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

Part 1:
Common underlying concepts

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Contents

Page

Foreword

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

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 documents J3016 [70] and 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 may 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 Figure 1 to 4). The following sub-clauses 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.*

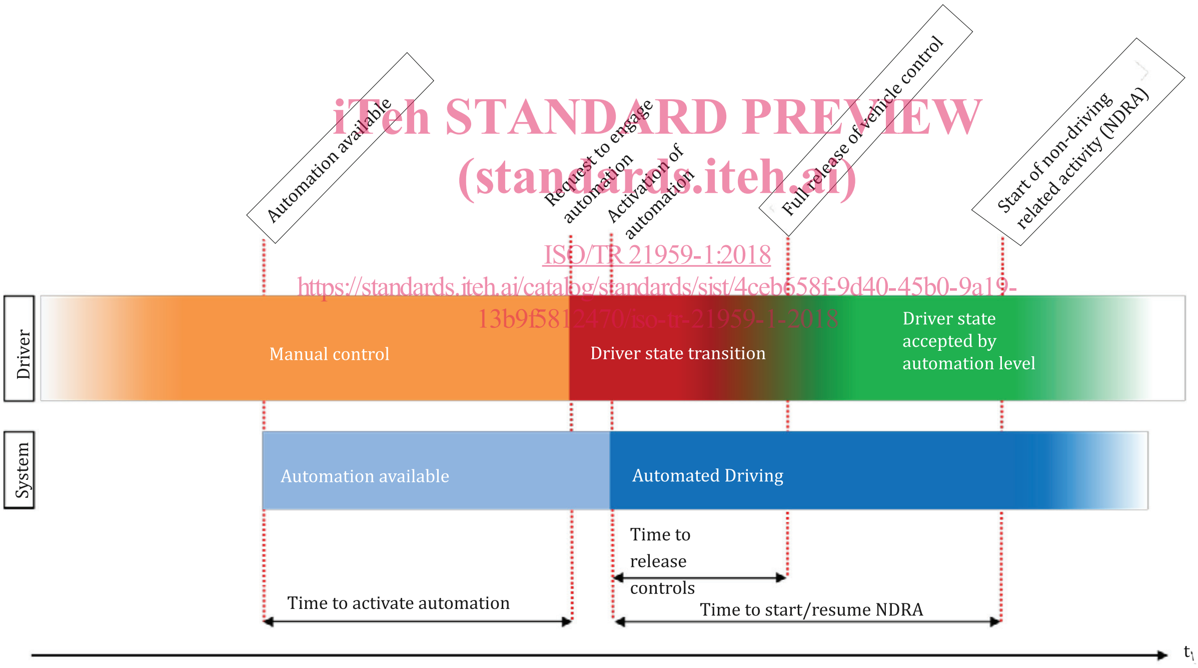

Figure 1 — Driver/system-initiated transition from manual to automated driving (concepts are further specified in 5.2.2 and 5.2.3)

5.2.2 Definition of related concepts

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 [70] 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

1) See: https://www.daimler.com/innovation/case/autonomous/highway-pilot-2.html, Hunger, 2017

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) sub-task.

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).

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.

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.

Driver state transition: 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.

Automated driving: Driving phase where a Level 1 - Level 5 (L1 to L5) system is performing specific aspects of the DDT.

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.

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.

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 consist 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 of automated driving – 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

Time to activate system: Time interval between events "Automation available" and "Activation of Automation"

Time to release controls: Time interval between events "Activation of Automation" and "Full release of vehicle control"

Time to start/resume NDRA: Time interval between events "Activation of Automation" and "Start of NDRA"

Method used to engage driving automation system: 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 sub-clauses 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 stabilized vehicle.

EXAMPLE *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.*

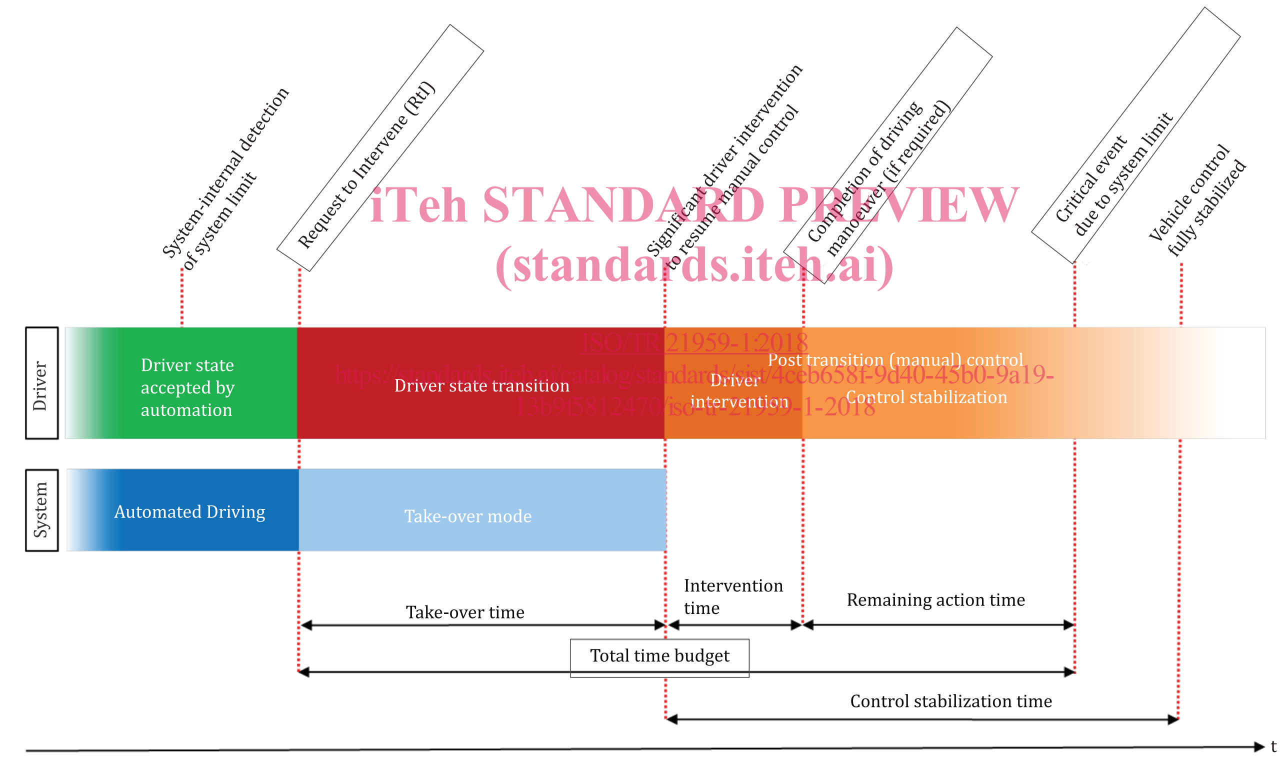

Figure 2 — System-initiated transition from automated to manual driving (concepts are further specified in 5.3.2 and 5.3.3)

In addition to system-initiated transitions, user-initiated transitions without a RtI should be 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.

2) See: https://www.daimler.com/innovation/case/autonomous/highway-pilot-2.html, Hunger, 2017

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

EXAMPLE *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).*

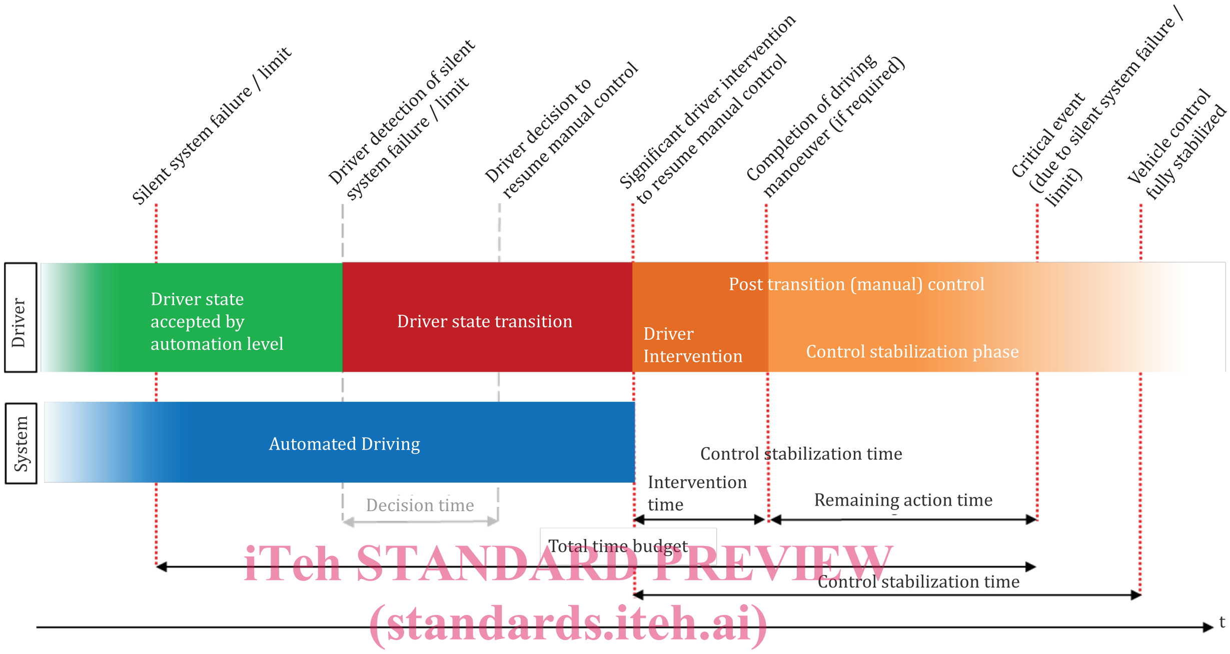

Figure 3 — Human-initiated transition of automated to manual driving due to detection of system performance limits (concepts are further specified in 5.3.2 and 5.3.3)

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

EXAMPLE *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.*

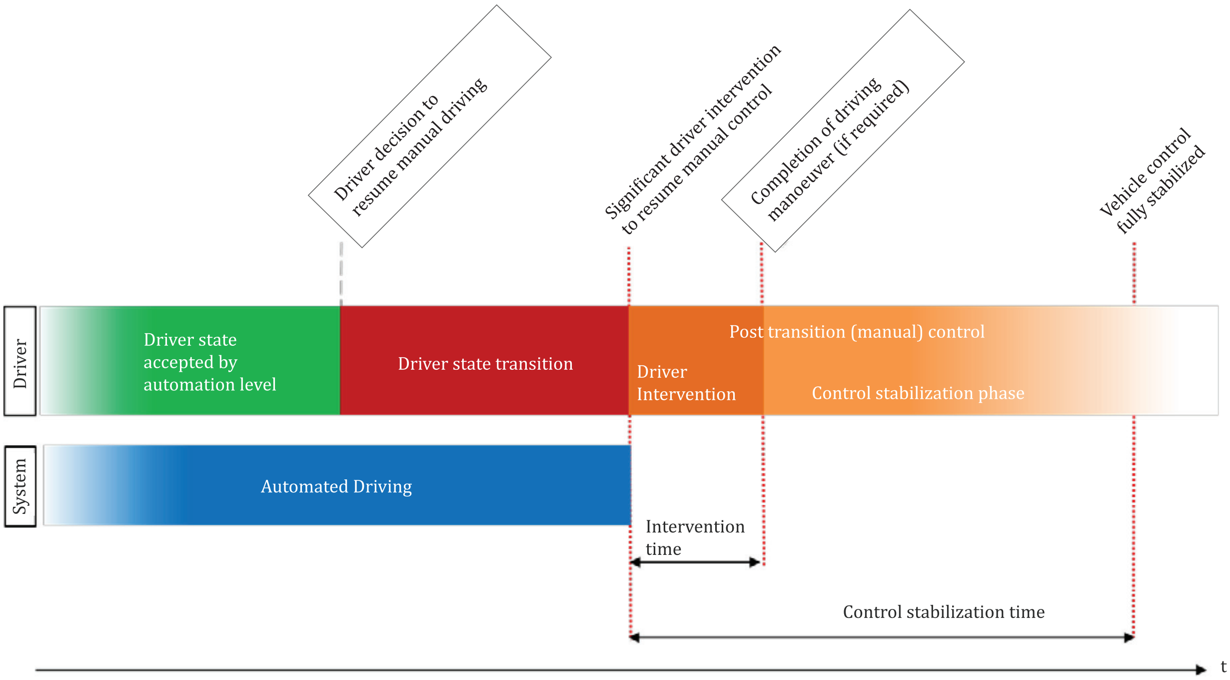

Figure 4 — Human-initiated transition of automated to manual driving (without system performance limit; concepts are further specified in 5.3.2 and 5.3.3)

5.3.2 Definition of related concepts

Request to Intervene (RtI): Notification by a driving automation system to a driver/fallback-ready user indicating that he/she should take over vehicle control (perform all or parts of the DDT). According to the requirements of SAE Level 3+ systems, all system related limits should be recognized and appropriate driver requests to take-over control should be triggered. The RtI time stamp is essential to analyse the subsequent transition process as it is regarded as the beginning of the driver state transition process. If a request to intervene is not issued by the driving automation system because of an automation-external vehicle failure (examples: flat tyre, broken steering system so on), the (perceivable) failure signal can alternatively be used as a corresponding event. Drivers of Level 2 automation may encounter (silent) system failures or performance limits which are not recognized and communicated by the driving automation system. In this case the driver may notice suspicious vehicle control due to a potential system limit which triggers the decision to regain manual control.

Silent system failure and/or silent system limit: System performance limitation of a driving automation system that is not recognized and communicated to the user. The performance limitation may be due to internal failure states or incorrect interpretation of the driving environment.

Critical event due to system limit: Situation that can be specified in time and space that the driving automation system cannot handle safely and that will occur in case the driver does not intervene. System limits are associated with different time budgets:

— Long-term system limits (e.g. the planned transition of a Highway Pilot when reaching the exit) can be communicated well in advance to allow for a sufficient preparation. Driver performances with respect to early communication of long-term system limits are not within primary interest of this document.

— Mid-term system limits (e.g. approaching a construction site that cannot be handled by the system) require the driver/fallback-ready user to take-over within a certain time budget. This type of system limit is central to the definition of SAE Level 3 systems.

— Short-term limits (e.g. due to sensor range) ask the driver for immediate take-over of the DDT. This type of system limit is central to the definition of SAE Level 2 systems.

