mission_Purpose	Enum	0) Initial Parking 1) Retrieval 2) Repark 3) Charging 4) car wash 5) Trunk delivery 6) xxy	Type identifier for mission purpose created by OB sub-system, only relevant for engagement request	1, 3, 5, 6, 7

A.2.8 Mission accomplished sequence



Key

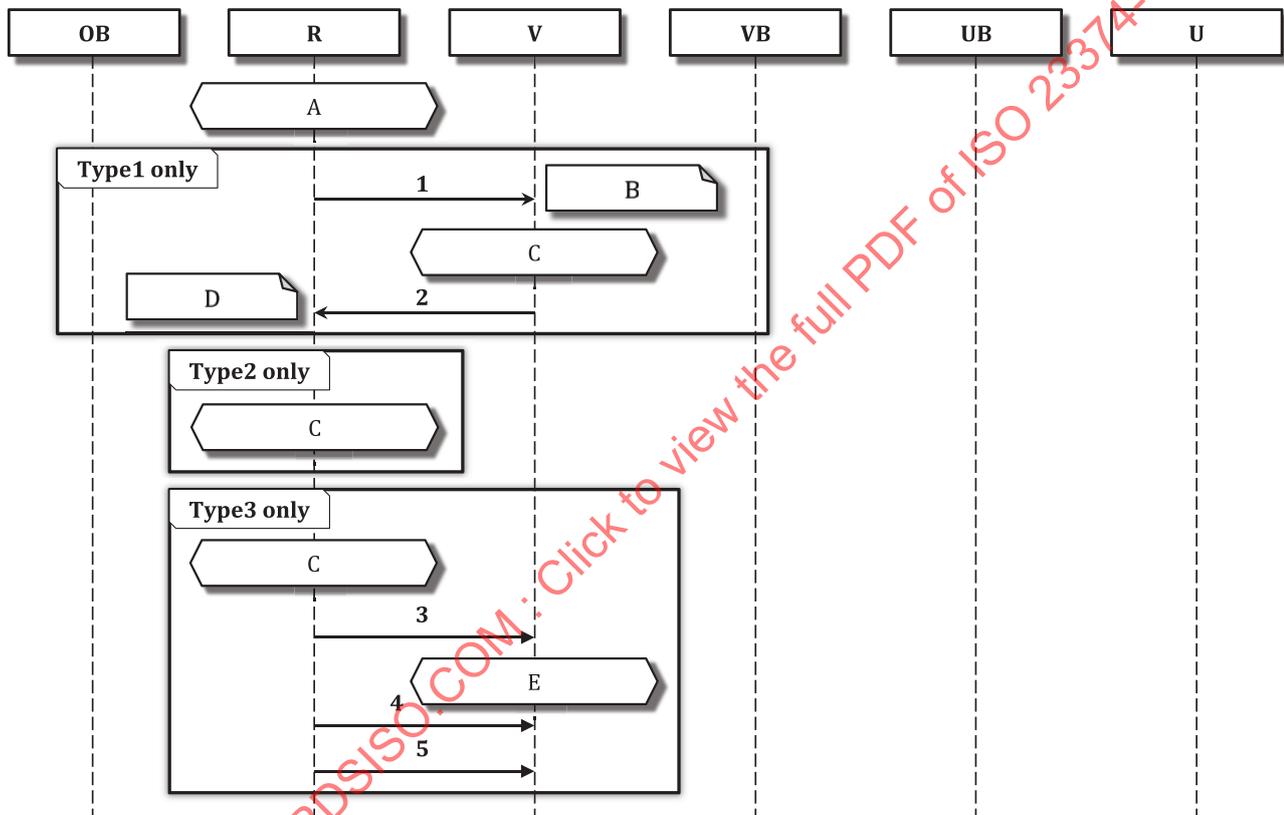
- OB Operator_Backend
- R Remote_Vehicle_Operation
- V Onboard_Vehicle_Operation
- VB Vehicle_Backend
- UB User_Backend
- U User_Frontend
- A SV arrived at destination
- B Determine and record
- C Revoke Mission_ID
- 1 Mission finished (Mission_ID, Mission_Result)
- 2 Mission finished (Mission_ID, Mission_Result)
- 3 Mission finished (Mission_ID, Mission_Result)
- 4 Mission finished (Mission_ID, Mission_Result)
- 5 Mission finished (Mission_ID, Mission_Result)

Figure A.9 — Mission accomplished sequence

Table A.8 — Data elements of Figure A.9

Data element	Unit	Value range	Description	Relevant message
Mission_ID	UID	no recommendation	Unique mission identifier created by OB sub-system at the start of engagement request	1, 2 (3, 4, 5)
Mission_Result	Enum	1) Successful 2) Failed	Result of the accomplished mission created by OB sub-system; in case of Failed, additional error code and reason has to be provided	1, 2 (3, 4, 5)
AVP_Timestamp	Unix Time	64 bits	Synchronized point in time	all

A.2.9 Destination and route



Key

- OB Operator_Backend
- R Remote_Vehicle_Operation
- V Onboard_Vehicle_Operation
- VB Vehicle_Backend
- UB User_Backend
- U User_Frontend
- A Target position determination
- B Prohibited_Route_IDs include road conditions
- C Route planning
- D Sequence may be restarted if result is not valid
- E Localization (initial)
- 1 Assign target (Target_ID, Service_POI_ID, Vis_Route_IDs, Prohibited_Route_IDs)
- 2 Send route result (SV_Route_IDs)
- 3 Landmark information delivery
- 4 Driving boundaries delivery
- 5 Route delivery

Figure A.10 — Destination and route sequence

Table A.9 — Data elements of [figure A.10](#)

Data element	Unit	Value range	Description	Relevant message
Mission_ID	UID	no recommendation	Unique mission identifier created by AVP_Backend for an engagement request	1, 2
Target_ID	UID	no recommendation	Identifier of target semantic unique for target type within facility, Type 1 only	1
Target_Type	List of Enum	<ol style="list-style-type: none"> 1) Parking Spot 2) Drop-Off/Pick-Up 3) Parking Section 4) Parking area 5) Segment for Wait 6) Point of Interest 	Type identifier for specified target, Type 1 only	1
Behaviour_Constraints	List of Enum	<ol style="list-style-type: none"> 1) Park forward 2) Park backward 3) Leave room to wall 4) Block parking 5) Precise positioning 	Instruct SV to obey behaviour at target (e.g. to enable successful service), Type 1 only. “Precise positioning” value means SV positioning priority is given to absolute map position (e.g. no influence of neighbouring vehicles)	1
Via_Route_Ids	List of UID	>16 elements	List of edge identifiers to be used in SV routing, only Type 1	1
Prohibited_Route_Ids	List of UID	>16 elements	List of edge identifiers forbidden to be used in SV routing, only Type 1	1
SV_Route_Ids	List of UID	>64 elements to enable long transfers in complicated environments	SV route planning result considering possible via or prohibited edges, only Type 1	2
Landmark_ChangeFlag	Enum	<ol style="list-style-type: none"> 1) New 2) Add 	Set new landmarks for SV or add to existing, only Type 3	3
Landmarks_Count	Int	≥0	Number of Landmarks identified, only Type 3	3
Landmark Info	List of Landmarks	—	List of landmark items, only Type 3 See Table A.10	3
Landmark_Confirmation	Enum	<ol style="list-style-type: none"> 1) OK 2) NG 	Confirmation of landmark delivery, only Type 3	3

Table A.9 (continued)

Data element	Unit	Value range	Description	Relevant message
Bounds_ChangeFlag	Enum	1) New 2) Add	Set new boundaries for SV or add to existing, only Type 3	4
Bounds_Count	Int	≥0	Number of boundaries identified, only Type 3	4
Bounds_Info	List of Bounds	—	See Table A.11 , only Type 3	4
Bounds_Confirmation	Enum	1) OK 2) NG	Confirmation of landmark delivery, only Type 3	4
Route_ResetFlag	Enum	1) Unreset (Add the route data) 2) Reset and newly add route data	only Type 3	5
Number of nodes	Int	≥0	only Type 3	5
Route_Nodes	List of Route Nodes		See Table A.12 , only Type 3	5
AVP_Timestamp	UTC	64 bites	Synchronized point in time	all

Table A.10 — Type 3 Landmark Elements

Data element	Unit	Value range	Description
Landmark_ID	Int	—	Unique identifier to identify landmark, only Type 3
Landmark_Type	Enum	0: Type A 1: Type B 2: Type C 3-255: reserved	Specify landmark type, only Type 3
Landmark_Location	x,y,z (mm)	—	Show landmark location, only Type 3
Landmark_Orientation	Degrees (3 axis)	0,00 to 359,99	Orientation of Landmark, only Type 3

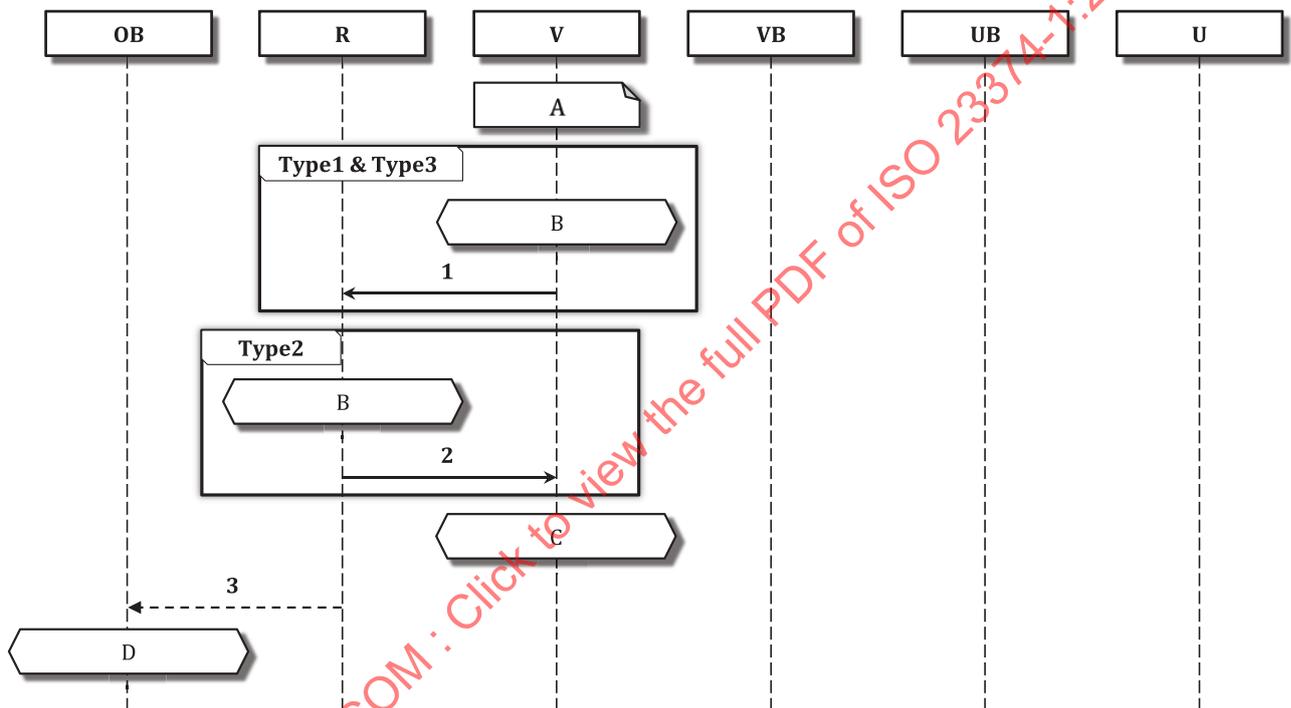
Table A.11 — Type 3 Bounds Elements

Data element	Unit	Value range	Description
Bounds_Location	x,y,z(mm)	—	Location of all boundaries, only Type 3
Bounds_Orientation	Degrees	0,00 to 359,99	Orientation of boundaries, only Type 3

Table A.12 — Type 3 Route Node Elements

Data element	Unit	Value range	Description
XYZ coordinate	x,y,z(mm)	—	x, y, z in map coordinates
Type	Enum	0: Waypoint 1: Target position	
Max velocity	m/s	0,00 to 8,33	Maximum allowed velocity for this part of the route
Direction	Degrees	0,00 to 359,99	Maximum allowed velocity for this part of the route, only Type 3

A.2.10 Destination reached



Key

- OB Operator_Backend
- R Remote_Vehicle_Operation
- V Onboard_Vehicle_Operation
- VB Vehicle_Backend
- UB User_Backend
- U User_Frontend
- A SV arrived at destination (e.g. parking spot)
- B Determine SV reached target destination
- C Establish stationary conditions
- D Determine mission processing
- 1 Target destination reached (Target_ID, Mission_ID)
- 2 Target destination reached (Mission_ID)
- 3 Target destination reached (Target_ID, Mission_ID)

Figure A.11 — Destination reached sequence

Table A.13 — Data elements of Figure A.11

Data element	Unit	Value range	Description	Relevant message
Mission_ID	UID	no recommendation	Unique mission identifier created by OB sub-system for an engagement request	1, 2 (3)

Table A.13 (continued)

Data element	Unit	Value range	Description	Relevant message
Confirmed_Target_ID	UID	no recommendation	Identifier of target semantic unique for target type within facility, Type 1 only. Can be different to assigned target, if a search was conducted by SV.	1
SV_Target_Type	List of Enum	1) Parking Spot 2) Drop-Off/Pick-Up 3) Parking Section 4) Parking area 5) Segment for Wait 6) Point of Interest	Type identifier for specified target, Type 1 only	1, 2 (3)
AVP_Timestamp	Unix Time	64 bits	Synchronized point in time	all

A.3 Data elements related to automated vehicle operation

A.3.1 R sub-system periodic message

A.3.1.1 Type 1

Table A.14 — Data elements of Type 1 R sub-system periodic message

Data element	Unit	Value range	Description
AVP_MovementPermission	Bool	—	Vehicle-specific driving permission by AVPS provider; failure to receive permission within a given frequency leads to suspended state
SV_OccupiedMovementAreas	List of UID	>32	List of unique identifiers of map areas, in which the specific SV is not allowed to manoeuvre
SV_MaxAllowedVelocity	m/s	0,00 to 8,33	Maximum allowed velocity imposed on SV by provider

A.3.1.2 Type 2

There are two interface types for Type 2 R sub-system cyclic message (driving command): the so-called “Path Interface” and the “Acceleration-Curvature (Acc-Curv) Interface”.

With the Path Interface, a path with limitations (or a “snippet”) is sent from the R sub-system and stored within the V sub-system. The V sub-system receives its current position estimated by the R sub-system and determines and performs VMC to keep the SV’s position on the stored path.

With the Acc-Curv Interface, VMC is determined in the R sub-system, and these VMC relevant information are transmitted to be performed by the V sub-system.

Table A.15 — Data elements of Type 2 R sub-system periodic message (driving command)

Data element	Unit	Value range	Description
SV_InterfaceType	Enum	1. Path 2. Acc-Curv	Drive control mode. Is initialized before vehicle moves, but not during the drive.
SV_PathSnippet	UID, list of path poses		<u>Path Interface:</u> This message contains the path which the vehicle is supposed to follow. Depending on the vehicle's capability this can be either the complete path or just a snippet. Path poses contain x,y, psi, parking deck, speed, curvature, driving direction indicator.
SV_Position	m, rad, s		<u>Path Interface:</u> 3D Vehicle pose (centre of rear axle) as determined by infrastructure in x,y, ψ in garage coordinate system with time of measurement.
SV_TargetVelocity	m/s	0,00 to 8,33	<u>Path Interface:</u> target velocity imposed on SV by provider (can be undercut by MaxDistanceToDrive control).
SV_MaxDistanceToDrive	m	>0	<u>Path Interface:</u> Maximum remaining distance the vehicle is currently allowed to drive.
SV_DirectionIndicator	Enum	1) none 2) left 3) right	<u>ACC-Curv Interface:</u> Command for driving direction indicator.
SV_DrivingDirection	Enum	1) standstill 2) forwards 3) backwards	<u>ACC-Curv Interface:</u> Command for driving direction.
SV_TrajectorySnippet	list of tuples with acceleration and curvature values	ax: -12 m/s ² ... +12 m/s ²	<u>ACC-Curv Interface:</u> Target acceleration/ deceleration and target curvature

Table A.16 — Data elements of Type 2 R sub-system periodic message (driving permission)

Data element	Unit	Value range	Description
expirationTime	s	32 bits	unix timestamp, i.e. milliseconds since 01.01.1970 00:00
velocityMax	m/s	≥ 0	maximum allowed vehicle velocity a) when driving forwards; and b) when driving backwards.
curvatureMin	1/m		right curvature bounds when driving a) forwards; and b) backwards.
curvatureMax	1/m		left curvature bounds when driving a) forwards; and b) backwards

Table A.17 — Data elements of Type 2 R sub-system periodic message (Safety time sync response)

Data element	Unit	Value range	Description
UID	UID	no recommendation	UID received in the Safety Clock Sync Request.
serverTime	s	>0	Server time when Safety Time Sync Request was received. Unix timestamp, i.e. milliseconds since 1970-01-01, 00:00

NOTE Safety signals are secured by additional cyclic redundancy checks (CRCs) in the application layer, etc.

A.3.1.3 Type 3

Table A.18 — Data elements of Type 3 R sub-system periodic message

Data element	Unit	Value range	Description
Message Counter	int	—	incremental counter value

A.3.2 V sub-system periodic message

A.3.2.1 Type 1 and 3

Table A.19 — Data elements of Types 1 and 3 V sub-system periodic message

Data element	Unit	Value range	Description
Mission_ID	UID	no ISO 23374 series recommendation	Unique mission identifier created by AVP_Backend for an engagement request
SV_Position	m, degrees	—	6D Vehicle pose in x,y,z in map coordinate system with respect to center of its rear axle and angles Φ, θ, Ψ
SV_Target_ETA	Seconds	≥ 0	Estimated time of arrival at current target for current move based on no traffic
System_State	None	0) Inactive 1) Ready 2) Standby 3) Preparation 4) Normal 5) Temp. Error 6) Suspend 7) Recovery	State of vehicle

Table A.19 (continued)

Data element	Unit	Value range	Description
SV_DrivingState	Enum	1) Cruise 2) Close quarter manoeuvring 3) Pausing 4) Stopped	Status of automated driving within state "normal"
Shift Position	None	0) Neutral 1) Parking 2) Drive 3) Reverse 4-6) Reserve 7) Not defined	Shift position of vehicle
Vehicle Longitudinal Acceleration	m/s ² (g)		Longitudinal acceleration of vehicle
Vehicle Steering Angle	degrees	-3 070,5 to +3 070,5	Angle of steering
SV_Velocity	m/s	0,00 to 8,33	Subject vehicle speed
AVP_Timestamp	Unix Time	32 bits	Synchronized point in time

A.3.2.2 Type 2

Table A.20 — Data elements of Types 2 V sub-system periodic message (vehicle state)

Data element	Unit	Value range	Description
pathSnippet_ID	UID		The identifier of the path snippet which the vehicle currently follows. 0 if not applicable.
SV_currentCurvature	1/m	>0	The current vehicle curvature as determined by vehicle
SV_Velocity	m/s	0,00 to 8,33	Subject vehicle speed as determined by vehicle
SV_YawRate	rad/s		current yaw rate
SV_Driving_Direction	Enum	1) Standstill 2) Forward 3) Backward	Subject vehicle driving direction with standstill below 0,01 m/s
SV_Shift_Position	Enum	0) Neutral 1) Parking 2) Drive 3) Reverse 4-6) Reserve 7) Not defined	Shift position of vehicle

Table A.21 — Data elements of Types 2 V sub-system periodic message (Functional clock sync request)

Data element	Unit	Value range	Description
localVehicleTime	s	>0	Local vehicle time. Will be returned in the Functional Time Sync Response together with a server time.

Table A.22 — Data elements of Types 2 V sub-system periodic message (Safety clock sync request)

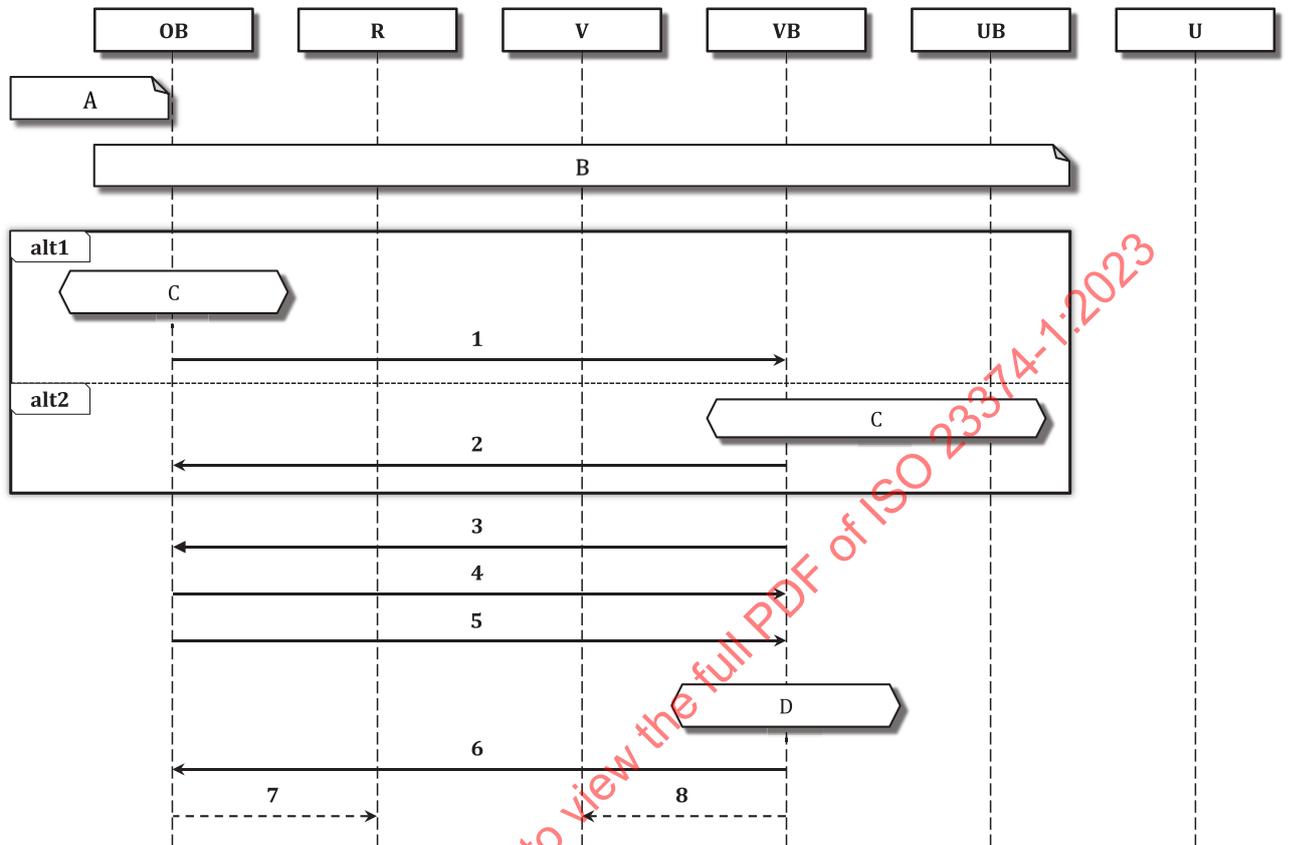
Data Element	Unit	Value Range	Description
SafetyClockSyncRequest	UID	no recommendation	Safety clock sync request from the vehicle. The vehicle shall use this identifier to relate the Safety Time Sync Response to this request.
NOTE Safety signals are secured by additional CRCs in the application layer, etc.			

A.3.3 Suspend condition codes

Refer to [9.4](#).

A.4 Communication sequences related to system participant management

A.4.1 Communication interface compliance check sequence



Key

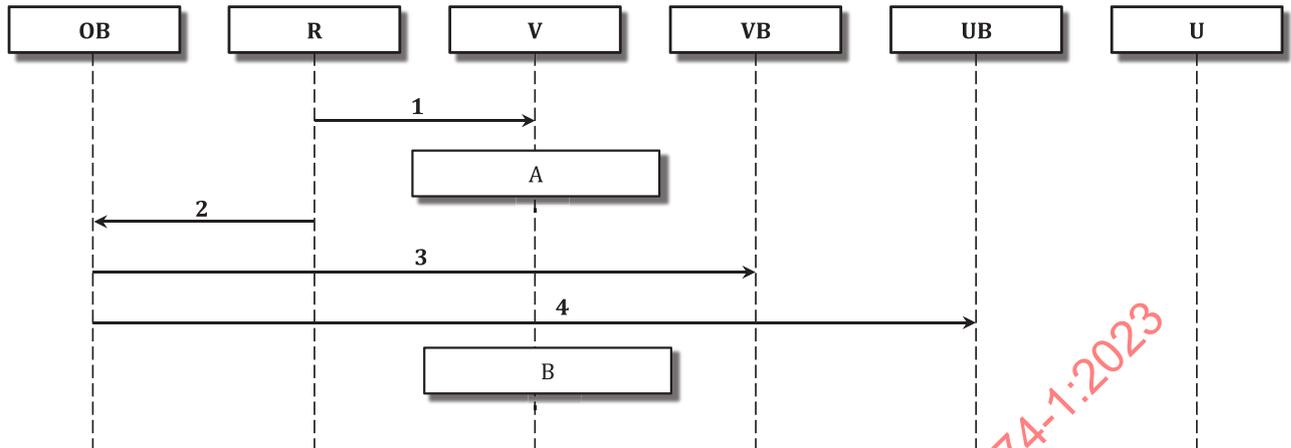
OB	Operator_Backend	R	Remote_Vehicle_Operation
V	Onboard_Vehicle_Operation	VB	Vehicle_Backend
UB	User_Backend	U	User_Frontend
A	Event based during session	B	Session confirmed by backend sub-systems
C	AVP protocol version revoked [Type 1: and/or Vehicle map version revoked]	D	Match protocol and map version, update if necessary
1	New protocol request (Session_ID)	2	New protocol request (Session_ID)
3	Supported types offer (Session_ID, SV_Supported_AVP_Types)	4	Type confirmation (Session_ID, Confirmed_AVP_Type)
5	Protocol offer (Session_ID, Valid_AVP_Protocol_Ver, [Type 1: Valid_AVP_Map_Ver])	6	Protocol confirmation (Session_ID, Confirmed_AVP protocol version, [Type 1: Confirmed vehicle map version])
7	Protocol confirmation (Confirmed_AVP_protocol version, [Type 1: Confirmed vehicle map version])	8	Protocol confirmation (Confirmed_AVP_protocol version, [Type 1: Confirmed vehicle map version])

Figure A.12 — Communication interface compliance check sequence

Table A.23 — Data elements of [Figure A.12](#)

Data element	Unit	Value range	Description	Relevant message
AVP_Session_ID	UID	large enough to identify single session for the legally required storage time in a market	Unique identifier for management of one SV from the time of check-in until check-out.	1, 2, 3, 4, 5, 6
AVP_Protocol_Ver	List of UIDs	future-proof	Unique identifier for AVP communication protocol used for specified type within this session confirmed by AVP_Backend.	5, 6 (7, 8)
AVP_Map_Ver	List of UIDs	no recommendation	Unique identifier for AVP map version used for session confirmed by AVP_Backend. Suitable data types from map standards can be applied.	5, 6 (7, 8)
SV_Supported_AVP_Types	List of Enum	1) Type 1 exclusive 2) Type 1 mixed 3) Type 2 exclusive 4) Type 2 mixed 5) Type 3 exclusive 6) Type 3 mixed	Type identifier for supported AVP ISO Type offered by SV. Contains information about supported scenario (mixed/exclusive). SV may offer multiple values, but only one mode is selected for a session.	3, 4
AVP_Timestamp	Unix Time	64 bits	Synchronized point in time.	all

A.4.2 Operation stop command



Key

- OB Operator_Backend
- R Remote_Vehicle_Operation
- V Onboard_Vehicle_Operation
- VB Vehicle_Backend
- UB User_Backend
- U User_Frontend
- A Emergency stop (see 6.3.3)
- B Transition to suspend state
- 1 Operation stop command (Mission_ID, SV_ID)
- 2 Info stop command (Remote_Stop_Reason)
- 3 Info stop command (Remote_Stop_Reason)
- 4 Info stop command (Remote_Stop_Reason)

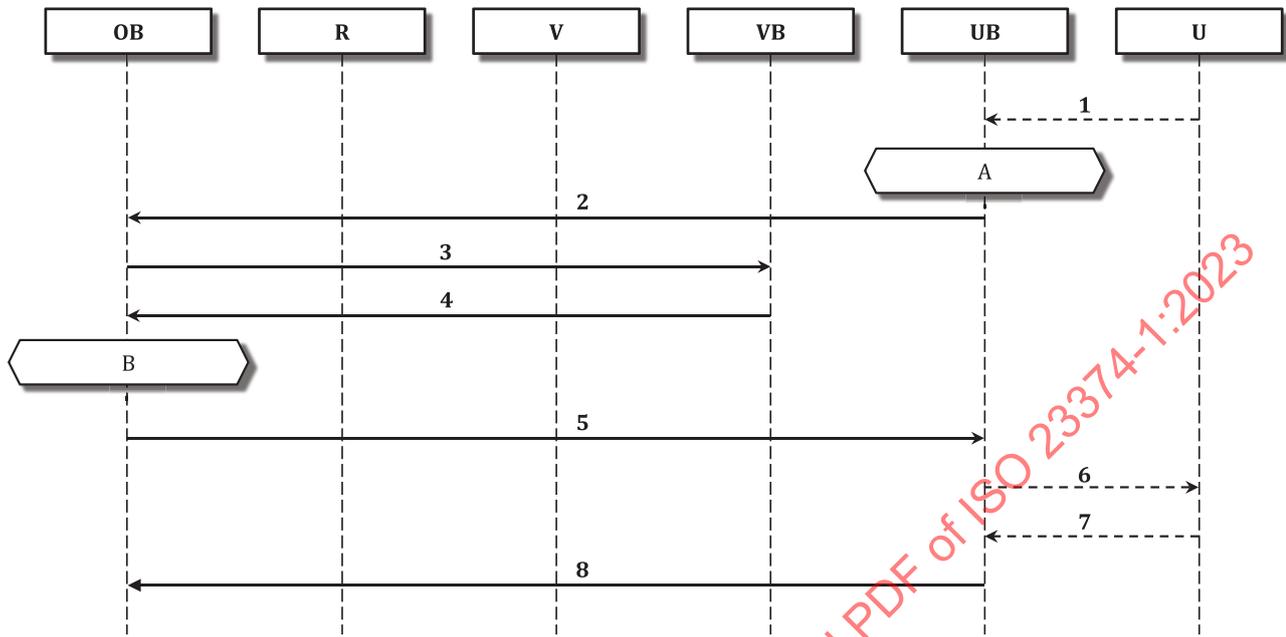
Figure A.13 — Operation stop request sequence

Table A.24 — Data elements of Figure A.13

Data element	Unit	Value range	Description	Relevant message
SV_ID	Hashed UID	≥ 128bits	Salted hash based on unique vehicle identifier (VIN).	1
Remote_Stop_Reason	Enum	1) Facility Hazard 2) Accident 3) Manual 4) Service Failure 5) Invalid SV Behaviour	Reason for AVPS to suspend operation for vehicle (e.g. earthquake = 1)	1, 2, 3, 4
Mission_ID	UID	no recommendation	Unique mission identifier created by AVP_Backend	1
AVP_Timestamp	Unix Time	64bits	Synchronized point in time	all

A.5 Communication sequences linked to on-demand user requests

A.5.1 Availability request



Key

- OB Operator_Backend
- R Remote_Vehicle_Operation
- V Onboard_Vehicle_Operation
- VB Vehicle_Backend
- UB User_Backend
- U User_Frontend
- A Check user policies
- B Confirm compatibility and vacancy
- 1 Request reservation
- 2 Request Availability (Duration, Terms, Services)
- 3 Request compatibility data (facility parameters)
- 4 Compatibility data
- 5 Offer reservation (Reservation_ID)
- 6 Offer reservation
- 7 Confirm reservation
- 8 Confirm reservation

Figure A.14 — Availability request sequence

Table A.25 — Data elements of [Figure A.14](#)

Data element	Unit	Value range	Description	Relevant message
User_ParkingPreference	List of Enum	1) Forward 2) Backwards 3) Extra Door Space 4) Indoor Only 5) Near Exit	User preference identified by UB sub-system to be considered by OB sub-system if offered	(1)
SV_ID	Hashed UID	≥128 bits	Salted hash based on unique vehicle identifier (VIN)	4
SV_Width	m	>0	Vehicle width (resolution 1 cm)	4

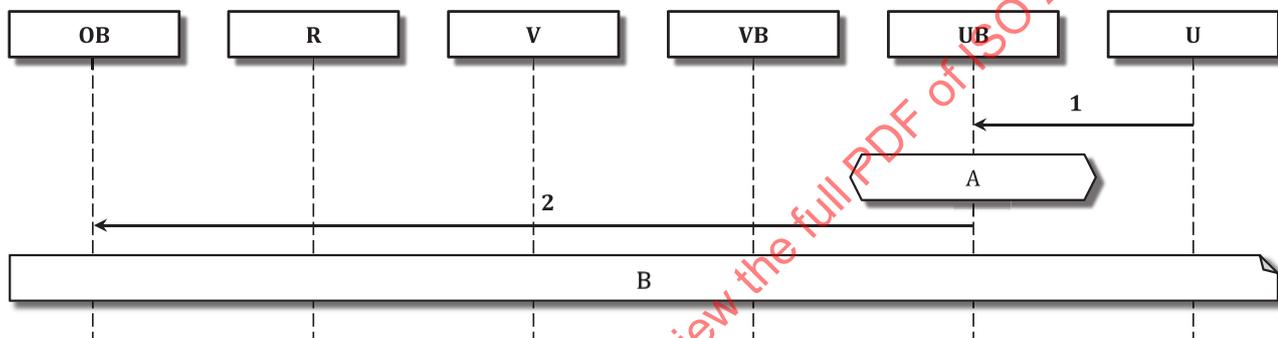
Table A.25 (continued)

Data element	Unit	Value range	Description	Relevant message
SV_Length	m	>0	Vehicle length (resolution 1 cm)	4
SV_Height	m	>0	Vehicle height (resolution 1 cm)	4
SV_FrontOverhang	m	>0	Vehicle front overhang (resolution 1 cm)	4
SV_RearOverhang	m	>0	Vehicle rear overhang (resolution 1 cm)	4
SV_GroundClearance	m	>0	Vehicle ground clearance (resolution 1 cm)	4
SV_InnerCurveRadius	m	>0	Minimum vehicle inner curve radius (resolution 1 cm)	4
SV_OuterCurveRadius	m	>0	Minimum vehicle outer curve radius (resolution 1 cm)	4
SV_Gradient	degree	>0	Maximum vehicle supported gradient (resolution 0,1 deg)	4
SV_SupportedForwardVelocity	m/s	0,00 to 8,33	Maximum vehicle supported forward speed	4
SV_SupportedReverseVelocity	m/s	0,00 to 8,33	Maximum vehicle supported reverse speed	4
SV_FuelType	List of Enum	0) invalid 1) petrol 2) diesel 3) LPG 4) CNG 5) Electrical 6) Hydrogen	Vehicle fuel type	4
SV_ElectricAdapterType	Enum	1) AC side 2) DC side 3) Wireless front 4) Wireless rear 5) AC underbody 6) DC underbody	EV connector type	4

Table A.25 (continued)

Data element	Unit	Value range	Description	Relevant message
SV_RefuelingAdapterPosition	enum	1) Front left 2) Front middle 3) Front right 4) Rear right 5) Rear middle 6) Rear left	Position of SV fuel or electric inlet in x, y, z with respect to its centre rear axle and angles Φ, θ, Ψ	4
SV_ExpectedMaxSleepTime	hours	>0	Maximum vehicle sleep time	4

A.5.2 Retrieval request



Key

- OB Operator_Backend
- R Remote_Vehicle_Operation
- V Onboard_Vehicle_Operation
- VB Vehicle_Backend
- UB User_Backend
- U User_Frontend
- A Check user policies
- B Mission request
- 1 Request retrieval
- 2 Request retrieval

Figure A.15 — Retrieval request sequence

Table A.26 — Data elements of [Figure A.15](#)

Data element	Unit	Value range	Description	Relevant message
AVP_Session_ID	UID	large enough to identify single session for the legally required storage time in a market	Unique identifier for management of one SV from the time of check-in until check-out	2
Pick-Up_ID	UID	no recommendation	Unique identifier of the required Pick-Up zone	2
Pick-Up_time	Unix Time	64 bits	Desired time the SV should be ready at the Pick-Up zone for takeover by the user	2
AVP_Timestamp	Unix Time	64 bits	Synchronized point in time	all

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Annex B (normative)

Test targets

B.1 Cube (see Figure B.1)



Figure B.1 — Cube test target

Dimension: 11 cm × 11 cm × 11 cm

Material: Wood

The dimension of the cube represents a size of a new-born infant's head.^[3]

B.2 Timber (see Figure B.2)



Figure B.2 — Timber test target

Dimension: 150 cm × 13 cm × 13 cm, tolerance of each dimension: ±1 cm

Material: Wood

The dimensions of the timber represent a curb, but also an object that could possibly exist within an exclusive traffic environment.

B.3 Infant (see Figure B.3)



Figure B.3 — Infant test target

Height (from crown to toe at standing posture): 65 cm (typical)

Head width: 11 cm diameter (typical)

Calf width: 5 cm diameter (typical)

Required postures: lying, crawling, standing with movable extremities but without articulation

Represents a twelve-month-old infant.

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Annex C (informative)

Description of localization markers

C.1 Contrast ratio

C.1.1 General

For successful recognition, the contrast ratio between the marks on the surface of the markers should fulfil either one of the criteria specified in [C.1.2](#) or [C.1.3](#). The two specifications are compatible to each other, whereas the relationship can be explained by the [Formula \(C.1\)](#).

$$K_M = \frac{K_W}{K_W + 2} \quad (\text{C.1})$$

where

K_M is the Michelson contrast ratio value specified in [C.1.3](#);

NOTE 1 The range of K_M becomes $0 \leq K_M \leq 1$

K_W is the Weber contrast ratio value specified in [C.1.2](#);

NOTE 2 The range of K_W becomes $0 \leq K_W \leq \infty$

C.1.2 Weber contrast

The contrast ratio should be equal to or greater than 2, calculated using [Formula \(C.2\)](#):

$$K_W = \frac{L_{\max} - L_{\min}}{L_{\min}} \quad (\text{C.2})$$

where

K_W is the Weber contrast ratio value;

L_{\min} is the minimum illuminance;

L_{\max} is the maximum illuminance.

C.1.3 Michelson contrast

The contrast ratio should be equal to or greater than 0,5 calculated using [Formula \(C.3\)](#).

$$K_M = \frac{L_{\max} - L_{\min}}{L_{\max} + L_{\min}} \quad (\text{C.3})$$

where

K_M is the Michelson contrast ratio value;

L_{\min} is the minimum illuminance;

L_{\max} is the maximum illuminance.

C.2 Coded markers

C.2.1 General

The following subclauses and [Figures C.1](#) and [C.2](#) describe the specifications of the coded markers recommended within this document. [Annex D](#) provides information for placing these coded markers in parking facilities, as well as a guidance for combining them with anonymous markers.

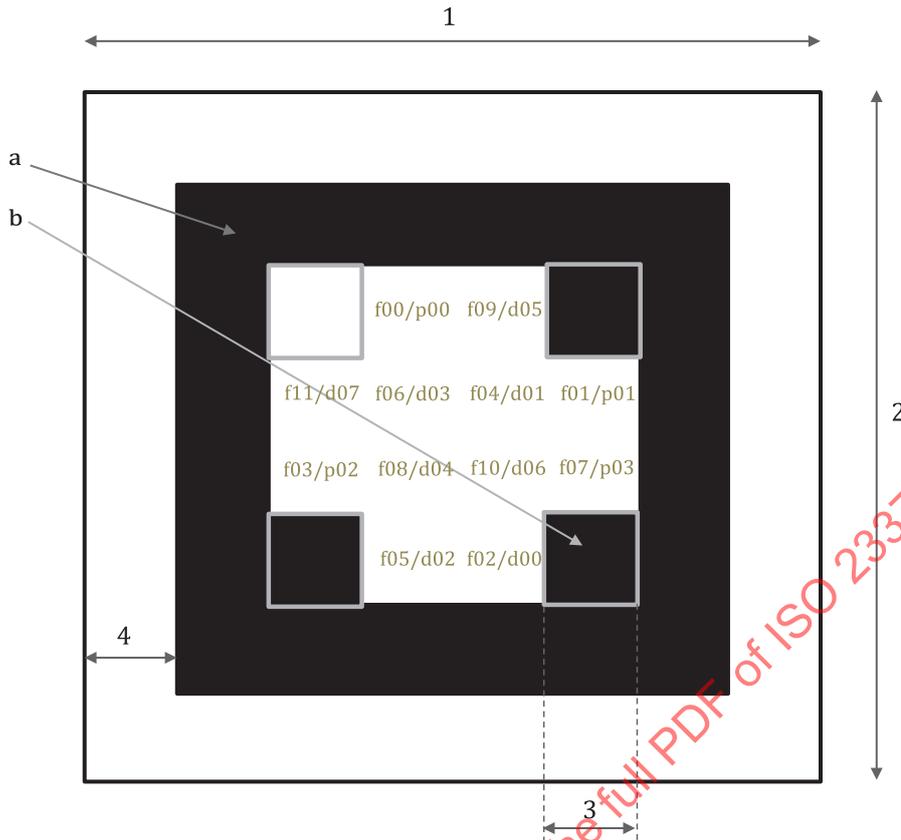
The marker is on a white background. There is a black rectangle and on it is inside a matrix for coded information. It has 4*4 Points.

The position of the marker needs to be entered correctly into the map database.

Values 0 to 250 are only used once within a certain parking facility.

Values 251 to 255 may be used repeatedly to allow the necessary coverage in larger parking facilities.

Markers shall be located on a flat surface for image sensing and recognition.



Key

- 1 40 cm
- 2 40 cm
- 3 5 cm
- 4 5 cm
- a separated 6 × 6 in black and white the squares on the boarder are always black
- b 4 edge squares are fix defined (black/white)

Figure C.1 — Schematic of the coded marker

C.2.2 Contents

- 4 bits for orientation in the corners:
 - the marker is correctly rotated, if the orientation bit on the top left is white.
- 8 data bits. These define the code:
 - d00-d07
 - to calculate the value:

```
// compute ID from data bits
for(tInt d=7; d>=0; d--){
    if(m_bitCode.m_bBits[d] == 1)
    {
        m_candidate.ID += (1<<d); // 2^d
    }
}
```

That means the data bits would be translated from d00-d07 in a binary code.

- 4 parity-Bits, to reduce failure in detection of single bits

```
// parity logic
p3 = d4+d5+d6+d7
```

$p2 = d1+d2+d3+d7$
 $p1 = d0+d2+d3+d5+d6$
 $p0 = d0+d1+d3+d4+d6$

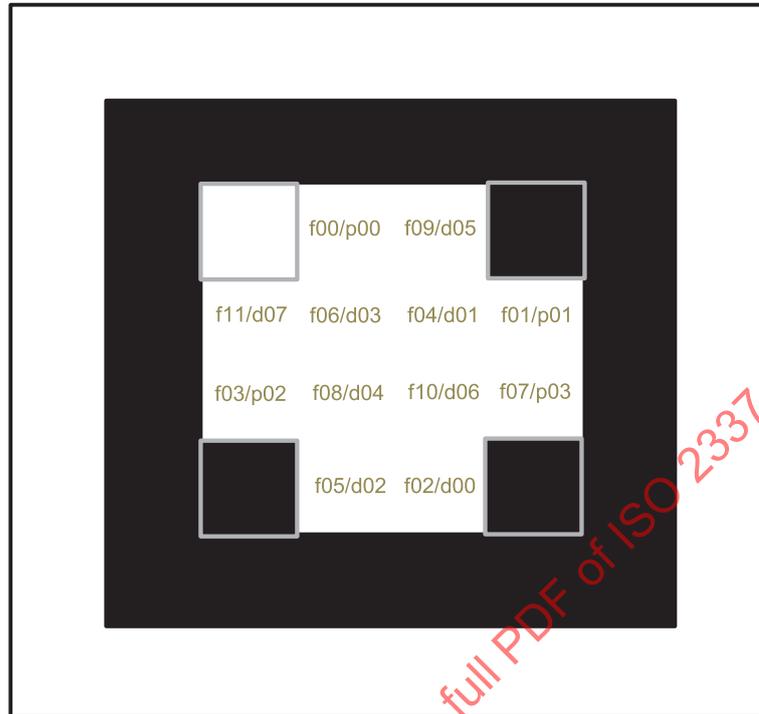


Figure C.2 — Contents of the coded markers

C.2.3 Distinguishing coded markers

C.2.3.1 Graphical icons for coded markers

In the marker layout for the localization, there are 255 different markers, each representing a unique ID as seen in [Figure C.3](#).

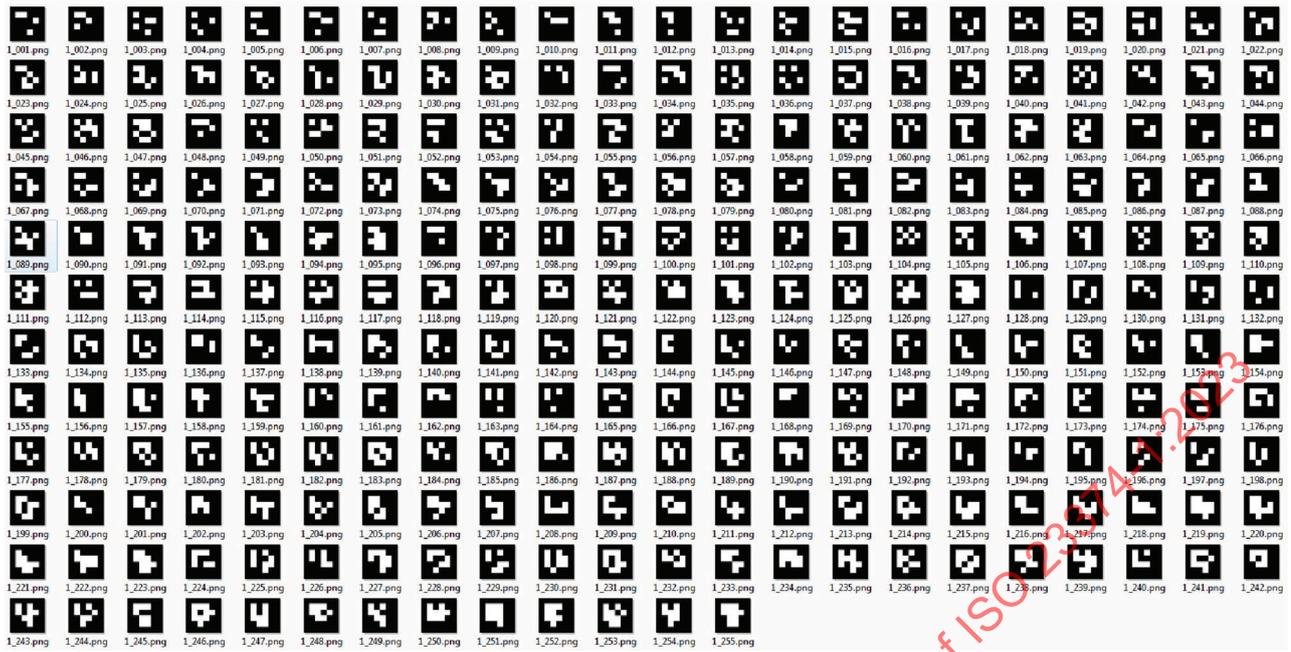


Figure C.3 — Overview of 255 unique IDs of coded markers

The ID is represented by a bit pattern. The pattern concept of a full marker and its elements are shown in [Figure C.4](#).

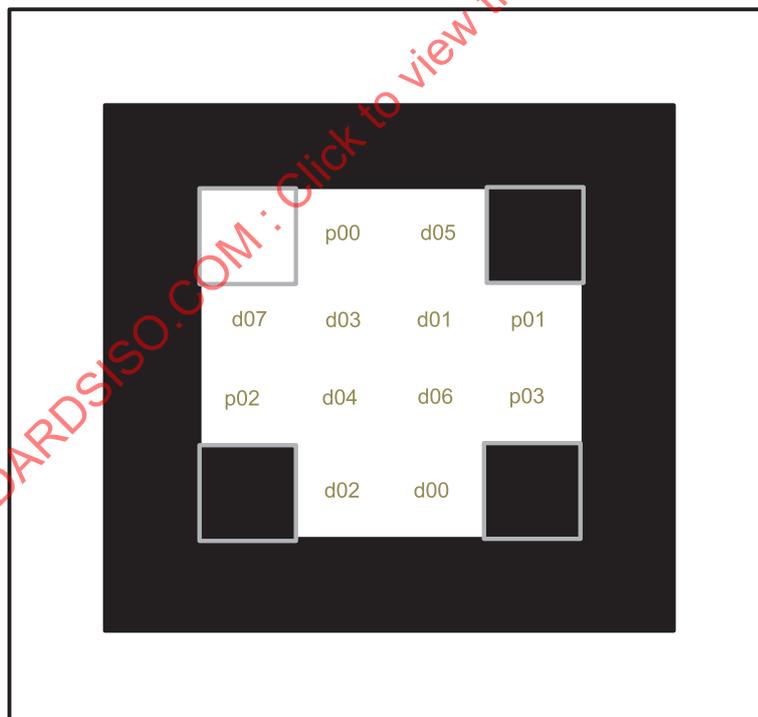
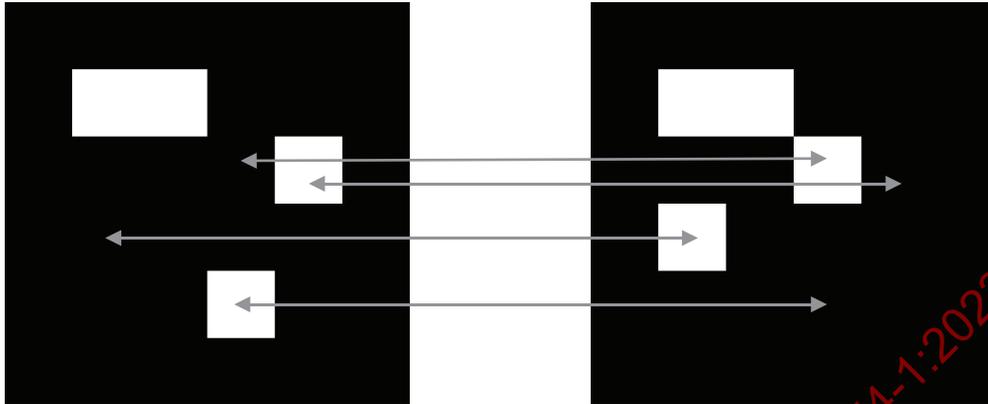


Figure C.4 — Setup of 2D-matrix code

The coding of the ID is implemented by an 8-bit pattern for data using the elements d00 to d07. Four bits with the pattern pxx describe the so-called parity bits to reduce the failure in detection of single bits. A checksum which is matched with the parity bits is computed from the data bits in order to ensure the correct extraction of the ID. Furthermore, "hamming coding" is used in order to reduce the possibility

of wrong detections as shown in [Figure C.5](#). The different bit pattern of the markers has a hamming distance of at least 3 to each other. This means that two different bit codes distinguish in at least 3 bits.



NOTE Hamming distance: 4

Figure C.5 — Example of two markers with a hamming distance of 4

The orientation of the marker is defined by a white orientation bit in the top left edge. Around the bit pattern, there is a frame of black bits followed by other frame of white bites (not shown in [Figure C.5](#)). The white, external frame is used to create a high contrast and homogeneous area around every marker and is necessary for the detection of the general structure of the marker.

C.2.3.2 Measurement of the markers

The described bit code of the marker is only used to distinguish the different IDs by the detection algorithm to extract their position and orientation from the digital map. The actual measurement which is needed for the determination of the vehicle position is the position of the four corners of the black frame in the figure. Therefore, each marker supplies four measurements for the localization algorithm.

C.2.4 Scale factor for coded markers

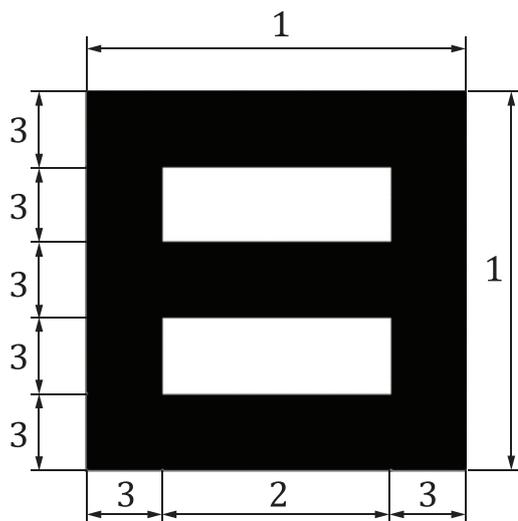
Coded markers may be produced in various sizes to fit to different needs of the parking facility. The same scale factor shall be used in one facility. [Table C.1](#) shows the variations.

Table C.1 — Scale factor for coded markers

Length cm	Scale factor	Remarks
100	1	Maximum size
80	0,8	
56	0,56	
40	0,4	Default
32	0,32	
28	0,28	
20	0,2	Minimum size

C.3 Anonymous markers

[Figure C.6](#) shows the specification of the anonymous marker recommended within this document. [Clause H.1](#) provides information for placing these anonymous markers in parking facilities.



Key

- 1 50 cm
- 2 30 cm
- 3 10 cm

Figure C.6 — Anonymous marker

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Annex D (informative)

Guidance in placing coded markers in parking facilities

D.1 Introduction

This annex deals with the use and optimal distribution of coded markers in parking facilities for indoor localization. [Clause D.2](#) provides some general information for localization with markers and [D.3](#) provides a guideline for placing coded markers in a facility.

D.2 General information for localization with markers

D.2.1 General

This subclause describes the basics of localization with coded markers in order to provide a general understanding for the decisive points for the generation of a marker plan.

D.2.2 Detection of coded markers

The essential aspect of localization based on detection of coded markers is the distinct recognition of coded markers by image processing algorithms. Every suitable image-providing sensor in the vehicle can be used as an image data source. Depending on the vehicle's sensor set, there can be other types of on-board sensors to detect coded markers.

These assumptions are the basis for the creation of a marker plan for parking facilities.

D.2.3 Illuminance conditions

Due to the use of image-providing sensors, the illuminance conditions of the parking facility have to be taken into account when creating a marker layout. In this case, the application is the localization in or around parking facilities, for which there are two distinct types. One type is parking facilities consisting of several levels above ground, and the other type are underground facilities. The essential difference for marker recognition for these types is the illumination. The above-ground facilities allow natural light to enter, but in basement garages or underground garages there is only artificial illumination.

Lighting conditions and the position of the markers have a great impact on the quality and robustness of the detection algorithm. Natural light, synthetic illumination, back light, headlights, reflections, flickering, and other aspects of lighting in the parking facilities are expected to meet certain conditions. For example, strong glare from the sun could blind the cameras in open-air scenarios, which can make it difficult to recognize objects in these situations. Service providers or facility managers are advised to take this into account by employing measures such as installing shades, specific light frequencies, spotlights on markers, suitable wall colours to increase contrast and varying marker positions avoiding direct illumination.

D.2.4 Digital maps

The information about the position and orientation of the markers in a parking facility is recorded in a digital map. The marker positions and orientations are stored in a local coordinate system (LCS) for a facility. Additionally, they have an attribute representing their coded marker ID.

D.3 Installation of coded markers in a parking facility

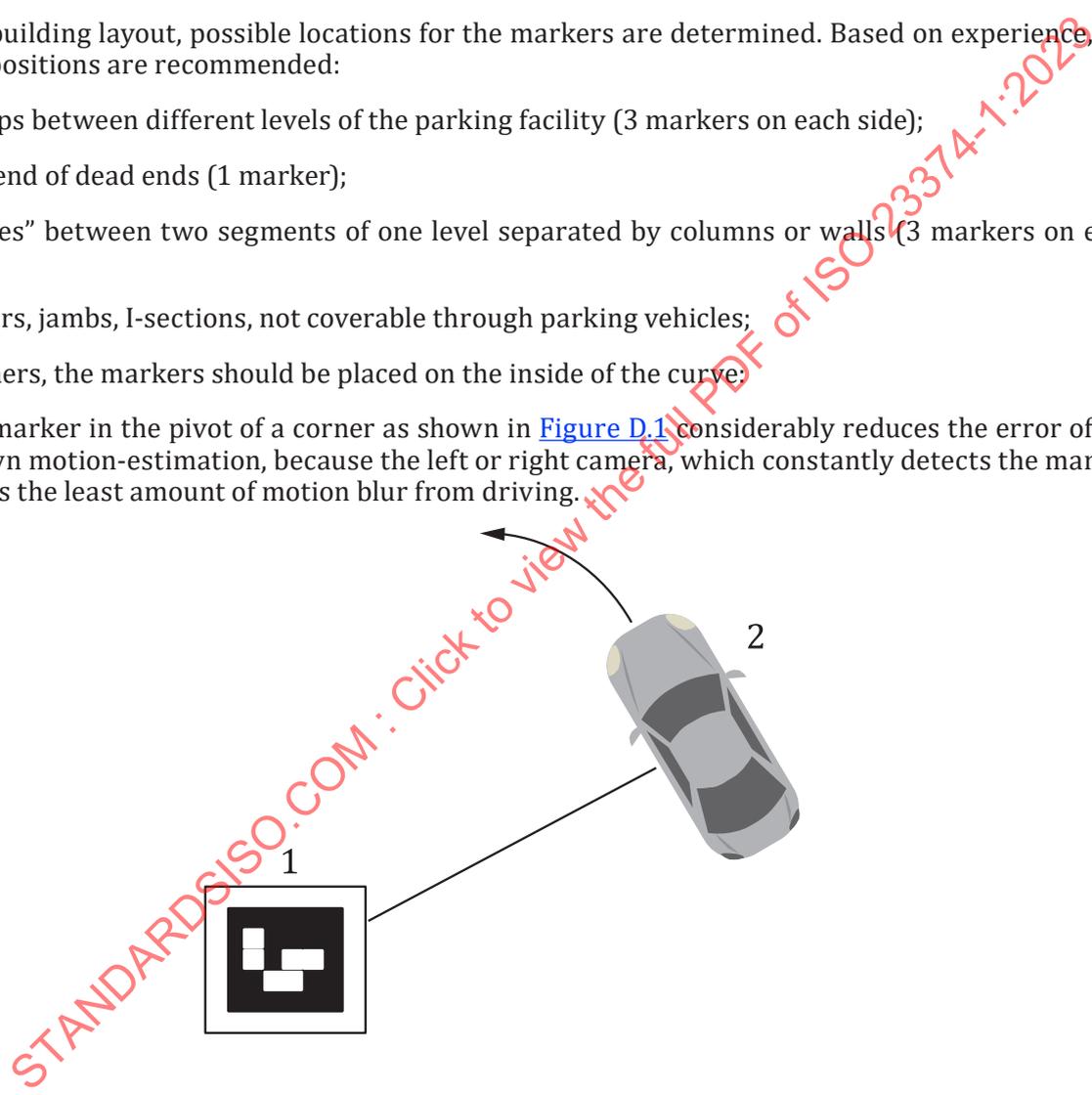
D.3.1 General

The following subclause describes how to install coded markers in a parking facility. The examples explain how requirements can be derived from the knowledge of the marker concept and the possible vehicle paths. At first, a blueprint of the basement garage, the parking lot, or the car park (in the following summarized with car park) is used as a base material for developing a marker layout.

D.3.2 Defining the number and general positions of the markers

Using the building layout, possible locations for the markers are determined. Based on experience, the following positions are recommended:

- at ramps between different levels of the parking facility (3 markers on each side);
- at the end of dead ends (1 marker);
- at “gates” between two segments of one level separated by columns or walls (3 markers on each side);
- at pillars, jambs, I-sections, not coverable through parking vehicles;
- at corners, the markers should be placed on the inside of the curve:
 - a marker in the pivot of a corner as shown in [Figure D.1](#) considerably reduces the error of the own motion-estimation, because the left or right camera, which constantly detects the marker, has the least amount of motion blur from driving.



Key

- 1 marker
- 2 subject vehicle

Figure D.1 — Marker in the centre of a curve

- at the ceiling above the drive path facing traffic directions (1 marker every 3 to 4 parking spots in both directions):
 - a high density of ceiling markers has been proven to be the most stable design. But this requires a suitable ceiling construction on which to mount the markers. Furthermore, attention needs to be given to the maximum driving height. Depending on the ceiling construction, it is sometimes necessary to take smaller marker sizes into account;

- to further enhance the localization quality, an alternate positioning of the markers at the ceiling is recommended to increase the number of visible markers while travelling. See [Figure D.2](#) for an example of the use of coded markers on ceiling structures.



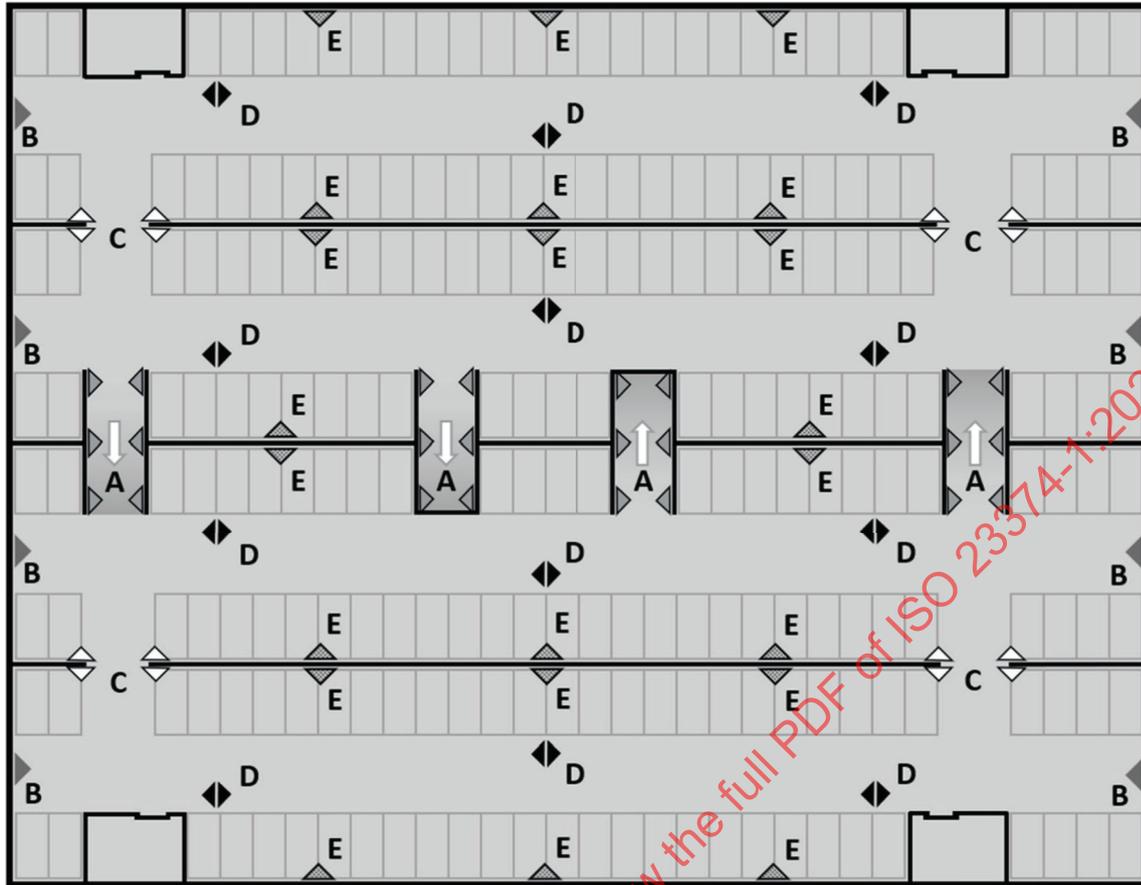
Figure D.2 — Example of the use of coded markers on ceiling structures

- on the wall behind parking spots:
 - markers behind parking spots have a high probability of being covered by parking cars. If possible, the markers should be mounted between two parking spots to enhance the visibility of the marker for at least these two parking spots. In general, these mounting positions are only recommended if other spots are not suitable for the specific facility.

D.3.3 Example

Gathering all information, a marker layout concept needs to be developed including all marker positions. This plan is the base for the following steps, e.g. installation of markers.

[Figure D.3](#) shows an example of a concept plan for a parking facility. The density of markers is not intended as a general guideline since it takes the specific facility layout into account.



Key

- A markers on ramps between different levels
- B marker at the end of dead ends
- C markers at gates / corners between two sections of one parking level
- D ceiling markers above the drive path
- E additional markers on the wall behind parking spots

Figure D.3 — Example of a marker concept in a parking facility

D.4 Localization with anonymous markers

D.4.1 General

With the given set of 255 unique markers, only a limited area of a parking facility can be fitted with localization markers. To adapt the concept to larger car parks, the concept of anonymous markers has been developed.

D.4.2 Use of anonymous and unique IDs

The anonymous marker concept subdivides the given set of 255 unique marker IDs into "unique IDs" (1-250) and "anonymous IDs" (251-255) for which the designations refer to the type of the association.

Detected markers with a unique ID trigger a conventional association at which the detected ID is used to search for a distinct marker in the digital map.

The anonymous IDs are used multiple times. These IDs trigger an anonymous association, which means that in the case of a detection marker with a similar position as detected is searched in the digital map.

The different anonymous IDs (251-255) are intended to be used for creating recognizable constellations between two or more markers to further enhance the localization quality.

Alternatively, a different, ID-less design for anonymous markers may be employed (see [Clause C.3](#)).

D.4.3 Limitations of anonymous markers

In general, the localization is capable of comparing the position of a detected marker in the digital map based on its physical proximity to the current vehicle position to determine the current positioning error. But this requires a sufficiently accurate vehicle position and orientation. The problem is thus that a set of unique markers can be necessary to initialize the vehicle position in the first place. To address this, a set of unique markers should be placed at the initialization areas.

D.4.4 Arrangement in the parking facility

To further enhance the anonymous marker concept, the parking facility can be divided into different segments (e.g. facility with 9 different sections named 0b, 1a, 1b, 2a, etc.). Every segment is fitted with a different pair of anonymous IDs. Neighboring segments are assigned with completely different ID pairs, so the localization algorithm can determine the change from one segment to another only by detecting the anonymous marker IDs. An example of this concept is shown in [Figure D.4](#).

0b	253	254
1a	251	255
1b	252	253
2a	254	255
2b	251	253
3a	252	254
3b	253	255
4a	251	254
4b	252	255

Figure D.4 — Distribution of the ID pairs in the different areas of the car park

An arrangement example for the anonymous marker concept is as follows.

- On the ceiling above the drive path, the same anonymous ID pairs are used for every driving direction.
- Exits receive one unique marker.
- Transitions between two areas receive two unique markers.
- At the end of dead ends, one unique marker is placed.
- At entrances, six unique markers are placed for initialization of localization.