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Road vehicles — Human performance and state in the context of automated driving —

Part 1: Common underlying concepts

Véhicules routiers — Etat et performance humaine dans le contexte de la conduite automatisée —
Partie 1: Concepts fondamentaux

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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 documents 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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This document was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 39, *Ergonomics*.

This second edition cancels and replaces the first edition (ISO/TR 21959-1:2018), which has been technically revised. The main changes compared to the previous edition are as follows:

— editorial modifications to the format of the figures;

— corrections of the references to clause numbers (Clause 7 is now Clause 8);

— corrections to redundant descriptions.

A list of all parts in the ISO 21959 series can be found on the ISO website.

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

Although automation technology is advancing at a very fast pace, the majority of automated driving levels (as defined by SAE) still require a human to fulfil specific remaining (driving related) tasks while being in automated driving mode. The basic requirements with respect to the driver strongly depend on the level of automation and are subject to human factors research all over the world. The SAE standards SAE J3016[70] [71] and SAE J3114[72] have already introduced working definitions of key concepts in this field. This document puts an emphasis on common underlying concepts of driver performance and state in the context of automated driving.

Driver performance includes driver's activities in transitions both from manual driving to automated driving and from automated to manual driving, as well as interaction behaviour while using the system. Driver state here means driver's internal conditions that may affect performance including knowledge of and attitudes toward driving automation systems.

Concepts on driver performances in transition from manual to automated driving and from automated to manual driving are described in Clause 5. Concepts on driver state related to the transition are described in Clause 6 and a specific concept "readiness/availability" that refers to driver state that predicts the intervention performance is described in Clause 7. Concepts for driver's experiences and attitudes that may affect driver performance and state in the context of automated driving are described in Clause 8.

Road vehicles — Human performance and state in the context of automated driving —

Part 1: Common underlying concepts

1 Scope

This document introduces basic common underlying concepts related to driver performance and state in the context of automated driving. The concepts in this document are applicable to all levels of automated driving functions that require a human/driver to be engaged or fallback-ready (SAE level 1, 2 and 3). It can also be used with levels that enable a driver to resume manual control of the vehicle (a compatible feature for SAE levels 1 to 5).

Common underlying concepts can be applicable for human factors assessment/evaluations using driving simulators, tests on restricted roadways (e.g. test tracks) or tests on public roads. The information applies to all vehicle categories.

This document contains a mixture of information where technical consensus supports such guidance, as well as discussion of those areas where further research is required to support technical consensus. These common underlying concepts can be also useful for product descriptions and owner manuals. The contents in this document are informative, rather than normative, in nature.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

No terms and definitions are listed in this document.

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

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

4 Purpose

The purpose of this document is to provide common underlying concepts for human performance and state for the researchers and developers of driving automation systems (more specifically SAE levels 1–5) in order to facilitate the sharing of information and knowledge as these systems are developed and deployed.

This document does not provide design principles on how a human-machine interface (HMI) for automated driving should be designed or developed. However, common concepts and measures could be used during the development phase when different HMI designs are evaluated in terms of usability, user experience and safety.

It is not intended that anything in this document restricts or provides direction regarding the technology used to create these systems, or the underlying design of these system.

5 Human performance in the context of automated driving

5.1 General

Human performance has two aspects—behaviour being the means and its consequence being the end[16]. The focus on consequences, and hence on performance, is especially relevant for situations such as the transition processes from automated to manual control (level 0) and vice versa (see Figures 1 to 4). The following subclauses give an overview of possible measures for driver- and system-initiated transitions. For transitions between different automation levels (e.g. 4→2 or 3→1) within one vehicle appropriate measures can be selected or adapted according to the specific circumstances.

5.2 Transition from manual to automated driving

5.2.1 Transition process model

Figure 1 shows a process model for a prototypical transition from manual to automated control, either initiated by the driver or by the system.

EXAMPLE After entering the highway the driver is informed about the availability of a "highway pilot function"[1)]. He/she decides to activate automation by a dedicated steering wheel button.

1) See: https://www.daimler.com/innovation/case/autonomous/highway-pilot-2.html, Hunger 2017. Highway pilot system is an example of a suitable product available commercially. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO of this product.

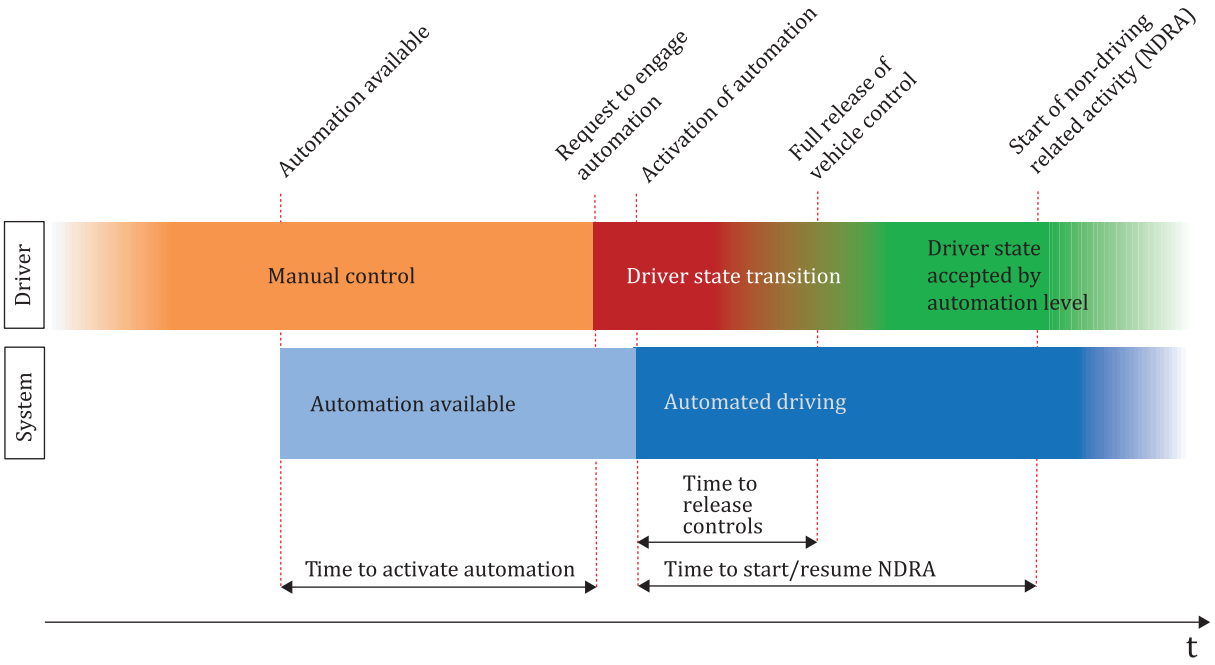

Figure 1 — Driver/system-initiated transition from manual to automated driving (concepts are further specified in 5.2.2 and 5.2.3)

5.2.2 Definition of related concepts

a) **Manual control**: Driving phase where a human driver is performing the dynamic driving task (DDT)—all of the real-time operational and tactical functions required to operate a vehicle in on-road traffic (see Reference [70] for the definition of level 0 automation). In cases where lower level automation features are already active, this phase can be regarded as including the remaining (manual) elements of the DDT required by the driving automation system. For example, driving with adaptive cruise control requires the driver to perform the lateral control (sub) task as well as the object and event detection and response (OEDR) subtask.

b) **Automation available**: If all operational conditions for a driving automation system are fulfilled the system is ready to be activated by either the user or the system. This system availability may be signalled to the user via the driver vehicle interface (e.g. screen, tones). However, even if an automation feature is available, the driver may have to judge whether activation is appropriate [taking into account the mechanical condition of the vehicle (not detected by the vehicle, e.g. broken suspension component)] This will be covered in a future planned document (ISO/SAE 22736).

c) **Request to engage automation**: Event usually initiated by the user through the driver-vehicle interface of the vehicle to activate the driving automation system. Apart from user-initiated transitions, system-initiated transitions from manual to automated control may also be possible, especially after the driver has temporarily overridden the automated mode by manual intervention. At the end of driver intervention, the system may automatically activate/resume from suspended to active mode. For example, in some automated steering control systems, after the driver has transitioned from automated to manual control by manual use of the steering wheel, when the driver is no longer moving the steering wheel, the system may automatically activate/resume from manual to automated steering control.

d) **Activation of automation**: Onset of the driving automation system activation. There may be a delay between requesting the activation and the activation itself either due to technical reasons or by intentionally introducing an activation process as an HMI design feature.

e) **Driver state transition** (manual to automated): Process where the driver is releasing control to the driving automation system. The transition includes physical aspects (releasing hands and feet from primary vehicle controls) as well as cognitive aspects (ensuring that automation has taken over successfully). The physical transition phase ends when the driver fully releases manual vehicle control (hands and feet do not have any action on longitudinal or lateral vehicle control). Behavioural markers for the end of the cognitive transition are less obvious.

f) **Automated driving**: Driving phase where a level 1 – level 5 (L1 – L5) system is performing specific aspects of the DDT.

g) **Acceptable driver state by automation level**: Driver state that is required or activity that is allowed by the driving automation system. The driver state may or may not be monitored by the driving automation system. Requirements on acceptable driver states are strongly dependent on the automation level. Sleep is commonly seen as not acceptable by L2/L3 features or physically leaving the driver's seat is not acceptable for L2/L3 features.

h) **Non-Driving Related Activity (NDRA)**: Any activity not related to the monitoring of the driving automation system and/or the current driving situation is called non-driving related activity. This can include activities that take up any of visual, auditory, visual-manual, auditory-manual, manual, or cognitive capabilities.

i) **Non-Driving Related Task (NDRT)**: Any activity related to a dedicated task that is different from the monitoring of the driving automation system and/or the current driving situation is called non-driving related task. An activity becomes a task when it has a specific goal, and the task can be made up of a series of activities leading up to this goal. A NDRT can also be called secondary task, but only as long as there is a primary task, in this case operating the vehicle. When driving is no longer the driver's primary task—such as during automated driving at SAE levels 3 and higher—the NDRT stops being a secondary task. Under such circumstances the NDRT itself can be regarded as the primary task.

5.2.3 Measures for human performance in releasing control to automation

a) **Time to activate system**: It is the time interval between events "automation available" and "request to engage automation".

b) **Time to release controls**: It is the time interval between events "activation of automation" and "full release of vehicle control".

c) **Time to start/resume NDRA**: It is the time interval between events "activation of automation" and "start of NDRA".

d) **Method used to engage driving automation system**: It is the specification of required driver action to fully release control to driving automation system (e.g. double-pull of stalk at steering column or simultaneous activation of dedicated steering wheel controls).

5.3 Transition from automated to manual driving

Transitions from automated to manual driving, may have two different "sources". They may be system initiated or they may be driver initiated as is presented in the subclauses below.

5.3.1 Transition process models

Figure 2 shows the process model for a system-initiated transition from automated to manual vehicle control with definitions of relevant time periods. This transition model assumes the result of a fully stabilised vehicle.

EXAMPLE 1 While using a highway pilot system[2)] the function issues a request to intervene (RtI) due to an internal system error. After preparing for taking over manual vehicle control the driver deactivates the highway pilot function and switches to manual driving mode.

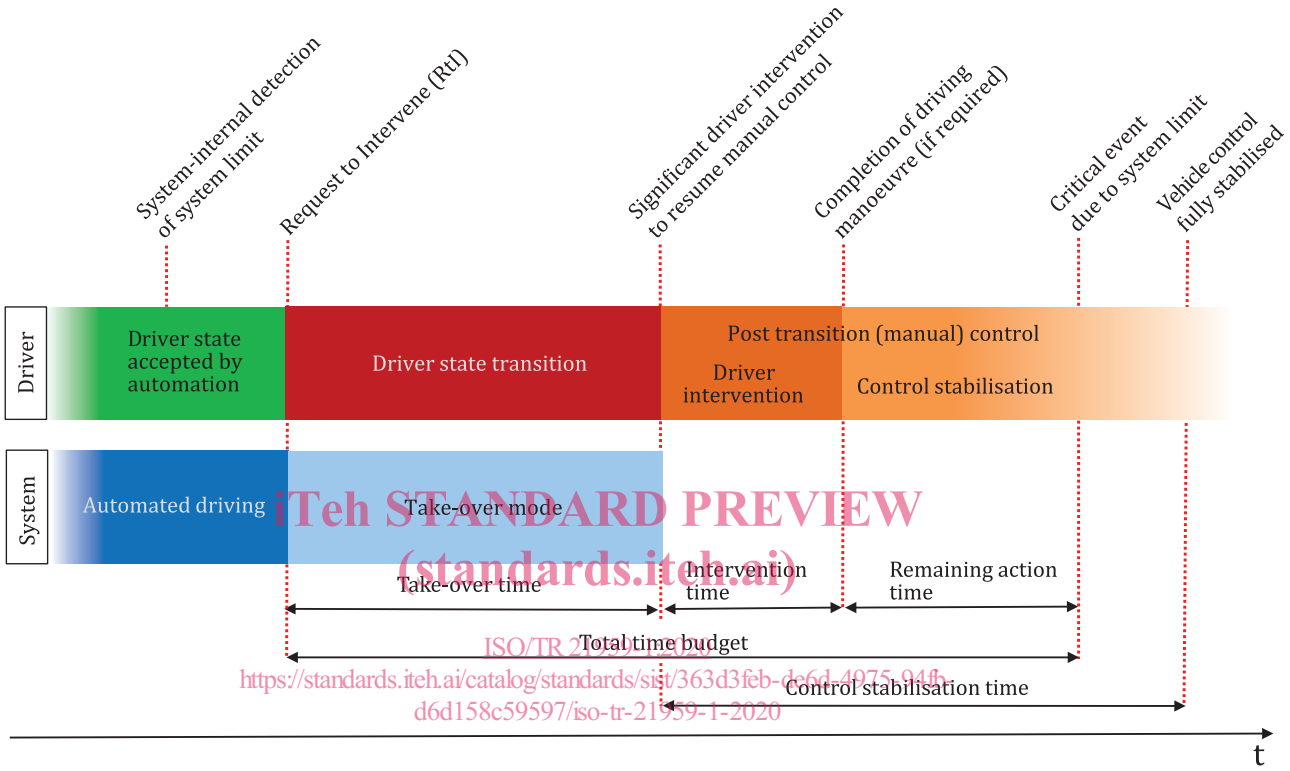

Figure 2 — System-initiated transition from automated to manual driving (concepts are further specified in 5.3.2 and 5.3.3)

In addition to system-initiated transitions, user-initiated transitions without a RtI are covered, as level 1 to level 3, and some level 4 or level 5 systems may be designed to be deactivated by the user at any point in time during full operation. There are two types of reasons for a user to deactivate the automation feature which are described below.

Figure 3 describes the process of regaining manual vehicle control due to the detection of system performance limitations (mandatory transition). In this case the L1/L2 driving automation system does not issue a RtI to the driver.

EXAMPLE 2 While using a L2 automation system in a construction zone the driver observes that the system is following invalid lane markings. He/she decides to immediately take-over control by manually overriding the lateral steering control (leading to manual driving mode).

2) See: https://www.daimler.com/innovation/case/autonomous/highway-pilot-2.html, Hunger 2017. Highway pilot system is an example of a suitable product available commercially. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO of this product.

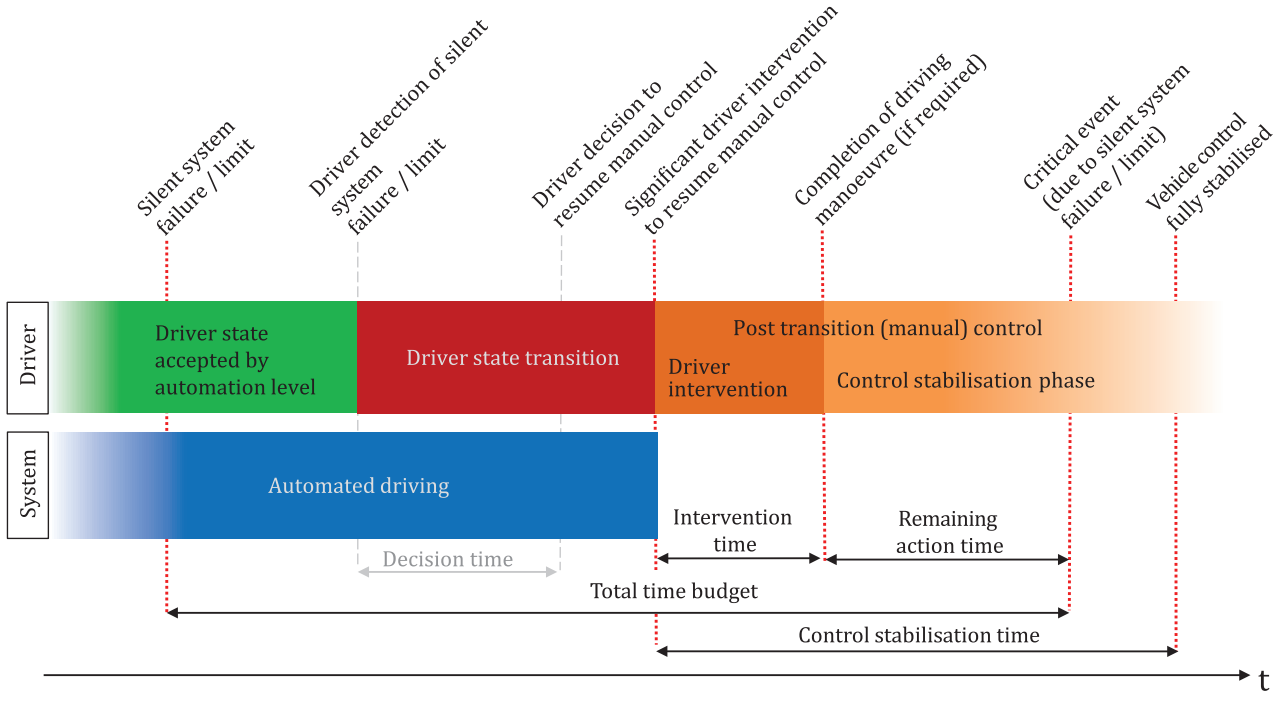

Figure 3 — Mandatory human-initiated transition of automated to manual driving due to detection of system performance limits (concepts are further specified in 5.3.2 and 5.3.3)

On the other hand, the driver may want to deactivate the driving automation system without detecting system performance limitations (optional limitations). For this case the transition process described above can be slightly adapted (see Figure 4).

EXAMPLE 3 While using a traffic jam pilot feature in heavy traffic on a city freeway, the driver deactivates all driving automation features using a designated control for that purpose and switches to manual driving in order to exit the freeway and find a faster route.

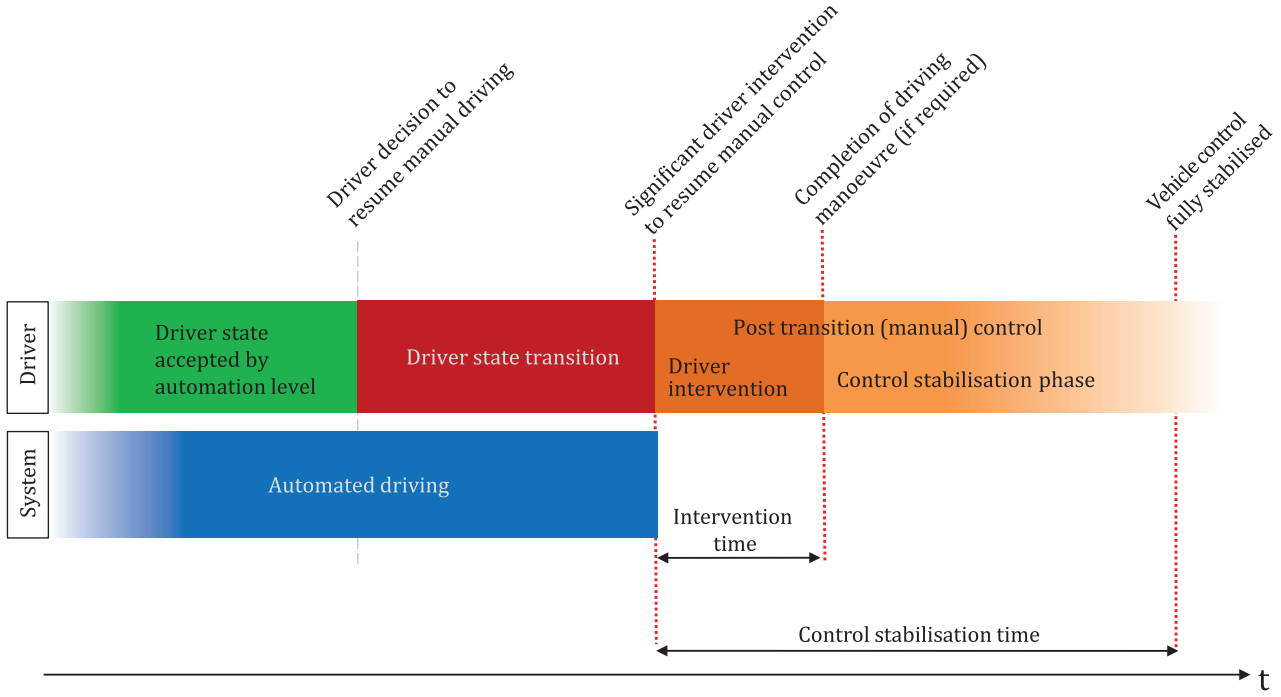

Figure 4 — Optional human-initiated transition of automated to manual driving (without system performance limit; concepts are further specified in 5.3.2 and 5.3.3)