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**Road vehicles — Partial driving
automation — Technical
characteristics of conditional hands-
free driving systems**

*Véhicules routiers — Automatisation partielle de la conduite —
Caractéristiques techniques des systèmes de conduite mains-libres
conditionnels*

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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This document was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 33, *Vehicle dynamics, chassis components and driving automation systems testing*.

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

This document can be used as a system level standard by other standards, which extend the combination of ACC according to ISO 15622 and PADS according to ISO 21717 with additional requirements motivated by customer use-cases and by safety to a more detailed standard for a higher level of functionality which will include the hands-free use case in certain conditions.

The main functionality of a "L2 hands-free system" is to control and limit the vehicle behaviour for longitudinal and lateral control, as it is described in ISO 15622 and ISO 21717, with respect to the performance, the intended ODD and the driver's capabilities. Together with an appropriate driver monitoring, which is typically realized with a driver monitoring camera and in addition a hands-on/off detection regarding to the steering wheel, it is possible for a system to operate while the driver can take the hands away from the steering without losing the ability and the responsibility to control the DDT.

This document contains the basic control strategy, basic driver interface elements and a minimum set of requirements for a L2 hands-free system. This document is applicable for, but not limited to, passenger cars. It is not applicable to automated driving systems of Level 3 according to ISO/SAE PAS 22736 or higher.

While a lane change functionality is not specified in this document, it is explicitly considered.

Regional regulation, e.g. UN/ECE R79, can limit the applicability of parts of this document.

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Road vehicles — Partial driving automation — Technical characteristics of conditional hands-free driving systems

1 Scope

This document provides technical characteristics of partial driving automation system according to ISO/SAE PAS 22736 and associated control strategies enabling hands-free driving.

These technical characteristics, together with an appropriate operational design domain enable the proper usage of such partial driving automation systems which is supervised by drivers.

This document does not address performance limits, verification and validation of such systems.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions 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

ODD

operational design domain

operating conditions under which the driving automation system is specifically designed to function, including, but not limited to, environmental, geographical, and time-of-day restrictions, and/or the requisite presence or absence of certain traffic or roadway characteristics

[SOURCE: ISO/SAE PAS 22736:2021, 3.21, modified —The notes to entry and examples have been removed.]

3.2

EOR

eyes-on request

request by the L2 hands-free system to the driver to monitor the traffic situation

3.3

HOW

hands-on warning

warning by the L2 hands-free system to the driver to *direct control* (3.12) the vehicle, at least by lateral steering control of the vehicle

Note 1 to entry: An HOW could be represented by a yellow warning signal accompanied by an acoustic warning.

3.4

HOA

hands-on alert

alert by the L2 hands-free system to the driver to *direct control* (3.12) the vehicle immediately, at least by lateral steering control of the vehicle

Note 1 to entry: A HOA could be represented by a red warning signal accompanied by an acoustic warning.

3.5

DMS

driver-monitoring system

system that detects the presence of a driver, assesses the driver's attention towards the traffic and assesses hands-on/off detection on steering wheel

Note 1 to entry: One part of a driver-monitoring system is typically a *driver-monitoring camera* (3.6) and/or other suitable means, e.g. capacitive hands-on/off detection.

3.6

DMC

driver-monitoring camera

camera as part of the *driver-monitoring system* (3.5) which can determine the driver's attention towards the traffic

3.7

driver information and warning system

system that informs the driver about the system status and warns the driver when actions are required by the driver

EXAMPLE *Eyes-on request* (3.2), *hands-on warning* (3.3).

3.8

override

action by the driver to *direct control* (3.12) of lateral and/or longitudinal motion of the vehicle which deactivates the L2 hands-free system

Note 1 to entry: Override is a possibility to deactivate the L2 hands-free system.

3.9

override

direct control (3.12) of lateral and/or longitudinal motion of the vehicle within a defined threshold without deactivation of the L2 hands-free system

3.10

hands-free

system condition under which the driver is permitted to remove his hands from the steering wheel

Note 1 to entry: Part of the system condition is that the vehicle is in a specified *operational design domain* (3.1), the driver monitors the traffic situation and system behaviour while the system monitors the driver.

3.11

hands-on

condition of the driver to hold the steering wheel

Note 1 to entry: During "L2 hands-on driving mode", the driver directly controls the vehicle either with or without support by a "L2 hands-free system" or a "L2 hands-on system".

3.12 direct control

control of the vehicle by the driver by holding or moving the steering wheel or using brake or driving pedal

Note 1 to entry: Within this document the acceleration is always positive and the negative acceleration is called deceleration.

3.13 DDT

dynamic driving task
control and execution of longitudinal and lateral movements of the vehicle

3.14 mode

behaviour of the driver in interaction with the system which depends on system states

EXAMPLE In an L2 hands-on driving mode the driver's hands are on the steering wheel, while the system can either be in L2 hands-on state or in L2 hands-free state with the corresponding technical requirements.

Note 1 to entry: The mode may differ from the *state* (3.15) of the system.

3.15 state

execution of implemented requirements depending on system and environmental conditions

4 Functionality

4.1 Overall system context

This document focus on requirements of the "L2 hands-free state" with the corresponding transitions as shown in Figure 1. The other states beside "lateral only" are briefly described only for completeness in this clause and those are defined in ISO 15622 and ISO 21717.

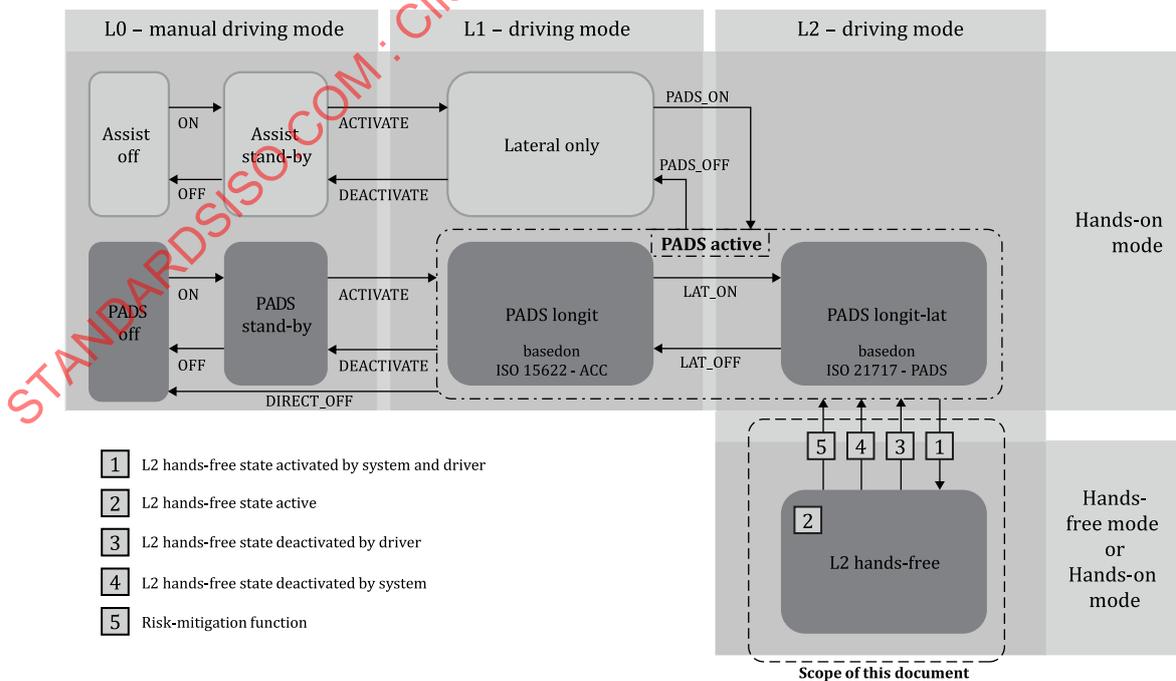


Figure 1 — L2 hands-free system modes, states and transitions in interaction with ACC (ISO 15622), PADS (ISO 21717) and lateral only

In this document the overall functionality of an "L2 hands-free system" is represented by an overall system-state-diagram with states and transitions. Therefore, it is possible to describe an L2 hands-free system with function modes from a customer perspective and with states and transition from a technical point of view. Functionality-like features or subfeatures can be distributed via several or other states.

Transitions will describe the trigger conditions which are needed to leave or to enter a state.

State "PADS off" (ISO 21717:2018, 6.1.1):

- in the state "PADS off" there is no action performed;
- the "ON" transition from state "PADS off" to state "PADS stand-by" can be performed by the driver or automatically, e.g. after the ignition is switched on.

State "PADS stand-by" (ISO 21717:2018, 6.1.2):

- in the state "PADS stand-by" the system is ready to be activated while the driver is performing the DDT manually;
- the transition "ACTIVATE" from "PADS stand-by" to "PADS active" can be initiated by the driver. The transition "ACTIVATE" could lead to "PADS longitudinal" or to "PADS longitudinal lateral" state as a part of the "L2 hands-on driving mode". A possible transition to "lateral only" is not described in any ISO standard yet;
- a transition to activate "L2 hands-free state" could be initiated automatically or by the driver when the conditions for the option for "L2 hands-free driving mode" are fulfilled.;
- the transition "OFF" from "PADS stand-by" to "PADS off" can be performed by the driver or automatically, e.g. after the ignition is switched off or a system failure has occurred.

State "lateral only":

- in "lateral only" the system does not perform accelerating or decelerating actions. This state is not described in any ISO standards, it is not used in context of this document;
- if the driver initiated all of the selected activation criteria for long-lateral, the system can perform the transition lateral state to PADS longitudinal-lateral state.

State "PADS active" - (L2 hands-on mode) (ISO 21717:2018, 6.1.3):

- in both substates, "longitudinal-lateral" and "longitudinal", of the "PADS active" state the system provides speed and distance control in accordance with ISO 15622. Therefore, longitudinal control is always active in "PADS active" state as long as the driver does not intervene;
- in both substates, "longitudinal-lateral" and "longitudinal", of the "PADS active" state the system evaluates the conditions for lateral control;
- depending on the substates, "longitudinal-lateral" and "longitudinal", the system within "PADS active" evaluates the activation criteria for lateral control or lat-long control which are typically the related ODD, speed, lane boundaries of the lane and/or relative distance to forward vehicles and the drivers vehicle control;
- under certain driving conditions (ODD, driver, vehicle, monitoring systems active) it is possible to take the hands off from steering wheel and switch to "hands-free" state which is described in more detail in [Clause 4](#);
- "PADS active" in both substates could be left to "PADS-off" or "PADS stand by" by "inactive" or "direct-off" due to the driver's action, for example, brake, or automatically for instance after a system failure has occurred.

State "PADS active" with "longitudinal" state as a substate (L2-hands-on-mode) (ISO 21717:2018, 6.1.4):

- in "longitudinal state" (ACC) the system performs longitudinal control with or without vehicle in front from standstill to a defined vehicle maximum speed;
- if all criteria for lateral control are met the system can perform the transition "LAT_ON" to PADS longitudinal-lateral state, driver initiated or automatically.

State "PADS active" with longitudinal-lateral state as a substate (L2 hands-on mode) (ISO 21717:2018, 6.1.5):

- in PADS longitudinal-lateral state the system is performing steering actions to influence the lateral movement of the subject vehicle with the intention to keep the vehicle within the lane while longitudinal control is already active as described before;
- in PADS longitudinal-lateral state the system evaluates the deactivation criteria for lateral control. If certain deactivation criteria for lateral control is fulfilled the system shall perform the transition "LAT_OFF" to PADS "longitudinal state".

State "L2 hands-free state active":

- in "L2 hands-free state active" state the system performs as described in 4.3. This includes the basic functionality for the control-loop, the possibility for driver intervention and the subsystems for "driver monitoring", "ODD monitoring", "driver information and warning";
- the conditions, which need to be fulfilled to reach or leave "L2 hands-free state", will be described in the subclauses:
 - 4.4.1 transition: "manual-driving mode" or "L1-driving mode" or "PADS active-driving mode" to "L2 hands-free state";
 - 4.4.2 transition: leaving "L2 hands-free state" due to drivers' intervention;
 - 4.4.3 transition: leaving "L2 hands-free state" due to system intervention;
 - 4.4.4 transition: leaving "L2 hands-free state" due to risk-mitigation.

4.2 General requirements

The following requirements are applicable for "L2 hands-free system":

- a) to ensure that the driver is supervising the vehicle and can perform the DDT, a DMS shall monitor the driver's presence and attentiveness;
- b) the intended ODD, for example, motorway, shall be defined based on the performance of the vehicle dynamics control and drivers' capabilities in L2 hands-free driving mode:
 - active-safety functions can support L2 hands-free driving mode, e.g. pedestrian detection;
 - the selection of the intended ODD depends typically on street curvature, driving speed, driver's capabilities and the implemented system performance to control vehicle by the driver also in case of failures or unwanted performance.
- c) the driver-monitoring system shall be active within the "L2 hands-free driving state";
- d) the ODD-monitoring system shall be active within the "L2 hands-free driving state";
- e) the driver information and warning system shall inform the driver about the driving mode and if necessary, shall request eyes on road, warn or alert the driver to take direct control;

NOTE Reasons for information, warning or alerts are:

- information on the current driving mode;
 - information on the availability of driving modes;
 - request take eyes on;
 - warning or alert due to system and safety integrity, or;
 - warning or alert due to driver misuse of the system.
- f) the risk-mitigation function shall be operational while L2 hands-free driving mode.

4.3 State: L2 hands-free

4.3.1 Control loop

The control loop of the "L2 hands-free state" shall:

- a) control the longitudinal and lateral motion;
- b) keep the vehicle sufficiently centred in the area of roadway that a vehicle is expected to travel along in the absence of any obstruction without the driver's desire to change the path of travel, for example, lane change. In addition, this requirement should not prohibit exceptions in specific situations, e.g. low-speed emergency corridor where crossing lane marking could be possible, a safety distance to a truck while overtaking where lane marking crossing is not planned;
- c) adapt the longitudinal control to keep the vehicle dynamics within the ODD boundaries, for example, adapt speed to curvature radius;
- d) limit the longitudinal and lateral control considering the related ODD.

4.3.2 Possibility for the driver to deactivate, overrule and override the L2 hands-free state

- a) The driver's wish to deactivate, overrule and override shall be executed within the ODD. This includes at least all of the following:
 - 1) the driver shall be able to deactivate the L2 hands-free state by a deliberate action, e.g. on/off button;

NOTE 1 This can be the same button which also activates or deactivates PADS.
 - 2) the driver's input to accelerate the vehicle shall override the L2 hands-free state within the ODD;
 - 3) the driver's input to decelerate the vehicle shall override or overrule the L2 hands-free state;
 - 4) the driver's input to change the lateral motion of the vehicle shall override or overrule the L2 hands-free state.

NOTE 2 In case of deactivating the "L2 hands-free state" in the menu while driving, the lateral control can be still active. Drivers' attention is typically lower when deactivating the function in the menu than in other cases.

- b) In case of overrule of longitudinal acceleration by the driver while being in L2 hands-free mode, lateral motion control shall stay active;
- c) To allow the driver to control the vehicle at any time, longitudinal and lateral control shall be limited in accordance with drivers' capabilities.

NOTE 3 Drivers' capabilities can be assessed by controllability studies.

4.3.3 ODD monitoring

- a) The ODD monitoring in combination with the driver shall ensure that L2 hands-free state is only active within the intended ODD.
- b) The ODD shall include at least the following conditions:

- 1) road type, for example, motorway or similar road with similar conditions;
- 2) road geometries by detected track width and curve radius;

NOTE 1 The selection of valid values for track width and curve radius depends on estimated reaction time of the driver for direct control and the performance of the lateral and longitudinal control.

- 3) road properties, for example, absence of construction sites, split road conditions, upcoming traffic, toll station;
- 4) valid vehicle speed.

NOTE 2 A speed range can be a fixed range or a dynamically adjusted depending on other driving or ODD conditions.

4.3.4 Driver monitoring

- a) Driver monitoring shall be active within "L2 hands-free state".
- b) Driver monitoring shall evaluate the:
 - 1) driver presence on driver's seat;
 - 2) visual attentiveness status with respect to driver monitoring the traffic sufficiently, tolerating other driving related tasks than monitoring the traffic for a certain time to ensure that the driver stays mentally active;
 - 3) hands-on mode and hands-free mode of the driver;
 - 4) longitudinal control inputs of the driver;
 - 5) lateral control inputs of the driver.

4.3.5 Driver information and warning

- a) If the "L2 hands-free state" is available, the driver should be informed about the option for activation.
- b) The "L2 hands-free mode" shall be perceptible for the driver.
- c) Requests shall be perceptible for the driver (EOR).
- d) Warnings shall be perceptible for the driver (HOW).
- e) Alerts shall be perceptible for the driver and have characteristics to emphasize the urgency (HOA).
- f) Active risk-mitigation shall be perceptible for the driver also if the driver is inattentive.
- g) The driver information system shall instruct the driver unambiguously.

4.4 Transitions

4.4.1 Enter "L2 hands-free state" from "manual-driving mode", "L1-driving mode" or "PADS active-driving mode"

The "L2 hands-free driving mode" shall only be activated if "L2 hands-free state" is active.

The "L2 hands-free state" shall only be activated if the following conditions are fulfilled, independent of if the driver has their hands on the steering wheel or not.

- a) The vehicle shall drive sufficiently in the middle of the lane.

NOTE 1 In low-speed driving higher deviations can be tolerated.

NOTE 2 This can be managed manually by the driver or by an active lateral and/or longitudinal control according to

- b) The DMS shall confirm that the driver is monitoring the traffic, according to [5.1](#).
- c) The ODD monitoring-system shall confirm a valid intended ODD, according to [5.3](#).

An activation from manual driving is permitted. After activation from manual driving all L2 hands-free state conditions shall be met.

The availability for activation of the L2 hands-free mode may be visible to the driver via the information and warning system according to [5.2](#) if a dedicated button is part of the L2 hands-free system.

If there is no dedicated button for L2 hands-free mode within the system, the availability for a possible activation of that mode shall be displayed to the driver by the information and warning system according to [5.2](#).

NOTE 3 For final activation of the "L2 hands-free driving mode" the driver takes off the hands from the steering wheel.

4.4.2 Leaving "L2 hands-free state" due to drivers' intervention

The driver shall be able to deactivate including by overrule the "L2 hands-free state" at any time at least with one of the following trigger conditions:

- operating the brake pedal;
- operating the steering wheel;
- holding the steering wheel;
- operating the element for deactivation, for example, button, voice or gesture control if available;
- disabling the "L2 hands-free driving system" in a selection menu if available.

NOTE Operating driving pedal can be used as override but can also be used as an overrule at ODD limits.

After leaving the "L2 hands-free state" the lateral control should still be active if no direct control is detected by DMS.

Leaving the "L2 hands-free state" shall be informed by the driver information and warning system [4.3.5](#).

4.4.3 Leaving "L2 hands-free state" due to system intervention

The system shall leave the "L2 hands-free state" if one or more of the trigger conditions disables the "L2 hands-free state":

- a) DMS is unavailable (see [5.1](#));

- b) driver attention cannot be ensured after EOR (see [5.1](#));
- c) ODD-monitoring system is unavailable;
- d) ODD monitoring indicates imminent violation of ODD criteria;
- e) safety or system integrity is considered insufficient, for example, if one or more of the underlying systems cannot be assured (steering system, braking system, sensor-perception).

While leaving the "L2 hands-free state" the transitions shall:

- f) be perceptible to the driver by suitable means, for example, optical, haptic acoustic measures;
- g) have a cooperative steering behaviour.

After leaving the "L2 hands-free state" the lateral control should still be active within the system boundaries.

NOTE Depending on the trigger condition, leaving the "L2 hands-free state" can lead to any hands-on driving mode.

Leaving the "L2 hands-free state" shall be informed by the driver information and warning system [4.3.5](#).

4.4.4 Leaving "L2 hands-free state" due to risk-mitigation

If the driver is assessed as unavailable the risk-mitigation shall be executed automatically.

The risk mitigation shall bring the vehicle to a speed lower than 10 km/h or to a stop within the system boundaries.

5 Technical characteristics of "L2 hands-free subsystems"

5.1 Driver-monitoring system

The DMS shall contain an appropriate combination of the following methods for the detection of driver presence on driver's seat:

- DMC being able to detect driver on seat;
- seatbelt status;
- seat occupancy mat.

To derive the visual attentiveness status the DMS shall contain a DMC.

The DMC shall include:

- detection of the head posture;
- thresholds for distraction, for example, eyes gaze side window, eyes gaze to HMI;
- detection of driver's eyes closure to ensure that the driver does not close eyes for a defined period of time.

If an L2 hands-free system allows driving at higher speeds, for example, above traffic-jam speed, the visual attentiveness status of the DMS shall contain detection of driver's eyes gaze, including the corresponding time.

Additionally, in higher speed the visual attentiveness status should include drowsiness recognition.

The DMS shall contain detection of hands-on mode (direct steering control) and hands-free mode of the driver by using, for example:

- hands on steering wheel sensor, e.g. capacitive sensors on the steering wheel;
- DMC being able to detect hands-on state on the steering wheel;
- torque on the steering wheel.

The DMS shall contain detection of longitudinal control inputs of the driver by evaluating brake pedal and accelerator pedal.

The DMS shall contain detection of lateral control inputs of the driver by evaluating torque on steering wheel.

5.2 Driver information and warning system

A driver information and warning system is needed to inform the driver and to keep him or her in the dynamic driving task. Without any reaction by the driver the vehicle will come to standstill or a speed below 10 km/h according to 5.4. The technical requirements for the driver information and warning including alerts will be described in this subclause.

- a) The system shall be able to inform the driver about the status of the L2 hands-free state.
- b) The system shall trigger/perform an EOR depending on the visual attentiveness status of the driver.
 - 1) Therefore, the system shall perform a perceivable request to the driver to follow the traffic flow by:
 - i) visual information and acoustic information; or
 - ii) visual information and visual request; or
 - iii) visual information and other adequate measures.
- c) The system should trigger an HOW, if any limit of a condition for "L2 hands-free state active" is expected to be reached or the driver does not comply after an EOR.
 - 1) Therefore, the system should perform a perceivable warning to the driver to direct control the steering wheel by visual warning.

NOTE 1 Acoustic and haptic warning can be additionally used.

- d) The system shall trigger an HOA if the driver does not comply after an HOW, or an EOR if no HOW is implemented or the limits of the conditions for "L2-hands-free-state-active" are reached.
 - 1) Therefore, the system shall perform a perceivable alert to the driver to take direct control of the vehicle by visual alert and acoustic alert.

NOTE 2 Haptic alerts can be additionally used.

An example of a possible warning and alert procedure can be found in [Annex A](#).

5.3 ODD-monitoring system

The ODD-monitoring system shall:

- a) provide the information for the "L2 hands-free system" if the vehicle is in the intended ODD;
- b) contain a geo-positioning subsystem, which is continuously determining the geographic position of the vehicle.

The ODD-monitoring system should either contain a lane-level detection while the L2 hands-free state is active or provide the information to deactivate the L2 hands-free state in a timely manner to avoid situations where a lane-level detection is necessary to ensure following the intended lane, e.g. lane splits or lane ends.

NOTE A lane-level detection determines the actual lane the vehicle is driving in.

5.4 Risk-mitigation system

The risk-mitigation system shall ensure that, while within the system boundaries, the vehicle does not enter a state of unacceptable risk if the driver fails to directly control when requested by the system. In this case the system will mitigate the risk without direct control of the driver.

- a) If the driver has no direct control after a defined time since an HOA was started, the risk mitigation system shall transfer the vehicle to a state of minimum risk, while the alert is still active.

NOTE 1 Such risk-mitigation systems are common for minimizing the risk, if incapacitations by drivers are detected, for example, due to medical issues.

- b) The risk-mitigation system shall perform longitudinal and lateral control of the vehicle.
- c) The risk-mitigation system shall ensure that the vehicle stays inside a defined driving corridor, which is not leading to an increased risk during the ongoing operation.

NOTE 2 The driving corridor is typically restricted to the ego lane. The vehicle can be stopped or slowed down in the current lane of travel or in another target stop area, e.g. emergency lane.

- d) The risk-mitigation system shall reduce the velocity of the vehicle in a manner that decreases the risk of a severe collision by applying a controllable deceleration.

NOTE 3 The deceleration is considered controllable if it does not lead to an unacceptable risk of a running-up accident by following traffic participants.

- e) The risk-mitigation system should transition the vehicle to a standstill or to speed lower than 10 km/h.
- f) If the vehicle will activate the risk mitigation system, the hazard lights shall be activated.
- g) While the risk-mitigation system is active, the driver shall be able to overrule the risk-mitigation-system above a defined threshold.

NOTE 4 Thresholds in steering systems can be a torque value or the time holding steering wheel.

- h) The risk-mitigation system may send an emergency call to support in providing the fastest possible medical assistance on site after the state of minimum risk is reached.