



**BSI Standards Publication**

# **Road vehicles — Driver readiness and intervention management**

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Part 1: Partial automation (Level 2)

## National foreword

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# Technical Specification

**ISO/TS 5283-1**

## Road vehicles — Driver readiness and intervention management —

### Part 1: Partial automation (Level 2)

*Véhicules routiers — Gestion de la préparation et de  
l'intervention du conducteur —*

*Partie 1: Automatisation partielle (niveau 2)*

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## Foreword

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

A list of all parts in the ISO 5283 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](http://www.iso.org/members.html).

## Introduction

According to the Society for Automotive Engineers (SAE) guidelines, in Level 2 partial driving automation (ISO/SAE PAS 22736), the driver is expected to be engaged in the dynamic driving task (DDT). Namely, supervising the automated system while both longitudinal and lateral control of the vehicle are executed by the system, and managing the object and event detection and response (OEDR), in case the system does not respond properly. This may be because of system limitations, when particular objects or events are not detectable by the system, operation condition is out of the vehicle's operational design domain (ODD), or due to a system malfunction. In each case, the driver is expected to immediately resume parts or all aspects of the DDT, managing the situation to either continue safe driving in manual mode or stop the vehicle safely. There are currently two types of Level 2 systems available in the market. Hands-on systems are features which require the driver to keep their hands on the steering wheel, while hands-off systems do not. However, the driver's role in performing the OEDR task, supervising system performance, and resuming control, without hesitation and when necessary, is the same for both hands-on and hands-off systems.

Overall, in Level 2 partial driving automation, the driver is always required to supervise system operation and be ready to resume part or all of the DDT, when necessary, whether or not the system issues an alert signal. Supervision of automated systems can entail multiple responsibilities and tasks. Among these are often one or more vigilance-based tasks—with which humans are known to struggle.<sup>[1][2]</sup> In the context of partial driving automation behavioural effects include reduced attention to driving related tasks, and increased boredom, and distraction,<sup>[3][4]</sup> although this depends on how the system is implemented.<sup>[5]</sup> To mitigate these driver states, dedicated in-vehicle systems are used to monitor relevant aspects of driver readiness, and help bring drivers back into a desirable state, so that they are ready to intervene, when needed.

This document summarizes key findings on human interaction with L2 driving automation systems as well as related standards and regulations. It also offers a conceptual framework for driver readiness and intervention management, providing high-level considerations on the design of these systems, as well as a synthesis of information required for their validation.

# Road vehicles — Driver readiness and intervention management —

## Part 1: Partial automation (Level 2)

### 1 Scope

The purpose of this document is to provide background information on driver state monitoring (DSM) in the context of partial driving automation (SAE L2). It describes existing DSM implementations (including system interventions), the underlying design guidelines and provisions by relevant stakeholders in the field, as well as considerations on how to validate the effectiveness of driver state-related system interventions.

Moreover, the document introduces a conceptual framework for “driver readiness and intervention management” for the purpose of providing a comprehensive view of relevant aspects of driver readiness and harmonizing terms and definitions in this field. It is believed that this framework can be helpful when comparing different approaches for driver state assessment.

The document does not contain any specific technical requirements for current or future system implementations of driver state monitoring.

### 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/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 driver readiness

driver's current ability to safely assume parts or all of the dynamic driving task while using driving automation

Note 1 to entry: Driver readiness includes *driver availability* (3.2), *engagement in DDT* (3.3) and *intention to intervene* (3.4).

#### 3.2 driver availability

subdimension of readiness, addressing fundamental prerequisites for successful user interventions such as receptivity, alertness, and motoric state

**3.3****engagement in DDT**

engagement in dynamic driving task

subdimension of readiness, addressing all aspects of human behaviour, that is associated with the performance of the remaining aspects of the dynamic driving task while using a driving automation feature

**3.4****intention to intervene**

subdimension of readiness, addressing the decision mechanisms to initiate user interventions during use of driving automation

**3.5****driver readiness and intervention management**

method which aims to mitigate undesirable driver states and associated safety issues in the context of driving automation by means of driver state detection and interventions

**4 Implementations of partial driving automation****4.1 General**

An SAE L2 driving automation feature is characterized by its execution of the lateral and longitudinal vehicle motion control subtasks of the DDT, on a sustained and ODD-specific basis, with the expectation that the driver completes the OEDR subtask and supervises the driving automation system (ISO/SAE PAS 22736). The widely adopted ISO/SAE taxonomy of automation levels classifies a wide range of potential driving automation features (from no driving automation to full driving automation) and it is also linked to the general roles and tasks of the user. However, ISO/SAE PAS 22736 does not provide details of how to design specific system implementations for each level of automation. These details are specified by the system manufacturer, considering any legal requirements (for example, regulations for type approval) and documents from standards organizations (see [Clause 6](#)). In the context of L2 driving automation, two general classes of L2 driving automation have emerged as implementations: "hands-on" and "hands-off" versions of partial driving automation, which are further described in [4.2](#).

**4.2 L2 hands-on and hands-off implementations**

In UN ECE (United Nations Economic Commission for Europe) adopting countries (contracting parties to the 1958 Agreement), currently available L2 features are approved by referencing to UN R79 ACSF B1 (steering assistance),<sup>[6]</sup> the International Standards ISO 21717 ["Partially Automated In-Lane Driving Systems (PADS)"]<sup>[7]</sup> and ISO 15622 ["Adaptive cruise control systems"].<sup>[8]</sup> The derived L2 driving automation features are of the hands-on type. The exact technology for hands-on detection is not regulated, but typically requires detection of manual steering activity (e.g. by utilizing the steering torque measuring unit which is a standard feature of the steering system), as well as detection of hand contact with the steering wheel (e.g. by utilizing capacitive sensors in the steering wheel).

In recent years, system manufacturers have begun to develop hands-off implementations of partial driving automation which allow drivers to release the steering wheel as long as certain conditions are met, which are determined by the particular system. However, the driver still needs to continue the OEDR subtask and intervene immediately, if necessary. Relevant products have been launched either in non-UN ECE adopting countries (according to the 1958 agreement) or with special (national) permission. Currently, a dedicated UN ECE task force on advanced driver assistance systems (ADAS) is developing a regulatory document to determine system requirements for type approval of "Driver Control Assistance Systems" (DCAS)<sup>[9]</sup> which is expected to include L2 hands-off states. According to ISO/PAS 11585,<sup>[10]</sup> hands-on and hands-off driving automation can both be implemented within one system design, appearing as alternative system states depending on their availability. For the hands-off system state, this document also requests a monitoring of additional aspects of the driver state, such as monitoring their visual attentiveness.

Unless used directly or cited from another document, the use of the term "hands-free" is avoided in this document although it is sometimes used interchangeably with "hands-off" in the context of L2 driving automation. However, the interpretation of the term free may induce the incorrect suggestion that the driver

is free to do other tasks with their free hands, which is not valid for L2 partial driving automation. For both hands-off and hands-on versions, driver monitoring systems are designed to intervene (e.g. issue warnings, require hands-on) when certain thresholds have been exceeded. The primary purpose of the driver monitoring systems, characterized in this document, is to motivate intended use of the automated system, and prevent misuse by the driver. [Subclause 4.3](#) provides an overview of the recommended interventions for L2 systems.

### 4.3 Current designs of driver state related system interventions

In countries adopting the UN ECE regulation (contracting parties of the 1958 agreement) partial driving automation was permitted under UN R79,<sup>[6]</sup> with hands-on features. These features require the following the minimum requirements (details are found in UN-R79, 5.6.2.2.5<sup>[6]</sup>):

- if, after a period of no longer than 15 s the driver is not holding the steering control, an optical warning signal shall be provided;
- if, after a period of no longer than 30 s the driver is not holding the steering control, at least the hands or steering control in the pictorial information provided as optical warning signal shall be shown in red and an acoustic warning signal shall be provided;
- the system shall be automatically deactivated at the latest 30 s after the acoustic warning signal has started. After deactivation the system shall clearly inform the driver about the system status by an acoustic emergency signal which is different from the previous acoustic warning signal, for at least 5 s or until the driver holds the steering control again.

The regulation does not specifically mention the haptic/kinesthetic modality as a substitution for either the visual or auditory component of the signals in the context of hands-off detection.

In addition to markets that adhere to UNECE regulations, other markets, such as the US, may have Level 2 driving automation features that allow for hands-free driving. These systems commonly escalate alerts to solicit a driver response when the driver is determined<sup>1)</sup> to be inattentive by the system. The alerting scheme may begin with a simple visual or auditory alert and escalate to a pattern of alerts and/or penalties (e.g. deactivation of the system and prevention of future activation) and emergency actions for non-response (e.g. pull over on the side of the road) based on the timing strategy of the manufacturer.

An example description of a three-stage alert sequence is described below based on the products available in the US market as of 2025. The descriptions are based on expert assessments of in-market products, rather than official disclosure or customer education materials from the manufacturers. Additionally, the descriptions may not reflect the latest implementations, as manufacturers continuously improve their systems.

- First stage alert: The driver monitoring system determines<sup>1)</sup> that the driver is not attentive to the road and provides visual, audible or haptic alerts when this exceeds a time threshold. The alerts stop when the system determines<sup>1)</sup> that the driver has returned their attention to the road. During the first stage, the Level 2 driving automation feature may continue to be engaged.
- Second stage alert: The driver monitoring system determines<sup>1)</sup> that the driver has exceeded a time threshold in the first stage without returning their attention to the road. The system communicates that the driver must place their hands on the steering wheel and return their attention to the road through an escalation of visual, audible, or haptic alerts. The alerts stop when the system determines<sup>1)</sup> that the driver has returned their attention to the road and has placed their hands on the steering wheel. The system must be re-engaged to continue using the Level 2 driving automation feature.
- Third stage alert: The driver monitoring system determines<sup>1)</sup> that the driver has exceeded a time threshold in the second stage without returning their attention to the road. The system communicates that the driver must immediately place their hands on the steering wheel and return their attention to

1) System implementations differ in how they determine driver attentiveness. For example, head and eye angle may both be used to determine whether a driver's gaze is toward the road. In addition, variety of angles may be used as criteria for this determination based on a design strategy, vehicle dimensions, or other factors. The same is true of the alert modality and alerting period.

the road through a further escalation of visual, audible, or haptic alerts. The alerts stop when the system determines<sup>1)</sup> that the driver has returned their attention to the road and has placed their hands on the steering wheel. The system must be re-engaged to continue using the Level 2 driving automation feature. If the driver does not immediately respond, the vehicle may slow in the lane of travel and brake to a stop with its hazard lights on. The system is then disengaged and is not available until the next ignition cycle.

Other different system intervention designs may be found in the market, especially following UN R171.<sup>[9]</sup>

Due to a lack of sufficient data and published material on user interaction with real L2 vehicles, [Clause 5](#) provides a summary of relevant empirical studies investigating driver state and behaviour in partially automated vehicles.

## 5 Empirical findings with respect to driver states and behaviour during partial driving automation

### 5.1 General

This clause summarizes results from empirical studies investigating driver states and driving performance in the context of partial driving automation. Moreover, the efficiency of driver state monitoring approaches and the related interaction strategies to maintain appropriate driver state (including system interventions) are described.

The collection of empirical findings comprises studies from a wide range of experimental settings, including studies based on driving simulators and naturalistic studies. Many of these studies do not include driver feedback management of any kind and the systems studied were designed to simply explore the driver response to alerts. Additionally, the studies that do include driver feedback are not representative of some production-intent systems, which may have specific nuances related to alert timing, escalation strategy, and safety system integration. The exception to these is naturalistic studies that involve/include production vehicles deployed in naturalistic settings (which may incorporate such feedback strategies by design). It is important to note that these findings do not indicate any adverse field safety effect associated with the current state of L2 automation features. There is currently no comparison of real-world crashes with and without production L2 systems. In fact, studies utilizing crash records and insurance data of production systems have not found any impact, positive or negative, of L2 usage on road safety.<sup>[11][12]</sup> However, continuous monitoring of real-world crashes is necessary to further evaluate the safety effect of production L2 systems. With these caveats in mind, the findings discussed here are intended to raise awareness of potential issues in the interaction between humans and driving automation systems.

### 5.2 General effects of driving automation on driver states and performance

This subclause provides an overview of the driver states that can frequently and consistently degrade when using inappropriately designed L2 systems, in comparison to manual driving, and how these degraded states reduce driver awareness and performance.

Historically, studies regarding the interaction between humans and automation have been conclusive in suggesting that, without effective countermeasures, humans are not very good supervisors of automated systems.<sup>[13][14][15]</sup> For example, detecting an infrequent visual target during partial automation has been found to decline in as little as 15 min. <sup>[16]</sup>

The inability to act appropriately in case of system limitation is also found during driving automation. Human factors studies suggest that drivers' supervisory performance decreases when they are given the opportunity to relinquish physical control of the driving task without effective countermeasures.<sup>[17]</sup> Drivers may seek to relieve boredom from supervising a system by engaging in other, non-driving related activities (NDRAs), which further reduces situation awareness by removing drivers' attention away from their supervisory role.<sup>[4]</sup> Relinquishing moment-to-moment steering control of the vehicle also leads to poor visuo-motor coordination by the driver<sup>[18]</sup> if they are asked to resume control either due to a system limitation, or at the end of the vehicle's operational design domain (ODD). Visual attention directed towards the road scene and hands placed on the steering wheel may not always be sufficient for initiation of an action by driver, to respond to a situation which cannot be handled by partial automation. For example, in a

test track study,<sup>[19]</sup> 21 out of 76 participants crashed into an obstacle, despite having their eyes on the road and their hands on the steering wheel. When asked about their unresponsiveness, participants stated that they trusted the vehicle to avoid a collision. This explains their delayed response, which was either because they expected the system to handle the situation, or because they could not avoid the collision by the time they realized the system was not handling the situation. This “expectation mismatch” provides an example of a misunderstanding of drivers’ expectations about vehicle capabilities. Such automation-induced changes in driver performance, showing slower or poorer driver response to potential and impending hazards and obstacles, when compared to manual driving, are commonly reported in empirical studies.<sup>[20][21][22]</sup>

Overall, studies suggest that if drivers are not actively engaged in vehicle motion control and likely to be out of the loop,<sup>[17]</sup> they need some time to gather sufficient mental and physical resources for providing the correct response, following a takeover request.<sup>[23][24]</sup> Results from driving simulator studies and a meta-analysis suggest that drivers’ response times to a takeover request varies from 1 s to 3 s, depending on the traffic context, although this is based on the time it takes drivers to grab the steering wheel, or apply the brake, and may not reflect the time needed for drivers to resume stable control of the vehicle, or appropriately avoid a crash.

The findings above suggest that inadequately designed automation systems can lead to a decline in driver states and performance, although additional field research with naturalistic L2 usage and longer exposure is needed to better understand the long-term naturalistic effect of partial driving automation. In addition, the frequency and severity of these effects can vary depending on various factors, such as the performance of the system. For example, drivers’ vigilance may decline when using a system that reliably maintains the lane, but it may stay high for a system that frequently requires driver intervention. The implementation of safeguards such as driver monitoring systems (DMS) and suitably designed human-machine interfaces (HMI) may also influence these results. The above literature underscores the significance of implementing suitable safeguards for Level 2 automation systems. This may involve proactive measures to prevent degradation of driver states and performance, as well as reactive detection and intervention, when necessary. It is important to recognize that addressing different issues may require the use of diverse solutions and technologies.

The next subclauses provide several examples of this research, focusing on how automation-induced driver distraction, drowsiness, lack of physical control of the vehicle, and incorrect mental models lead to impaired performance after a request to intervene is provided.

### 5.2.1 Driver distraction

Without effective countermeasures, drivers are likely to increase engagement with secondary tasks or non-driving-related activities (e.g. smartphone usage, looking down towards the vehicle centre stack, looking around the driving scene) when using L2 systems. This is especially the case when drivers are not prevented from looking away from the forward roadway by a reliable alert from DMS.<sup>[4][25][26][27][28][29][30]</sup> Distractions caused by engaging in such secondary activities lead to excessive and prolonged eyes-off-road glances that could impact drivers’ ability to predict, detect or process road hazards.<sup>[31]</sup> Both driving simulator and real-world studies have illustrated the dispersion of driver gaze away from the forward roadway, and reduced glances towards rear-view and side mirrors during L2 driving.<sup>[29][30]</sup>

In addition, gaze is found to be more dispersed when a resumption of control is required, with drivers looking towards the centre stack or dash area for information about automation status (on/off) perhaps in an attempt to determine their responsibility (whether or not to resume control from the driving automation).<sup>[31]</sup> The dispersed eye movement may lead to less focus to the forward roadway and a degraded motor control coordination – leading to late braking,<sup>[21][22]</sup> poor steering control,<sup>[20][32]</sup> or both.

Although there is no direct evidence that increased driver distraction during L2 driving automation leads to a higher crash risk, there is a well-established association between increased visual glances away from the road and safety critical events during manual driving.<sup>[33][34][35][36][37]</sup> Therefore, assessing the effect of driver visual distraction on safety is an important aspect to consider, when designing L2 driving automation.

Prolonged periods of L2 driving automation can lead to cognitive distraction by drivers, even if their eyes are on the forward roadway and surrounding areas <sup>[38][39]</sup> (commonly termed mind wandering, MW), although there is no direct evidence of reductions in safety due to this driver state. Nevertheless, studies in manual driving have shown that MW is associated with degraded driving performance, such as longer responses to sudden events, driving at a higher speed and maintaining a shorter headway.<sup>[40][41][42]</sup> Driving simulator

experiments suggest that lower frequency of strategic glances outside the road centre (e.g. to check for traffic in the mirrors, or glance to the dash area), are indicators of drivers' lack of situation awareness and potential cognitive distraction.<sup>[43][44]</sup> In term of real-world risks, in Reference <sup>[45]</sup> mind wandering is reported as a contributor by 17 % of the "at-fault" crashes for hospitalised patients, and 9 % of the "not-at-fault" patients. An obvious weakness of this approach is that it is not clear whether MW is prevalent amongst the same patients when they are not getting into crashes. Furthermore, as the self-report was not provided at the time of the crash, the fallibility of memory may have diminished the accuracy of the reporting. Considering the lack of compelling evidence for increased MW associated with L2 usage or elevated safety risks linked to MW, additional research may be needed to better inform L2 system design.

### 5.2.2 Drowsiness

Automated driving may result in cognitive underload, which can cause drowsiness over longer periods of active driving automation.<sup>[38]</sup> Even in manual driving, long, monotonous driving on straight sections of road is known to induce fatigue and drowsiness within 20 min– 30 min.<sup>[46]</sup> For automated driving, high levels of drowsiness after long periods of automated driving could lead to drivers falling asleep at the wheel if they do not seek to resolve this state, e.g. by taking breaks or engaging in activities that keep them vigilant and alert.<sup>[47]</sup> Even at lower levels of drowsiness and fatigue, drivers' response is known to be poorer and slower, with drowsiness reducing availability of mental and physical resources required for good performance. This can impair the quality and timeliness of a takeover.<sup>[48]</sup> A drowsy driver may also fail to detect an object/event that requires driver-initiated transition for a Level 2 system. Results regarding the effect of drowsiness on takeover performance are rather mixed and depend on the nature of the study. For example, in Reference <sup>[49]</sup> an increase in drowsiness was seen with conditional driving automation, but no significant effects have been found by other researchers.<sup>[50]</sup> This may be because most of these studies are conducted in the laboratory, for short periods of driving, but see Reference <sup>[47]</sup> for further discussions on this point.

Many studies have found that drivers develop higher levels of drowsiness when using a driving automation system in comparison to manual driving, during similar traffic/road conditions.<sup>[39][51][52][53]</sup> Studies also suggest that driving automation leads to a higher level of drowsiness when drivers are already sleep-deprived (i.e. at night) but not when they were generally alert (i.e. during daytime hours).<sup>[51]</sup> Moreover, drivers are seen to engage driving automation when they feel drowsy, which in turn helps increase sleepiness, due to the monotony associated with supervising driving automation.<sup>[54]</sup> It should be noted that the partial driving automation systems examined in most of these studies did not include a driving attention monitoring/management system, except for one that issued alerts if drivers' hands were away from the steering wheel for too long – which is not a direct indicator of drowsiness.<sup>[51]</sup>

### 5.2.3 Disconnection from physical control

As outlined above, disconnecting the perceptual-motor link between steering control and eye movements could be problematic for safe resumption of control after L2 driving automation. There is currently some debate in the literature regarding hands-on versus hands-off L2 driving, with regulatory guidelines also different between regions. When using an L2 automated system, drivers' hand position on the steering wheel has been found to impact their ability to take over steering control, after an unexpected fault in vehicle torque.<sup>[55]</sup> Specifically, when drivers' hands were removed from the steering wheel, results found excessive/incorrect steering and an increase in lane crossing events. In contrast, drivers' ability to control the vehicle and recover was significantly improved when they were allowed to put one hand on the steering wheel (see also Reference <sup>[56]</sup>). The following subclauses provide evidence from other studies, including those that have considered the value of DMS.

#### 5.2.3.1 Studies on driver states and performance for L2 hands-on

It has been argued that unless appropriate countermeasures are adopted, driver state decrements can also occur for automation systems that require drivers to keep their hands on the steering wheel.<sup>[17][28]</sup> This is thought to be because the visuo-motor mapping required for good resumption of steering control fades over time with driving automation engagement, since in these conditions drivers are simply keeping their hands on the wheel or making contact, but not controlling the steering. Upon a request to intervene, a (re)calibration must be accurately re-established within a short time, which is regularly the case for short takeover requests of 10 s or less. In Reference <sup>[57]</sup>, it was reported that drivers oversteered when asked to take over from driving automation. However, since steering sensitivity was artificially increased during