TECHNICAL SPECIFICATION

# ISO/TS 23792-1

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# Intelligent transport systems — Motorway chauffeur systems (MCS) —

## Part 1: Framework and general requirements

*Systèmes de transport intelligents — Systèmes de conduite automatisée sur voie à chaussée séparée (MCS) —*

*Partie 1: Cadre et exigences générales*



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# Foreword

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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

An automated driving system (ADS) needs to be designed with the capability to cope with various conditions, such as the driving environment, behaviour of other vehicles in the surroundings, traffic regulations, etc.

In addition, an ADS designed to operate on motorways can encounter various situations such as merging into the main lane of traffic, adjusting the speed according to congested or freely flowing traffic, overtaking other vehicles, or changing lanes when approaching an exit/lane closure.

For Level 3 automated driving, the ADS issues a request to the fallback-ready user (FRU) to take over driving tasks when it cannot respond to certain conditions/situations.

The ISO 23792 series identifies the performance requirements for an ADS based on its capability to respond to certain conditions and situations. The requirements are derived in order to reliably transfer the control between the human driver and ADS, and for safe operation by the ADS.

The ISO 23792 series focuses on the system functionalities, under the assumption that the FRU is available and responsive to system requests to take over driving tasks.

# Intelligent transport systems — Motorway chauffeur systems (MCS) —

# Part 1: Framework and general requirements

## 1 Scope

Motorway chauffeur systems (MCS) perform Level 3 automated driving[1] on limited access motorways with the presence of a fallback-ready user (FRU). MCS can be implemented in various forms capable of responding to different driving scenarios. This document describes a framework of MCS including system characteristics, system states/transition conditions and system functions.

MCS are equipped with a basic set of functionalities to perform in-lane operation and can also be equipped with additional functionalities such as lane changing.

This document specifies requirements of the basic set of functionalities and test procedures to verify these requirements. The requirements include vehicle operation to perform the entire dynamic driving task (DDT)[1] within the current lane of travel, to issue a request to intervene (RTI)[1] before disengaging, and to extend operation and temporarily continue to perform the DDT after issuing an RTI.

This document describes one specific form of system engagement. Other forms are possible. These other system engagement forms, especially those provided in combination with other driving automation system features, are not within the scope of this document.

Requirements and test procedures for the additional functionalities are provided in other parts of the ISO 23792 series.

Means related to setting a destination and selecting a route to reach the destination are not within the scope of this document. This document applies to MCS installed in light vehicles.[2]



## 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 15622:2018, *Intelligent transport systems — Adaptive cruise control systems — Performance requirements and test procedures*

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

## 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**
**subject vehicle**
vehicle equipped with a motorway chauffeur system (MCS) feature

**3.2**
**motorway**
road specially designed and built for motorized traffic that does not serve properties bordering on it, and which;

— is provided, except at special points or temporarily, with separate carriageways for the two directions of traffic, separated from each other either by a dividing strip not intended for traffic or, exceptionally, by other means;

— does not cross at level with any road, railway or tramway track, or footpath;

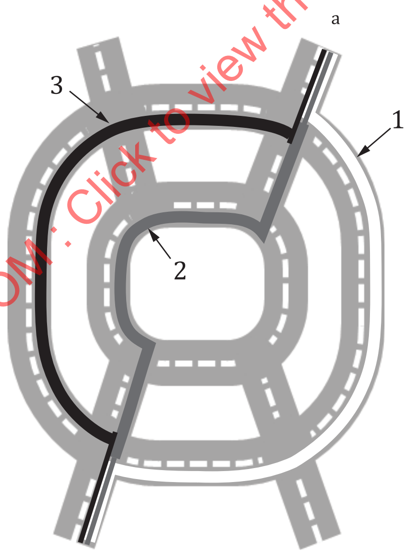
— is specifically sign-posted as a motorway;

— is prohibited for access from non-motorized road users, such as pedestrians and cyclists.

Note 1 to entry: Roads which satisfy the defined conditions above may be referred to using different terms in different countries.

**3.3**
**route**
planned sequence of waypoints to reach a destination

Note 1 to entry: See Figure 1:




**Key**

1 route A

2 route B

3 route C

a To destination.

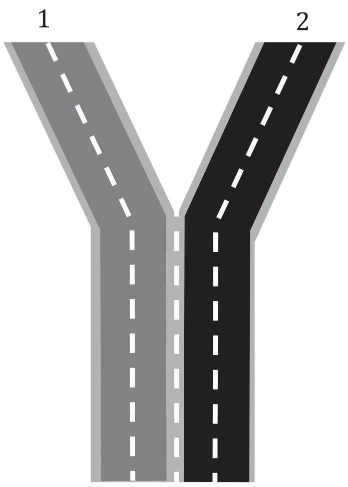
**Figure 1 — Route**



**3.4**
**path**
combination of one or more neighbouring lanes in the same direction of travel along a given route

Note 1 to entry: See Figure 2:




**Key**

1 path A

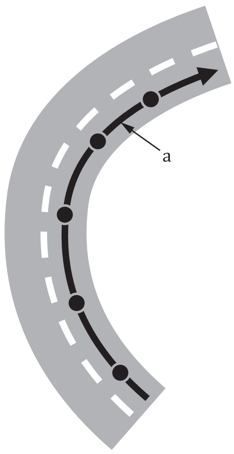
2 path B

**Figure 2 — Path**

**3.5**
**trajectory**
sequence of locations that define the intended motion vector of the subject vehicle (SV) used as references for vehicle motion control

Note 1 to entry: The motion vector includes longitudinal position and/or speed, also lateral position and/or the vehicle's orientation information.

Note 2 to entry: see Figure 3:




**Key**

a Trajectory.

**Figure 3 — Trajectory**

**3.6**
**vehicle motion control**
activities necessary to adjust vehicle movement continuously in real time, which include “lateral vehicle motion control” and “longitudinal vehicle motion control”

Note 1 to entry: “Lateral vehicle motion control” and “longitudinal vehicle motion control” are defined in ISO/SAE PAS 22736.

## 4 Abbreviated terms

| | |
|---|---|
| ADS | Automated driving system [1] |
| DDT | dynamic driving task [1] |
| FRU | fallback-ready user [1] |
| FV | forward vehicle |
| HMI | human machine interface |
| MCS | motorway chauffeur system |
| MRC | minimal risk condition [1] |
| MRM | minimal risk manoeuvre |
| ODD | operational design domain [1] |
| OEDR | object and event detection and response [1] |
| TTC | time to collision |
| RTI | request to intervene [1] |
| SV | subject vehicle |
| VMC | vehicle motion control |



## 5 Characteristics of MCS

### 5.1 General

This document covers a variety of implementations of MCS based on its operational design domain (ODD) (see 5.2) and functionalities (see 5.3).

The ODD definition of an MCS is considered to be design-specific for its implementation. Therefore, the requirements in this document apply to the functionalities and performance of the MCS within its prescribed ODD.

### 5.2 Operational design domain

#### 5.2.1 General

Each MCS shall have a pre-defined ODD, and the user shall be informed of the general ODD limitations (i.e. to make clear under which conditions a given MCS is capable of operating or not).

The description of an ODD shall, at minimum, include the following information unless the item does not represent a restriction for system operation.

— Roadway physical characteristics.

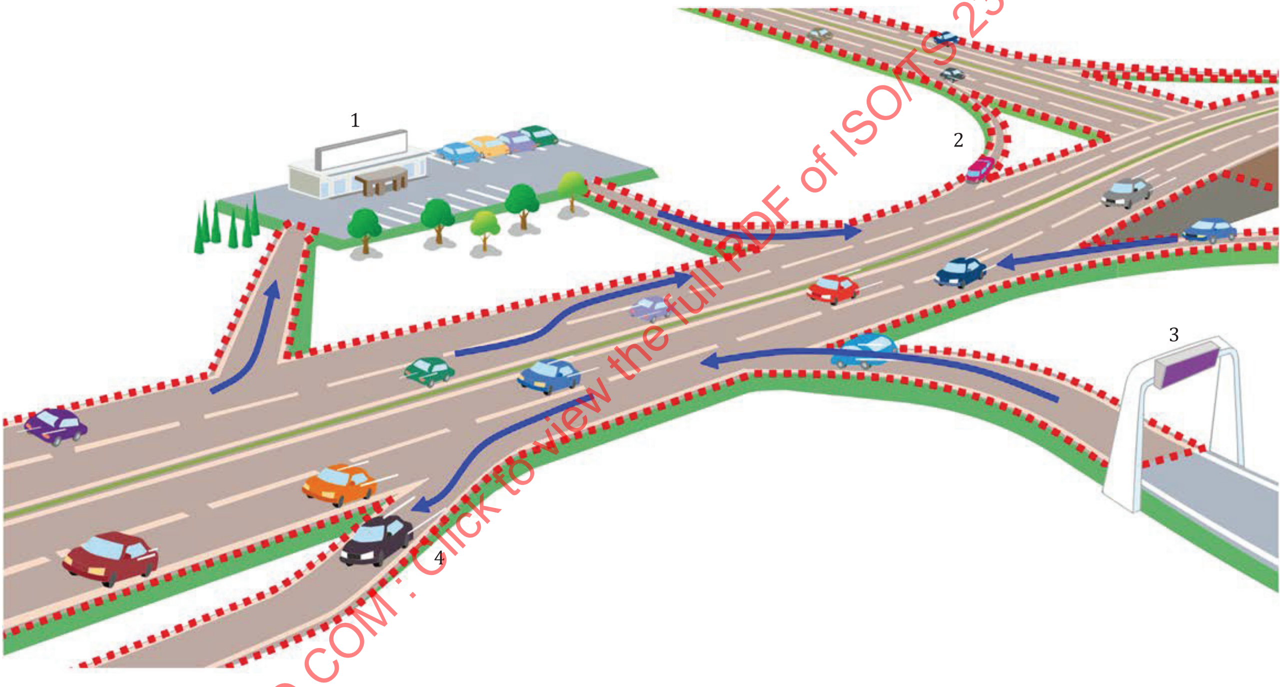
— Traffic in the surrounding environment.

— Abnormalities in roadway operational condition.

— Ambient environmental conditions.

The following subclauses provide examples of possible ways to describe the above-mentioned ODD attributes. However, such attributes are not limited to those listed below, and more details should also be added as needed. ISO 34503 provides a sample list of ODD attributes.

Figure 4 illustrates an image of the geographical ODD boundaries for an MCS capable of operating from the entrance through the exit of a motorway.




**Key**

1 service area
2 junction
3 tollgate
4 exit

example of geographical ODD of MCS

MCS may also be designed to operate within more restricted boundaries that do not include entrance and exit ramps or merging and lane changing locations

**Figure 4 — Example of geographic boundary (geofence) of an ODD**

### 5.2.2 Roadway physical characteristics

Roadway characteristics should be considered as possible ODD attributes. MCS may be designed to operate on roads with or without certain characteristics such as those mentioned below.

— Road configuration (e.g. number of lanes in each direction, existence of medians, road shoulders).

— Road structure characteristics (e.g. curvatures, slopes, undulations).

— Quality and visibility of lane markings.

— Surface characteristics of road structures (e.g. irregularity, running resistance friction coefficient, potholes).

NOTE To explain the above general roadway characteristics as part of the ODD to the user, sections of the motorway can be mentioned. For example, if the absence of a median strip to divide the carriage way is an out of ODD condition, the starting point and the end point of the section with no median strips can be considered as the geographical boundaries of the ODD.

### 5.2.3 Traffic in the surrounding environment

Existence of traffic in the surrounding environment and its motions (e.g. travelling speed, travelling direction) may be considered as a possible ODD attribute. Vehicles in the forward direction, as well as in the adjacent lanes and behind the subject vehicle (SV) may be considered as ODD attributes for an MCS to operate.

Existence of emergency vehicles (e.g. ambulance) may also be considered as a possible ODD attribute. If an MCS is not capable of responding appropriately to emergency vehicles, existence of approaching emergency vehicles should be considered as an out of ODD condition.

### 5.2.4 Abnormalities in roadway operational condition

Restrictions in roadway operational conditions, such those in the following list, should be considered as possible ODD attributes.

— Lane blockage.

— Traffic incident (e.g. crash, failed vehicle).

— Existence of road work (e.g. construction, maintenance).

### 5.2.5 Ambient environmental conditions

Characteristics related to ambient environmental conditions (including weather conditions), such as those in the following list, should be considered as possible ODD attributes.

— Sunlight (e.g. illuminance, direction).

— Temperature.

— Rain, snow, hail (e.g. precipitation impact on visibility).

— Wind (e.g. speed, direction).

— Fog (e.g. visual distance).

## 5.3 System functionalities

### 5.3.1 General

The following subclauses define the functionalities of an MCS. Each MCS shall be equipped with the basic set of functionalities (5.3.2) and may also be equipped with additional functionalities (6.3.13). Each functionality may have further detailed classifications associated with individual requirements.

### 5.3.2 Basic functionalities to realize in-lane operation

The following items are the basic set of functionalities with which all MCS shall be equipped, including those that only operate in a single lane.

— Perform the entire DDT within the current lane of travel. See Clause 7 for minimum performance requirements of the DDT.

— Continuously monitor (at minimum, the driving environment, system conditions, vehicle conditions, and driver/FRU) if the required operating conditions are satisfied. See 6.2 for the requirements on the changes in system states as the result of monitoring these items. See 6.3.2, 6.3.8, 6.3.9, and 6.3.10 for requirements on the monitoring functions.

— Inform the driver/FRU of the MCS operating state and state changes. See 6.2 for requirements related to state transitions, and 6.3.5 for status indication requirements.

— Issue an RTI when operating conditions are either detected or predicted to no longer be satisfied. See 6.3.4 for related requirements.

— While issuing an RTI, extend operation and continue to perform the DDT for a sufficient time for the FRU to respond. See 6.4 for related requirements.

— If the FRU does not respond adequately to the RTI, bring the SV to a stop. See 7.5 for related requirements.

### 5.3.3 Lane changing functionalities

In addition to the basic set of functionalities, an MCS may be equipped with additional functionalities, for example to perform a lane change during its operation. The ISO 23792 series classifies lane changes into two categories: a discretionary lane change and a mandatory lane change.

The primary difference between discretionary and mandatory lane changes are the time-criticality to perform a lane change, whereas a mandatory lane change becomes time-critical for trip continuation.

Examples of situations where a mandatory lane change can be necessary include when the appropriate lane needs to be selected to pass junctions, or the current lane of travel will end and so merging into another lane is required. For a mandatory lane change, the lane change manoeuvre shall be completed before reaching a specific location. Requirements and test procedures to verify these requirements are specified in ISO 23792-3.

Examples of situations when an MCS may perform a discretionary lane change include overtaking slower traffic or selecting a lane to prepare for a future diverging/merging scenario. For a discretionary lane change, MCS may delay the manoeuvre until the conditions for initiating the lane change are satisfied or cancel the lane change when conditions are not satisfied. Requirements and test procedures to verify these requirements are specified in Part 2 of this set of documents.

MCS may be equipped with additional functionalities other than lane changes. However, they are not defined in ISO 23792 series.

## 5.4 System limitations

Situations with performance impairing effects (see 6.4.2.5) and incapacitating effects (see 6.4.2.6) and their possible consequences should be documented.

## 5.5 Providing information to the user

Providers of an MCS shall provide the user with the necessary information regarding its usage prior to the first actual usage of the MCS, for example by actively explaining the intended usage and roles of the FRU to the user and including the information in the owner's manual. When doing so, information provided in 5.2, 5.3, and 5.4 should be considered as the basis of the information.

# 6 Operational requirements

## 6.1 Operating conditions

### 6.1.1 General

The following sub-clauses describe the basic principles of MCS engagement and disengagement. These principles serve the purpose of highlighting the specifics for a Level 3 ADS compared to other levels of automation, especially considering the interaction with the driver/FRU.

### 6.1.2 Engagement conditions

The MCS shall engage to perform the entire DDT within its prescribed ODD, only when minimum performance requirements of the DDT during normal operation specified in 7.3 can be satisfied. The MCS shall have a predefined set of engagement conditions specified in the overall system design. See 6.2.3.2 for details.

### 6.1.3 Disengagement triggering conditions

The MCS shall continue to operate for a sufficient time for the FRU to respond (see 6.2.5) before disengaging, unless specific direct disengagement conditions described in 6.1.4 are satisfied. For this reason, the MCS shall have a predefined set of disengagement triggering conditions specified in the overall system design (see 6.2.4.3) which occur within the prescribed ODD to notify the FRU of a need to disengage. The MCS should avoid trip continuation and unnecessary acceleration after detecting a disengagement-triggering condition.

Refer to 6.4 for detailed requirements related to continuation of MCS operation after encountering disengagement-triggering conditions.

### 6.1.4 Direct disengagement conditions

The MCS shall be designed to disengage in such a way that the risk of relinquishing control of the SV in active traffic, without confirming that the FRU has taken over the control (i.e. becoming a driver to perform the DDT) is minimized. See 6.3.7 for system reaction to driver FRU input.

## 6.2 State transition

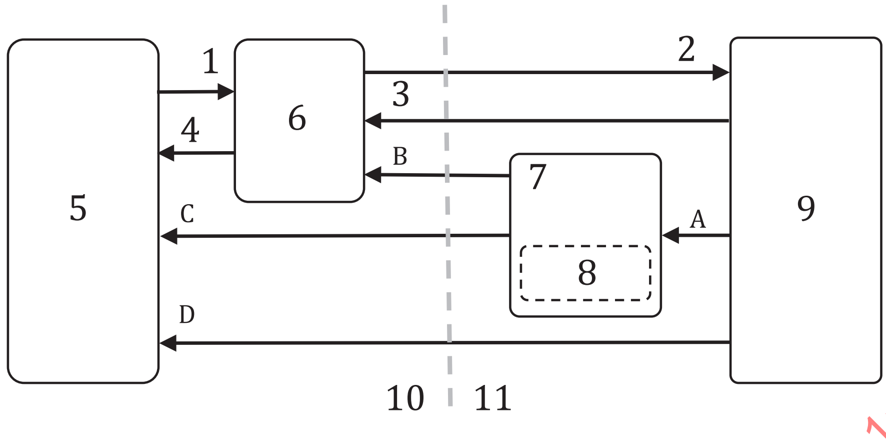
### 6.2.1 General

The MCS shall operate based on the system states and transition conditions specified in the following subclauses.

Figure 5 shows the fundamental system state transition diagram for an MCS. The following subclauses define the system condition of each state as well as the transition conditions when the system state changes. Sub-states may be added as needed. In general, all of the system states and transitions described in Figure 5 shall be indicated to the user (see 6.3.5 for requirements).






**Key**

1 MCS turned on
2 engagement conditions are satisfied
3 FRU initiated transfer of control from MCS to FRU
4 MCS turned off
5 off state
6 standby state
7 requesting fallback state
8 MRM
9 normal state
10 MCS does not perform the DDT (i.e. MCS is disengaged, user is expected to be a driver)
11 MCS performs the DDT (i.e. MCS is engaged, user is expected to be a FRU)

A disengagement triggering condition detected
B MCS requested and FRU responded transfer of control from MCS to FRU
C MCS turned off
D MCS turned off

**Figure 5 — State transition diagram**

### 6.2.2 Off state

#### 6.2.2.1 State definition

In the off state, the MCS is turned off. Therefore, the VMC function (see 6.3.3) shall be inactive. Monitoring functions (e.g. localization as described in 6.3.11) may be active in order to detect conditions that influence transitions.

#### 6.2.2.2 Transition 1 (from off state to standby state)

At least the following conditions shall be satisfied for the MCS to transition from its off state to the standby state (key element 1 of Figure 5).

— Absence of performance-impairing situations (see 6.4.2.5).

— Powertrain of the SV is activated.

— SV is approaching to or detected to be on a motorway (see 6.3.11).

### 6.2.3 Standby state

#### 6.2.3.1 State definition

In the standby state, the MCS shall determine if engagement conditions are satisfied by continuously monitoring, at a minimum, the conditions of the driving environment (see 6.3.2), system (see 6.3.10) and SV (6.3.8).

#### 6.2.3.2 Transition 2 (from standby state to normal state)

The MCS shall transition from the standby state to the normal state (key element 2 of Figure 5) when engagement conditions are satisfied. Engagement conditions shall, at minimum, include all of the following conditions.

— The driving environment satisfies the ODD.

— FRU is present within the designated driver's seat (see 6.3.8).

— The current speed of travel is within the operating speed range (see 7.2).

— Absence of performance-impairing situations (see 6.4.2.5)

— Explicit driver command for system engagement is provided through the user control interface (see 6.3.6).

The MCS should indicate when all of the engagement conditions other than the driver command are satisfied. When the MCS detects the driver command in response to this indication, MCS shall either

— immediately transition to its normal state;

— notify the driver of an unsuccessful engagement (see 6.3.5.3) due to unsatisfied engagement conditions; or

— withhold its engagement for up to 10 s when some engagement conditions are temporarily unsatisfied.

  — If all of the engagement conditions are satisfied during this 10-second period, the MCS shall immediately transition to its normal state.

  — If all of the engagement conditions are not satisfied during this 10-second period, the MCS shall indicate an unsuccessful engagement (see 6.3.5.3) and the driver command shall therefore become invalid.

  — A distinct visual display shall be provided to indicate that the MCS is withholding its engagement.

#### 6.2.3.3 Transition 4 (from standby state to off state)

The MCS shall transition from its standby state to the off state (key element 4 of Figure 5), when at minimum, any of the following conditions are detected.

— Powertrain of the SV is deactivated.

— User control interface to turn on/off MCS is turned off (see 6.3.6).

— SV is exiting or detected not to be on the motorway (see 6.3.11).

### 6.2.4 Normal state

#### 6.2.4.1 State definition

In the normal state, the MCS shall:

— perform the entire DDT (see 6.3.2 and 6.3.3) in accordance with the minimum DDT performance requirements during normal operation (see 7.3);

— detect the occurrence of disengagement-triggering conditions (see 6.1.3) and direct disengagement conditions (see 6.1.4) by continuously monitoring, at a minimum, conditions of the driving environment, FRU, MCS system and SV.

#### 6.2.4.2 Transition 3 (from normal state to standby state)

The MCS shall transition from its normal state to the standby state (key element 3 of Figure 5) when a user input that satisfies the criteria for direct disengagement (see 6.3.7) is detected.

#### 6.2.4.3 Transition A (from normal state to requesting fallback state)

The MCS shall transition from its normal state to the requesting fallback state (key element A of Figure 5), when disengagement-triggering conditions are detected. Disengagement-triggering conditions shall, at minimum, include any of the following conditions.

— Changes in the driving environment are detected such that the prescribed ODD is either no longer satisfied, or predicted to be no longer satisfied in the near future.

— Minimum performance requirements of the DDT during normal operation (7.2) are either detected to be no longer satisfied (this includes detecting occurrence of a performance impairing situation as described in 6.4.2.5), or predicted to be no longer satisfied in the near future.

— Presence of the FRU cannot be confirmed (see 6.3.7.2).

The MCS may also transition from its normal state to the requesting fallback state (key element A of Figure 5) under further conditions such as the following.

— The MCS detects a situation with either potential future effect, minor effect, or degrading effect (see 6.4.2).

— The MCS detects an FRU input that does not satisfy the criteria for direct disengagement.

— The MCS determines that the FRU is not available for performing the fallback (see 6.3.8).

#### 6.2.4.4 Transition D (from normal state to off state)

MCS shall transition from its normal state to the off state (key element D of Figure 5) when, at minimum, any of the following direct disengagement conditions are detected.

— Interface to turn on/off the MCS is manually turned off upon the SV reaching a stationary condition.

— Powertrain of the SV is deactivated upon the SV reaching a stationary condition.

— Occurrence of an incapacitating situation (see 6.4.2.6 for details). The MCS should be designed to minimize the occurrence of such forced disengagement.

### 6.2.5 Requesting fallback state

#### 6.2.5.1 State definition

In the requesting fallback state, the MCS shall:

— extend its operation and continue to perform the DDT (see 6.4) for a sufficient length of time for the FRU to perform the fallback, unless transition condition B or C is satisfied;

— be capable of bringing the SV to a complete stop in case the FRU does not respond adequately to the RTI in accordance with 7.4 or 7.5;

— continue to issue RTIs (see 6.3.4);

— detect the occurrence of disengagement-triggering conditions (see 6.1.3) and direct disengagement conditions (see 6.1.4) by continuously monitoring, at a minimum, conditions of the driving environment, FRU, MCS system, and SV.

In the requesting fallback state, MCS should, if it is so capable:

— perform a minimal risk manoevre (MRM) and reach minimum risk condition (MRC) in case the FRU does not respond adequately to the RTI.

  — The timing to start an MRM should be considered based on the criticality of the event and its effect on the system operation.

#### 6.2.5.2 Transition B (from requesting fallback state to standby state)

The following are the minimum conditions for the MCS to transition from its requesting fallback state to the standby state (key element B of Figure 5):

— a user input that satisfies the criteria for direct disengagement (see 6.3.7) is detected; and

— sufficient time for the FRU to respond has not elapsed; and

— the MCS is not performing an MRM.

#### 6.2.5.3 Transition C (from requesting fallback state to off state)

The MCS shall transition from its requesting fallback state to the off state (key element C of Figure 5) when any of the following conditions are detected.

— A user input that satisfies the criteria for direct disengagement (see 6.3.7) is detected while the MCS is performing an MRM.

— Interface to turn on/off MCS is manually turned off upon the SV reaching a stationary condition.

— Powertrain of the SV is deactivated upon the SV reaching a stationary condition.

— Occurrence of an incapacitating situation (see 6.4.2.6 for details). MCS should be designed to minimize the occurrence of such forced disengagement.

## 6.3 System functions

### 6.3.1 General

The functions of MCS are described in the following subclauses, categorized into minimum requirements, conditional requirements, and other related functions to support the basic functionalities (5.3.2) and lane-changing functionalities (5.3.3). Table 1 summarizes the functions of MCS.



**Table 1 — MCS functions**

| Functions | Basic functionalities | Lane-changing functionalities | Reference subclause |
|---|---|---|---|
| **Minimum required functions** | | | |
| OEDR | Required | Additional requirements apply | 6.3.2 |
| VMC | Required | Additional requirements apply | 6.3.3 |
| RTI generation | Required | Required | 6.3.4 |
| Status indication | Required | Additional indication recommended | 6.3.5 |
| User control interface | Required | Additional interface recommended | 6.3.6 |
| FRU input detection | Required | Required | 6.3.7 |
| MCS monitoring the FRU | Required | Required | 6.3.8 |
| SV condition monitor | Required | Required | 6.3.9 |
| MCS condition monitor | Required | Required | 6.3.10 |
| Localization | Required | Required | 6.3.11 |
| External warning generation | Required | Required | 6.3.12 |
| **Function required for route following functionalities** | | | 6.3.12 |
| Path selection | Not required | Conditionally required | 6.3.13.1 |
| **Other related functions** | | | 6.3.14 |
| MRM | Recommended | Recommended | 6.3.14.1 |
| Wireless communication | Optional | Optional | 6.3.14.2 |

### 6.3.2 Object and event detection and response (OEDR)

OEDR is a function which includes monitoring of the driving environment (i.e. detecting, recognizing, and classifying objects/events) and preparing and executing an appropriate response to such objects or events.

The MCS shall detect, at a minimum, objects such as obstacles and motorized vehicles that are in the forward path of the SV and have the potential to influence system operation. Other relevant objects to be considered are traffic signs, non-motorized road users, animals, etc.

The MCS shall detect events, at a minimum, those which could potentially affect system operation. Relevant events may include motions of other road users (e.g. a vehicle cutting in front of the SV from the adjacent lane) or changes in the driving environment (e.g. rain fall).

As the response to the results of the object and event detection, the MCS shall continuously attempt to identify possible space for the SV to travel, and either calculate a trajectory as the basis of performing VMC (6.3.3), or determine to transition to the requesting fallback state if the detection results exceed the system capabilities. This includes the capability of MCS to recognize the availability of its lane of travel. For example, roadway construction can be blocking the current lane of travel, requiring the MCS to respond adequately (e.g. change lanes to avoid the lane closure, or issue an RTI for the FRU to perform the DDT).

The required performance of OEDR will vary significantly depending on the intended functionalities (see 5.3) of a given MCS. However, the requirements of the OEDR function itself are not directly addressed within this set of documents, but are instead indirectly required by the state transition (see 6.1) and the minimum performance requirements of the DDT (see Clause 7).

### 6.3.3 Vehicle motion control (VMC)

VMC is a function by which MCS controls the longitudinal and lateral movement of the SV in order to follow the calculated trajectory.

The required performance of VMC will vary significantly depending on the equipped functionalities and capabilities of a given MCS. Detailed requirements associated with the basic system functionalities are provided in Clause 7 of this document, and performance requirements for the additional functionalities will be provided in subsequent parts of the ISO 23792 series.

Note that prompt reactions to hazardous situations (e.g. collision avoidance) are also a part of the OEDR and VMC that MCS shall perform.

### 6.3.4 Generation of request to intervene (RTI)

The RTI generation function determines the appropriate timing, the types of modalities to be used, and the level of stimulus intensity of each modality used in alerting the FRU of a need for disengagement.

RTI shall be unambiguously displayed in a way that can be promptly detected by the FRU. For this reason, RTI;

— shall use multi-modal displays:

  — either or both audible and haptic modalities shall be used in addition to visual indications;

— shall be continuously or repetitively provided while the MCS is in the requesting fallback state;

— shall be capable of providing different levels of stimulus intensity.

Stimulus intensity should vary according to the time criticality of the FRU's expected response to the situation.

— In case of a less time-critical situation, it is recommended that the stimulus intensity and combination of modalities of the RTI be escalated until the FRU performs the fallback.

— In case of a more time-critical situation (e.g. occurrence of a performance-impairing event), it is recommended that the strongest stimulus intensity and combination of modalities be used immediately.

In addition:

— visual RTI indications should appear within the FRU's field of view, for example by indicating an RTI through the infotainment display, considering that the FRU is potentially not facing towards the direction of travel;

— when using audible indications, other auditory sources provided from the SV (e.g. radios) should be suppressed.

If the SV is designed to provide infotainment (activities other than driving) to the FRU while the MCS is engaged, such infotainment (e.g. audio, video) shall be adjusted automatically (e.g. suspended, suppressed) when an RTI is issued (e.g. by indicating the RTI through the infotainment display, replacing the infotainment contents, lowering the audio volume).

### 6.3.5 Status indication

#### 6.3.5.1 General

Status indication is a function by which the MCS ensures that necessary information related to the system states and transitions is presented to the driver/FRU. Status indications shall conform to the requirements specified in the following subclauses. Table 2 summarizes the requirements in relation to the system states, and Table 3 summarizes the requirements in relation to the transitions between the states.



**Table 2 — Status indication of system state**

| System state | Requirements for visual indications | |
|---|---|---|
| Off state<br>(no system failure) | Not required by direct means | Each state shall be distinct from each other. |
| Off state<br>(system failure) | Each state shall be continuously visually displayed.<br>(refer to 6.3.4 for requirements for RTI during the requesting fallback state) | |
| Standby state | | |
| Normal state | | |
| Requesting fallback state | | |

**Table 3 — Status indications of transitions between states**

| Transition (see Figure 5) | Requirements for audible/ haptic indications |
|---|---|
| 1 (MCS turned on) | Optional |
| 2 (Engagement conditions are satisfied) | |
| 3 (Direct disengagement by FRU override) | At least audible or haptic indication required |
| 4 (MCS turned off) | Optional |
| A (Disengagement triggering condition detected) | Optional (see also 6.3.4) |
| B (Direct disengagement by FRU override) | At least audible or haptic indication required |
| C (Direct disengagement condition detected) | Either or both required, unless an incapacitating event occurs |
| D (Direct disengagement condition detected) | |

#### 6.3.5.2 Engagement conditions are satisfied

Information should be provided to the driver when the MCS engagement conditions are satisfied.

#### 6.3.5.3 Unsuccessful engagement

MCS shall indicate by visual and by either audible or haptic means that the MCS cannot be engaged (see also 6.2.3.2).

#### 6.3.5.4 MCS is engaged

— The MCS shall continuously visually display to the FRU, in a way that can be quickly and accurately recognized, that MCS is performing the entire DDT. The normal state and requesting fallback state shall have a distinct visual indicator.

— The normal state and requesting fallback state shall also be visually distinct from other MCS states and transition displays (e.g. when the system is either not performing the entire DDT or turned off).

— The normal state and requesting fallback state shall be clearly differentiated from other driving automation features, particularly level 2 features which have a high potential for confusion with MCS.

#### 6.3.5.5 When transitioning between states

State transition shall be indicated by the change in the display of the state.

Additional momentary audible or haptic notification is required upon disengagement (i.e. transitions expressed by key elements 3, B, C, and D of Figure 5).

#### 6.3.5.6 Hazardous situations

Visual combined with audible and/or haptic notifications shall be issued to the FRU if the MCS responds to hazardous situations (e.g. emergency braking/steering) or initiates an MRM.

#### 6.3.5.7 Faults and failures

The MCS shall continuously provide visual indications for system failures that have performance limiting effects and incapacitating effects.

The MCS shall provide visual indications for faults or failures that have a degrading effect, which may not necessarily be displayed continuously.

### 6.3.6 User control interface

User control interface is a function by which the MCS receives user input through, at a minimum, the following interfaces.

- Control interface to explicitly engage/disengage the MCS.
- Control interface to engage/disengage the MCS shall be directly accessible and distinct from other vehicle/ driving automation feature interfaces.
- Control interface to engage/disengage the MCS shall be combined together.
  - An engaged MCS shall continue operation when detecting input only through the user control interface while the SV is moving (see 6.3.7.1).
  - An engaged MCS may directly disengage when detecting input through the user control interface while the SV is stationary.

The following user control interfaces may also be provided.

- Interface to turn on/off the MCS (e.g. for ensuring off state).
- Interface to allow the user to set a specific operating speed (see 7.3.1).
- Interface to request a specific following time gap
- Interface to request/decline a discretionary lane change.

### 6.3.7 FRU input detection

#### 6.3.7.1 General

While the MCS is performing the entire DDT, the MCS shall detect FRU inputs through, at minimum, the steering, acceleration, and brake control interfaces of the SV (see 6.3.6).

The MCS shall determine the appropriate response to such user input under the current situation. User inputs can be intentional or unintentional, and can also result in hazardous behaviour of the SV (e.g. road departure).

The MCS shall be designed with predetermined criteria to either directly disengage (i.e. transition to standby or off state) or continue operation (i.e. maintain its current state or to transition from the normal state to requesting fallback state) based on the inputs detected through these interfaces. The threshold input levels and the combination of these inputs to use in determining direct disengagement can vary according to the situation (e.g. in relation to the lateral acceleration being induced by MCS).

The MCS shall also determine how the input influences the VMC.

Detection of a deliberate action, at a minimum through the steering interface, shall be required to disengage the MCS in order to avoid accidental or unintentional disengagement while the SV is moving. Refer to 6.3.7.2 for details.

#### 6.3.7.2 Steering interface

The MCS shall directly disengage upon detecting input(s) judged by the MCS to be an intentional request for transfer of control from MCS to the user, unless the input is predicted to result in hazardous behaviour of the SV.

FRU inputs to the steering interface judged to be intentional by the MCS shall directly perform the VMC, unless the input is predicted to result in hazardous behaviour of the SV.

Upon detecting inputs judged by MCS to be unintentional, the MCS shall continue operation and may transition to the requesting fallback-state.

This document does not define how the MCS should respond to user inputs predicted to result in a hazardous behaviour of the SV.

Different threshold values or methods of detecting user inputs may be applied when detecting combinations of inputs through the steering and other interfaces.

For example, the threshold/type to apply on the input from the steering interface for determining direct disengagement may be designed to be lower (e.g. by steering grip/touch detection) when simultaneously detecting input from the brake interface, compared to when detecting input through only the steering interface (e.g. by use of steering torque or angle detection).

#### 6.3.7.3 Acceleration interface

The MCS shall continue operation when detecting input only through the acceleration interface.

The MCS may accelerate within the operating speed range (see 7.2) while satisfying the speed determination requirement (see 7.3.1), or may deny the input and transition to the requesting fallback state.

#### 6.3.7.4 Brake interface

The MCS shall continue operation when detecting input only through the brake interface. The MCS may transition to the requesting fallback state upon detecting input only through the brake interface to prompt the user to initiate an appropriate transfer of control (i.e. to operate the steering interface).

When detecting a brake interface input sufficient to result in activation of the brake lamps of the SV, MCS shall decelerate consistently with that brake interface input while performing in-lane operation.

### 6.3.8 MCS monitoring the FRU

The MCS shall not transition from the standby state to the normal state, or maintain its normal state in the absence of an FRU. The MCS shall continuously monitor the presence of the FRU in the designated driver's seat.

— The MCS shall detect that the seat belt buckle of the designated driver's seat is unfastened.

— The MCS shall also be equipped with additional means of FRU detection (e.g. visibly detecting the presence of the FRU, weight on the driver's seat consistent with the presence of an FRU).

— The MCS shall estimate whether or not the FRU is available to perform the fallback (e.g. by detecting eye closure), and take appropriate countermeasures to resolve the situation (e.g. issue an alert, transition to the requesting fallback state) when the FRU is determined to be unavailable.



### 6.3.9 Subject vehicle condition monitor

SV condition monitor is a function by which the MCS detects, at a minimum, conditions of the SV that have an effect on the system operation (see 6.4.2). Monitoring may be performed indirectly, for example by monitoring the position of the SV relative to the calculated trajectory, or by obtaining information from other sources such as vehicle motion sensors, tyre pressure sensors, or fuel/energy meters.

### 6.3.10 MCS condition monitor

MCS condition monitor is a function by which the MCS monitors its own operation and, at a minimum, detects events that have a negative effect on system operation (see 6.4.2).

### 6.3.11 Localization

Localization is a function by which the MCS recognizes its geographical location, at a minimum, to determine if the SV is located within the geographical boundaries of the ODD. This can sometimes also include determining the SV's lane of travel.

### 6.3.12 External warning generation

External warnings are provided by the MCS in order to notify surrounding road users of a potentially hazardous situation of the SV. External warnings shall be issued when the MCS brings the SV to a complete stop. External warnings may include, but are not limited to, visual notification using hazard lamps, or auditory notification using a horn or a security alarm.

### 6.3.13 Function required for route following functionalities

#### 6.3.13.1 Path selection

Path selection is a function in which the MCS selects the lane to use to follow the route towards the destination defined in a data source (e.g. digital map). This function is needed to change lanes towards junctions and to perform diverging manoeuvres.

The lane to use is selected based on information about the position of the SV along the route. Such information may be obtained through GNSS signals, navigation systems, or from external sources (e.g. road administrators, vehicle manufacturer backend servers) using wireless communication.

Note that performing merging manoeuvres does not necessary require the path selection function, but instead may be realized by detecting the unavailability of the current lane of travel.

### 6.3.14 Related functions

#### 6.3.14.1 Minimal risk manoeuvre (MRM)

MRM is a function in which MCS automatically performs the DDT fallback in an attempt to reach MRC. MRM is not required for MCS, but when MRM is performed, it will be designed to conform to the requirements stated in ISO 23793-1.

#### 6.3.14.2 Wireless communication (V2X)

The MCS may be equipped with V2X functions, for example, to receive real-time roadway status information (see 5.2.2), to call for support (e.g. road service, ambulance) upon achieving MRC, to communicate with surrounding traffic also equipped with V2X functions, etc.

## 6.4 Requirements for continuing operation after detecting disengagement-triggering conditions

### 6.4.1 General

The functions which perform the DDT shall be operational after detecting disengagement-triggering conditions (and indicating the need for disengagement) for a sufficient length of time for the FRU to perform the fallback, regardless of the adverse situation that MCS has encountered other than experiencing an incapacitating situation (see 6.4.2.6).

Representative adverse situations that the MCS can potentially encounter and in which MCS shall still be operational are, occurrence of a failure (excluding those considered incapacitating), change in the driving environment, approaching operational limits, experiencing malicious (e.g. adversary, cyber) attacks, and an unresponsive FRU.

The following subclauses classify these adverse situations and expected responses by the MCS. Note that an MRM is considered as one form of this response.

Due to the variety of possible design implementations to continue operation, this document does not specify the required response to each possible adverse situation.

### 6.4.2 Classification of adverse situations

#### 6.4.2.1 General

This document classifies adverse situations by the severity of their effects on system operation. The severity of a given situation is system design dependent. Therefore, allocation of events to the classification shall be defined by the system designer. For this reason, the same situation can result in differing effects on different MCS implementations.

#### 6.4.2.2 Potential future effect

An adverse situation causing a potential future effect on system operation refers to a situation that does not directly affect the current performance of the DDT, but can increase the severity of a future adverse situation.

An unavailable FRU is one example of this category. Occurrence of a failure in the RTI generation function can also be a situation with a potential effect. Failure of a sensor that provides redundancy for another sensor that remains operational is another example.

#### 6.4.2.3 Minor effect

An adverse situation causing a minor effect on system operation refers to a situation that can impair the comfort or convenience of system operation, while the minimum performance requirements can still be met.

An example would be a change in the driving environment by encountering a strong side wind that forces the SV's lateral position to deviate from the calculated trajectory but does not result in exceeding lane boundaries.

#### 6.4.2.4 Degrading effect

An adverse situation which causes a degrading effect on system operation refers to a situation that restricts a certain functionality or capability of the system, but the minimum performance requirements can still be satisfied by changing the form of operation, for example, by a reduction in the operating speed.

An example would be operational limits caused by performance limitations of actuators (e.g. brake/steering actuators), or weather conditions reducing visibility and thereby limiting the range of forward obstacle detection sensors.

#### 6.4.2.5 Performance-impairing effect

An adverse situation which causes a performance-impairing effect on system operation refers to a situation in which the minimum performance requirements can no longer be met, but operation with the remaining resources is still possible for a limited amount of time.

An example would be loss of the ability to detect forward objects on the road surface, but still being able to detect the lane of travel.

#### 6.4.2.6 Incapacitating effect

A situation which results in incapacitation of the system, therefore the MCS is forced to be disengaged. Situations considered to be incapacitating should be limited to those that are not reasonably avoidable.

Loss of both the primary and backup power supplies can be considered as an incapacitating failure.

### 6.4.3 Responses to adverse situations

While the MCS is in the normal state (see 6.2.4), the following requirements apply.

- In response to situations with potential, minor or degrading effect on system operation, MCS shall continue operation while continuing to conform to the DDT minimum performance requirements during normal operation as specified in 7.3. MCS may transition to the requesting fallback state.
  - If the MCS transitions to the requesting fallback state in response to situations with potential, minor or degrading effect on system operation, and if the FRU does not respond adequately to an RTI, the MCS shall be capable of bringing the SV to a stop in accordance with 7.5.
- In response to situations with performance-impairing effects on system operation, the MCS shall extend operation while conforming to the DDT minimum performance requirements during performance-impaired operation as specified in 7.4. The MCS shall transition to the requesting fallback state.

Occurrence of an incapacitating effect to system operation can lead to a forced direct disengagement. Therefore, requirements related to system response do not apply. However, the likelihood of encountering incapacitating events should be decreased as much as possible by system design.

## 7 Minimum performance requirements of the DDT

### 7.1 General

Subclauses 7.3 and 7.4 specify the minimum performance requirements of the DDT while the MCS is engaged.

- Performance requirements during normal operation (see 7.3) shall apply when MCS is in the normal state (see 6.2.4). Also refer to 6.4 for system conditions under which MCS is required to continue operation while satisfying these performance requirements.
- Refer to 6.4 for system conditions under which requirements during performance impaired operation (see 7.4) may apply.

Subclause 7.5 specifies the required response of an MCS to an unresponsive FRU.



## 7.2 Operating speed range

The MCS shall have a predefined operating speed range. The system designer shall specify the value for the maximum operating speed.

— The minimum operating speed shall be zero.

— The maximum operating speed shall be greater than 40 km/h.

## 7.3 Normal operation

### 7.3.1 Sustained longitudinal vehicle motion control

#### 7.3.1.1 Speed and time gap determination

The MCS shall be capable of dynamically controlling the operating speed of the SV within the predefined operating speed range. The MCS shall determine the operating speed and conform to the performance requirements during normal operation. This includes determining a time gap with a leading vehicle in the current lane of travel, and satisfying crash avoidance requirements specified in 7.3.3 at the current speed and time gap.

The following items, at a minimum, shall be considered when determining the operating speed.

— Speed regulations, including the posted speed limit and minimum required speed to travel.

— Speed of surrounding traffic (when applicable).

— The distance between the SV and the forward vehicle (when applicable).

— Road geometry (e.g. radius of curvature).

— If provided, the driver's preferred set speed (see 6.3.6).

Note that under situations in which the system operation is degraded (see 6.4.2.4), or when MCS is in the requesting fallback state, the driver's preferred set speed is not necessarily prioritized.



#### 7.3.1.2 Deceleration control

The MCS shall be capable of bringing the SV to a complete stop, and of maintaining the SV in a stopped, stationary condition.

The allowable amount of deceleration that the MCS may induce depends on the existence of a hazardous situation (e.g. imminent risk of collisions, road departures). Examples of potentially hazardous situations are given in 7.3.3.

— In the absence of a hazardous situation, the MCS shall not exceed the allowable deceleration performance specified in ISO 15622:2018, 6.4 (ACC).

— In the presence of a hazardous situation, the above limitation does not apply. However, unnecessarily harsh deceleration should be avoided.

### 7.3.2 Sustained lateral vehicle motion control

The MCS shall be capable of maintaining the SV within the boundaries of its current lane of travel except under the following conditions.

— The MCS is equipped with a lane change functionality, and the conditions are satisfied to perform a lane change.

— The MCS is equipped with a collision avoidance lateral manoeuvring functionality, which determines that crossing the lane boundary is preferable (this document does not specify the requirements for such additional functionality).

— The MCS is within its requesting fallback state, and determines that crossing the lane boundary is preferable (e.g. pulling over to a road shoulder).

#### 7.3.3 Crash avoidance

##### 7.3.3.1 General

The MCS should be capable of avoiding reasonably foreseeable and preventable crashes. The following subclauses provide representative hazardous situations that are reasonably foreseeable during in-lane operation.

Test Scenarios 4, 5, and 6 in Clause 8 specify reasonably preventable conditions that are at the borders of situations considered unreasonable to prevent.

##### 7.3.3.2 Deceleration of forward vehicle

A vehicle travelling in front of the SV in its current lane of travel can potentially perform a strong deceleration. The MCS shall be capable of avoiding a rear-end collision, at least when the deceleration of the forward vehicle is 0,6 G or less.

##### 7.3.3.3 Cut-in vehicle from the adjacent lane

Vehicles travelling in the adjacent lane can potentially cut in front of the SV. The MCS shall be capable of avoiding a collision with such vehicles, when the TTC to the cut-in vehicle is greater than 2,5 s at the time when the cut-in vehicle overlaps with the SV.

##### 7.3.3.4 Obstacles in the current lane of travel

Obstacles can be present in the current lane of travel which could lead to a crash if not avoided. These obstacles can be occluded by preceding vehicles or road curvatures. The MCS shall be capable of avoiding injury of the occupants resulting from a crash with such obstacles, at a minimum, those which are bigger than a loose tyre of a light duty passenger vehicle, located on the road surface within the boundaries of the current lane of travel.



### 7.4 Performance-impaired operation

The following items are the minimum set of requirements and recommendations which apply when encountering a performance-impairing situation (see 6.4.2.5). Note that the MCS shall transition to the requesting fallback state when encountering a performance-impairing situation. Therefore, this subclause does not apply to operation within the normal state. Performance-impaired operation should be limited in duration.

— The MCS shall be capable of decelerating the SV and bringing the SV to a stop. When bringing the SV to a stop, external warnings shall be issued. A stop does not necessarily mean achieving MRC. However, reaching MRC should be attempted.

— The MCS should be capable of maintaining the original lane of travel.

### 7.5 MCS reaction to unresponsive FRU

The following items are the minimum set of requirements and recommendations which apply when the FRU does not respond adequately to an RTI, and there are no performance-impairing situations (see 6.4.2.5) or incapacitating situations (see 6.4.2.6). The MCS is expected to conform to the minimum performance requirements during normal operation as specified in 7.3 while in its requesting fallback state.

— The MCS shall not aim for trip continuation. The MCS should not accelerate, unless acceleration is considered to reduce risks.

— The MCS shall be capable of decelerating the SV and bringing the SV to a stop. When bringing the SV to a stop, external warnings shall be issued. A stop does not necessarily mean achieving MRC, but reaching MRC should be attempted.

— The MCS shall be capable of controlling the lateral motion of the SV in accordance with 7.3.2.



# 8 Test procedures

## 8.1 General

### 8.1.1 Purpose

The purpose of the following test procedures is to demonstrate conformance to the requirements of the basic functionalities and minimum DDT performance requirements during normal operation of a given MCS.

The test scenarios and values of the parameters are representative and intended to be performed on test tracks or public roads. They are not meant to serve as an exhaustive validation. As such, additional testing, including simulations, as well as document-based assessment, should also be considered. Related information for creating a comprehensive set test scenario for ADSs can be found in ISO 34502.

The test scenarios do not consider performance during performance-impaired operation, since situations that have a performance-impairing effect on system operation are design-dependent.

### 8.1.2 Driving environment

The full testing process shall be performed in a driving environment based on the ODD of the MCS being tested. There shall be no situations that have a performance-impairing effect on the system operation during the test processes.

It is also recommended to test the system reaction to changes in the driving environment. However, this document does not specify such a test scenario due to the variety of ODDs for different MCS implementations.

Additional vehicles shall be included in the surrounding traffic if they are part of the ODD definition of the MCS under test.

### 8.1.3 System settings and test driver roles

Once the MCS is engaged and the preferred set speed/following time gap is selected (when applicable), the test driver (FRU) shall not operate the MCS or any vehicle interfaces for the test to be considered successful, except if otherwise required to do so in the test procedure (i.e. test scenarios 2 and 3). Alterations to the system settings shall not be made during the test procedure.

### 8.1.4 Common test pass criteria

All requirements stated in 7.3 shall be satisfied.

### 8.1.5 Confirmation of the HMI design

Requirements related to the status indications (see 6.3.5) and FRU monitoring (see 6.3.8) should be confirmed independently, as they play an important role for MCS. However, this document does not identify test procedures of the human machine interface (HMI) design since specific requirements are not provided.

Compliance with the requirements of the RTI generation function (see 6.3.4) can be verified in test scenarios 1 and 8 of Table 4.

### 8.1.6 Success rate and number of trials

The MCS shall satisfy all of the pass criteria of each test scenario at every trial. This document does not specify the number of test trials to repeat for each test scenario due to the variety of possible purposes of testing MCS.

Note that the results of a test trial that does not conform to the stated conditions in 8.1 and the test procedures stated in each test scenario are considered as an unsuccessful test trial, and shall not be counted as a pass or fail. Examples of situation where a test trial could be considered unsuccessful are:

— failure in engaging MCS (test scenarios other than scenario 8);

— changes in the driving environment during a test trial exceeding the operating conditions of the MCS under test (test scenarios other than scenario 8);

— failure to control the FV within its specified ranges (test scenarios 4, 5, and 6);

— placement position or properties of the selected obstacle do not match the specification (test scenario 6).

### 8.1.7 List of test scenarios

Test scenarios identified in Table 4 shall be performed in order to demonstrate conformance to the requirements of the basic functionalities and minimum DDT performance requirements during normal operation.

**Table 4 — List of Test Scenarios**

| | Test Scenario | Clause |
|---|---|---|
| 1 | MCS reaction to unresponsive FRU | 8.2 |
| 2 | Direct disengagement by steering input | 8.3 |
| 3 | Continued operation after brake intervention | 8.4 |
| 4 | Forward vehicle braking hard | 8.5 |
| 5 | Aggressive cut-in from the adjacent lane | 8.6 |
| 6 | Obstacle in lane | 8.7 |
| 7 | Approaching geographical ODD exit | 8.8 |
| 8 | Engagement restricted outside ODD | 8.9 |

### 8.1.8 Test sites

Test scenarios 1, 4, 5 and 6 are intended for testing on a closed course test track to avoid unnecessary risk of crashes.

It should be noted that a closed test course would be considered outside of the geographical ODD boundaries of the MCS, therefore restricted from engagement. If testing is aimed at certifying an MCS, a special exemption to modify the software to include the test site as part of the ODD should be considered when testing.

Test scenarios 7 and 8 are intended to be performed on public roads. Therefore, there shall be no modifications to the software for the purpose of the testing.

Test scenarios 2 and 3 can be performed on either a closed test course or public roads.

