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Taxonomy and definitions for terms related to driving automation systems for on-road motor vehicles

Taxonomie et définitions des termes relatifs aux systèmes de conduite automatisée des véhicules routiers à moteur

PROOF/ÉPREUVE

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This document was jointly prepared by Technical Committee ISO/TC 204, *Intelligent transport systems*, and SAE Committee *On Road Automated Driving Committee, Definitions Task Force*.

This document and its counterpart document published by SAE (SAE J3016 APR2021) are technically equivalent. The only difference between the documents is the standard number and name and minor editorial elements.

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. Alternatively, to provide feedback on this document, please visit http://standards.sae.org/PRODCODE.

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Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles

1. SCOPE

This document describes [motor] *vehicle driving automation system*s that perform part or all of the *dynamic driving task* (*DDT*) on a *sustained* basis. It provides a taxonomy with detailed definitions for six levels of *driving automation*, ranging from no *driving automation* (Level 0) to full *driving automation* (Level 5), in the context of [motor] *vehicles* (hereafter also referred to as "*vehicle*" or "*vehicles*") and their *operation* on roadways:

Level 0: No Driving Automation

Level 1: Driver Assistance

Level 2: Partial Driving Automation

Level 3: Conditional Driving Automation

Level 4: High Driving Automation

Level 5: Full Driving Automation

These level definitions, along with additional supporting terms and definitions provided herein, can be used to describe the full range of *driving automation features* equipped on [motor] *vehicles* in a functionally consistent and coherent manner. "On-road" refers to publicly accessible roadways (including parking areas and private campuses that permit public access) that collectively serve all road *users*, including cyclists, pedestrians, and *users* of *vehicles* with and without *driving automation features*.

The levels apply to the *driving automation feature*(s) that are engaged in any given instance of on-road *operation* of an equipped *vehicle*. As such, although a given *vehicle* may be equipped with a *driving automation system* that is capable of delivering multiple *driving automation features* that perform at different levels, the level of *driving automation* exhibited in any given instance is determined by the *feature*(s) that are engaged.

This document also refers to three primary actors in driving: the (human) *user*, the *driving automation system*, and other *vehicle* systems and components. These other *vehicle* systems and components (or the *vehicle* in general terms) do not include the *driving automation system* in this model, even though as a practical matter a *driving automation system* may actually share hardware and software components with other *vehicle* systems, such as a processing module(s) or *operating* code.

The levels of *driving automation* are defined by reference to the specific role played by each of the three primary actors in performance of the *DDT* and/or *DDT fallback*. "Role" in this context refers to the expected role of a given primary actor, based on the design of the *driving automation system* in question and not necessarily to the actual performance of a given primary actor. For example, a *driver* who fails to monitor the roadway during engagement of a Level 1 adaptive cruise control (ACC) system still has the role of *driver*, even while s/he is neglecting it.

Active safety systems, such as electronic stability control (ESC) and automatic emergency braking (AEB), and certain types of *driver* assistance systems, such as lane keeping assistance (LKA), are excluded from the scope of this *driving automation* taxonomy because they do not perform part or all of the *DDT* on a *sustained* basis, but rather provide momentary intervention during potentially hazardous situations. Due to the momentary nature of the actions of *active safety systems*, their intervention does not change or eliminate the role of the *driver* in performing part or all of the *DDT*, and thus are not considered to be *driving automation*, even though they perform automated functions. In addition, systems that inform, alert, or warn the *driver* about hazards in the driving environment are also outside the scope of this *driving automation* taxonomy, as they neither automate part or all of the *DDT*, nor change the *driver*'s role in performance of the *DDT* (see 8.13).

It should be noted, however, that crash avoidance *features*, including intervention-type *active safety systems*, may be included in *vehicles* equipped with *driving automation system*s at any level. For *automated driving system* (*ADS*) *features* (i.e., Levels 3 to 5) that perform the complete *DDT*, crash mitigation and avoidance capability is part of *ADS* functionality (see also 8.13).

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

SAE J670 *Vehicle* Dynamics Terminology

SAE J3063 Active Safety Systems Terms and Definitions

Shi, E., Gasser, T., Seeck, A., and Auerswald, R., "The Principles of Operation Framework: A Comprehensive Classification Concept for Automated Driving Functions," SAE Intl. J CAV 3(1):27-37, 2020, https://doi.org/10.4271/12-03-01-0003.

2.1.2 ANSI Accredited Publications

Copies of these documents are available online at http://webstore.ansi.org/.

ANSI D16.1-2007 Manual on Classification of Motor *Vehicle* Traffic Accidents

2.1.3 Other Publications

49 U.S.C. § 30102(a)(6) (definition of [motor] *vehicle*)

Crash Avoidance Metrics Partnership - Automated Vehicle Research Consortium, "Automated Vehicle Research for Enhanced Safety - Final Report," available at https://www.regulations.gov/document?D=NHTSA-2014-0070-0003.

Gasser, T. et al., "Legal Consequences of an Increase in Vehicle Automation," July 23, 2013, available at http://bast.opus.hbz-nrw.de/volltexte/2013/723/pdf/Legal_consequences_of_an_increase_in_*vehicle*_automation.pdf.

Michon, J.A., 1985, "A Critical View of Driver Behavior Models: What Do We Know, What Should We Do?" In Evans, L. and Schwing, R.C. (Eds.). Human behavior and traffic safety (pp. 485-520). New York: Plenum Press, 1985.

Smith, B.W., "Engineers and Lawyers Should Speak the Same Robot Language," in ROBOT LAW (2015), available at https://newlypossible.org.

2.2 List of Abbreviations

ACC Adaptive cruise control

ADAS Advanced driver assistance system

ADS Automated driving system

ADS-DV Automated driving system-dedicated vehicle

AEB Automatic emergency braking

DDT Dynamic driving task

DSRC Dedicated short range communications

ESC Electronic stability control

LKA Lane keeping assistance

ODD Operational design domain

OEDR Object and event detection and response

3. DEFINITIONS

3.1 ACTIVE SAFETY SYSTEM (SAE J3063)

Active safety systems are *vehicle* systems that sense and monitor conditions inside and outside the *vehicle* for the purpose of identifying perceived present and potential dangers to the *vehicle*, occupants, and/or other road *users*, and automatically intervene to help avoid or mitigate potential collisions via various methods, including alerts to the *driver*, *vehicle* system adjustments, and/or active control of the *vehicle* subsystems (brakes, throttle, suspension, etc.).

NOTE: For purposes of this report, systems that meet the definition of *active safety systems* are considered to have a design purpose that is primarily focused on improving safety rather than comfort, convenience, or general *driver* assistance. *Active safety systems* warn or intervene during a high-risk event or maneuver.

3.2 AUTOMATED DRIVING SYSTEM (ADS)

The hardware and software that are collectively capable of performing the entire *DDT* on a *sustained* basis, regardless of whether it is limited to a specific *operational design domain* (*ODD*); this term is used specifically to describe a Level 3, 4, or 5 *driving automation system*.

NOTE: In contrast to *ADS*, the generic term "*driving automation system*" (see 3.6) refers to any Level 1 to 5 system or *feature* that performs part or all of the *DDT* on a *sustained* basis. Given the similarity between the generic term, "*driving automation system*," and the Level 3 to 5 specific term, "*automated driving system*," the latter term should be capitalized when spelled out and reduced to its abbreviation, *ADS*, as much as possible, while the former term should not be.

3.3 [DRIVERLESS OPERATION] DISPATCHING ENTITY

An entity that *dispatch*es an *ADS*-equipped *vehicle*(s) in *driverless operation*.

NOTE: The functions carried out by a *dispatching entity* may be divided among one or several agents, depending on the *usage specification* for the *ADS*-equipped *vehicle*(s) in question.

EXAMPLE: A fleet of Level 4 closed campus *ADS-dedicated vehicles* is placed into service by a *driverless operation dispatching entity*, which engages the *ADS* for each *vehicle* after verifying its *operational* readiness and disengages the *ADS* when each *vehicle* is taken out of service.

3.4 DISPATCH [IN DRIVERLESS OPERATION]

To place an *ADS*-equipped *vehicle* into service in *driverless operation* by engaging the *ADS*.

NOTE 1: The term "*dispatch*," as used outside of the context of *ADS*-equipped *vehicles*, is generally understood to mean sending a particular *vehicle* to a particular pick-up or drop-off location for purposes of providing a transportation service. In the context of *ADS*-equipped *vehicles*, and as used herein, this term includes software-enabled *dispatch* of multiple *ADS*-equipped *vehicles* in *driverless operation* that may complete multiple *trip*s involving pick-up and drop-off of *passengers* or goods throughout a day or other pre-defined period of service, and which may involve multiple agents performing various tasks related to the *dispatch* function. In order to highlight this specialized use of the term *dispatch*, the term is modified and conditioned by the stipulation that it refers exclusively to *dispatching vehicles* in *driverless operation*.

NOTE 2: Only *ADS*-equipped *vehicles* capable of *driverless operation* (namely, an *ADS-DV* or a *dual-mode vehicle*) are potentially subject to being *dispatched*.

3.5 DRIVING AUTOMATION

The performance by hardware/software systems of part or all of the *DDT* on a *sustained* basis.

3.6 DRIVING AUTOMATION SYSTEM OR TECHNOLOGY

The hardware and software that are collectively capable of performing part or all of the *DDT* on a *sustained* basis; this term is used generically to describe any system capable of Level 1 to 5 *driving automation*.

NOTE: In contrast to this generic term for any Level 1 to 5 system, the specific term for a Level 3 to 5 system is "*automated driving system* (*ADS*)." Given the similarity between the generic term, "*driving automation system*," and the Level 3 to 5 specific term, "*Automated Driving System*," the latter term should be capitalized when spelled out and reduced to its abbreviation, *ADS*, as much as possible, while the former term should not be (see 3.2).

3.7 [DRIVING AUTOMATION SYSTEM] FEATURE

A Level 1-5 *driving automation system's* design-specific functionality at a given level of *driving automation* within a particular *ODD*, if applicable.

NOTE 1: Because the term "*driving automation system*" subsumes both *driver support features* and *ADS features*, it is also acceptable to refer to them as such.

NOTE 2: A given *driving automation system* may have multiple *features*, each associated with a particular level of *driving automation* and *ODD*.

NOTE 3: Each *feature* satisfies a *usage specification*.

NOTE 4: *Features* may be referred to by generic names (e.g., automated parking) or by proprietary names.

EXAMPLE 1: A Level 3 *ADS feature* that performs the *DDT*, excluding *DDT fallback*, in high-volume traffic on fully access-controlled freeways.

EXAMPLE 2: A Level 4 *ADS feature* that performs the *DDT*, including *DDT fallback*, in a specified geo-fenced urban center.

3.7.1 MANEUVER-BASED FEATURE

A *driving automation system feature* equipped on a *conventional vehicle* that either:

1. Supports the *driver* by executing a limited set of lateral and/or longitudinal *vehicle* motion control actions sufficient to fulfil a specific, narrowly defined use case (e.g., parking maneuver), while the *driver* performs the rest of the *DDT* and supervises the Level 1 or Level 2 *feature's* performance (i.e., Level 1 or Level 2 *driver support features*);

   or

2. Executes a limited set of lateral and longitudinal *vehicle* motion control actions, as well as associated *object and event detection and response* (*OEDR*) and all other elements of the complete *DDT* in order to fulfil a specific, narrowly defined use case without human supervision (Level 3 or 4 *ADS features*).

EXAMPLE 1: A Level 1 parking assistance *feature* automatically performs the lateral *vehicle* motion control actions necessary to parallel park a *vehicle*, while the *driver* performs the longitudinal *vehicle* motion control actions and supervises the *feature*.

EXAMPLE 2: A Level 2 parking assistance *feature* automatically performs the lateral and longitudinal *vehicle* motion control actions necessary to parallel park a *vehicle* under the *supervision* of the *driver*.

EXAMPLE 3: A Level 3 highway overtaking assistance *feature* automatically performs the lateral and longitudinal *vehicle* motion control actions, as well as associated *OEDR*, necessary to pass a slower-moving *vehicle* on a multi-lane highway when activated by the *driver* or *fallback-ready user*.

3.7.2 SUB-TRIP FEATURE

A *driving automation system feature* equipped on a *conventional vehicle* that requires a human *driver* to perform the complete *DDT* for at least part of every *trip*.

NOTE: *Sub-trip features* require a human *driver* to *operate* the *vehicle* between the point-of-origin and the boundary of the feature's *ODD* and/or after leaving the *feature's ODD* until the destination is reached (i.e., *trip* completion).

EXAMPLE 1: A Level 1 adaptive cruise control (ACC) *feature* performs longitudinal *vehicle* motion control functions to support the *driver* in maintaining consistent headway to a lead *vehicle* in its lane when travelling at higher speeds.

EXAMPLE 2: A Level 2 highway *feature* performs lateral and longitudinal *vehicle* motion control functions to support the *driver* in maintaining position within its lane of travel, as well as consistent headway to a lead *vehicle* in its lane when travelling at higher speeds.

EXAMPLE 3: A Level 3 traffic jam *feature* performs the complete *DDT* on a fully access-controlled freeway in dense traffic, but requires a human *driver* to *operate* the *vehicle* upon *ODD* exit (e.g., when traffic clears, as well as before entering the congested freeway, and again upon exiting it).

EXAMPLE 4: During a given *vehicle trip*, a *user* with a Level 4 automated parking *feature dispatches* the *vehicle* in *driverless operation* for the purpose of finding a parking space in a nearby designated parking facility. Following a period of shopping, the *user* retrieves the *vehicle* via *dispatch* in order to begin his/her *trip* home.

3.7.3 FULL-TRIP FEATURE

ADS features that *operate* a *vehicle* throughout complete *trip*s.

EXAMPLE 1: A Level 4 *ADS-DV* is *dispatched* in *driverless operation* for purposes of providing ride-hailing services to customers located within its geo-fenced area of *operation*.

EXAMPLE 2: A Level 5 *dual-mode vehicle* is *dispatched* in *driverless operation* by its owner to go to a designated airport, pick up several family members, and bring them home. All *vehicle* occupants remain *passengers* throughout the return *trip*.

Figure 1 illustrates how a *trip* could be completed by use of various combinations of *driving automation features* engaged at different levels of *driving automation*.

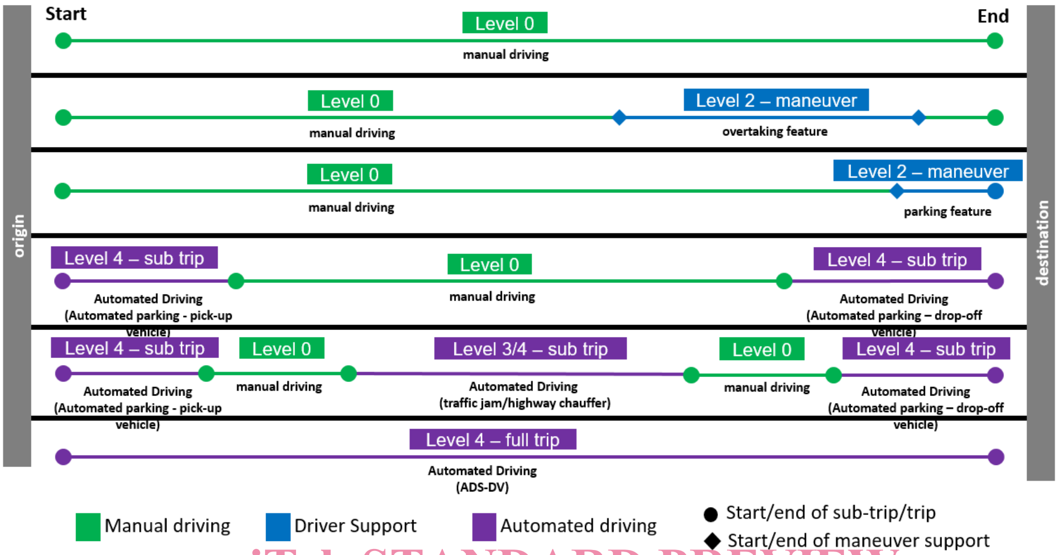

Figure 1 — Examples of driving automation system features/types that could be available during a given trip

3.8 DRIVER SUPPORT [DRIVING AUTOMATION SYSTEM] FEATURE

A general term for Level 1 and Level 2 *driving automation system features*.

NOTE: Level 1 (*driver* assistance) and Level 2 (partial automation) *features* are capable of performing only part of the *DDT*, and thus require a *driver* to perform the remainder of the *DDT*, as well as to supervise the *feature's* performance while engaged. As such, these *features*, when engaged, support—but do not replace—a *driver* in performing the *DDT*.

3.9 DRIVERLESS OPERATION [OF AN ADS-EQUIPPED VEHICLE]

On-road *operation* of an *ADS*-equipped *vehicle* that is unoccupied, or in which on-board *users* are not *drivers* or *in-vehicle fallback-ready users*.

NOTE 1: *ADS-DVs* are always *dispatched* in *driverless operation* (subject to NOTE 3 in 3.33.3).

NOTE 2: *ADS*-equipped *dual-mode vehicles* may be *dispatched* in *driverless operation*.

NOTE 3: On-board *passengers* are neither *drivers* nor *fallback-ready users*.

EXAMPLE: A Level 4 *ADS-DV* is *dispatched* in *driverless operation* for purposes of providing transportation service.

3.10 DYNAMIC DRIVING TASK (DDT)

All of the real-time *operational* and tactical functions required to *operate* a *vehicle* in on-road traffic, excluding the strategic functions such as *trip* scheduling and selection of destinations and waypoints, and including, without limitation, the following subtasks:

1. Lateral *vehicle* motion control via steering (*operational*).

2. Longitudinal *vehicle* motion control via acceleration and deceleration (*operational*).

3. Monitoring the driving environment via object and event detection, recognition, classification, and response preparation (*operational* and tactical).

4. Object and event response execution (*operational* and tactical).

5. Maneuver planning (tactical).

6. Enhancing conspicuity via lighting, sounding the horn, signaling, gesturing, etc. (tactical).

NOTE 1: Some *driving automation systems* (or the *vehicles* equipped with them) may have a means to change longitudinal *vehicle* motion control between forward and reverse.

NOTE 2: For simplification and to provide a useful shorthand term, subtasks (3) and (4) are referred to collectively as *object and event detection and response* (*OEDR*) (see 3.19).

NOTE 3: In this document, reference is made to "complete(ing) the *DDT*." This means fully performing all of the subtasks of the *DDT*, whether that role is fulfilled by the (human) *driver*, by the *driving automation system*, or by a combination of both.

NOTE 4: Figure 2 displays a schematic view of the driving task. For more information on the differences between *operational*, tactical, and strategic functions of driving, see 8.11.

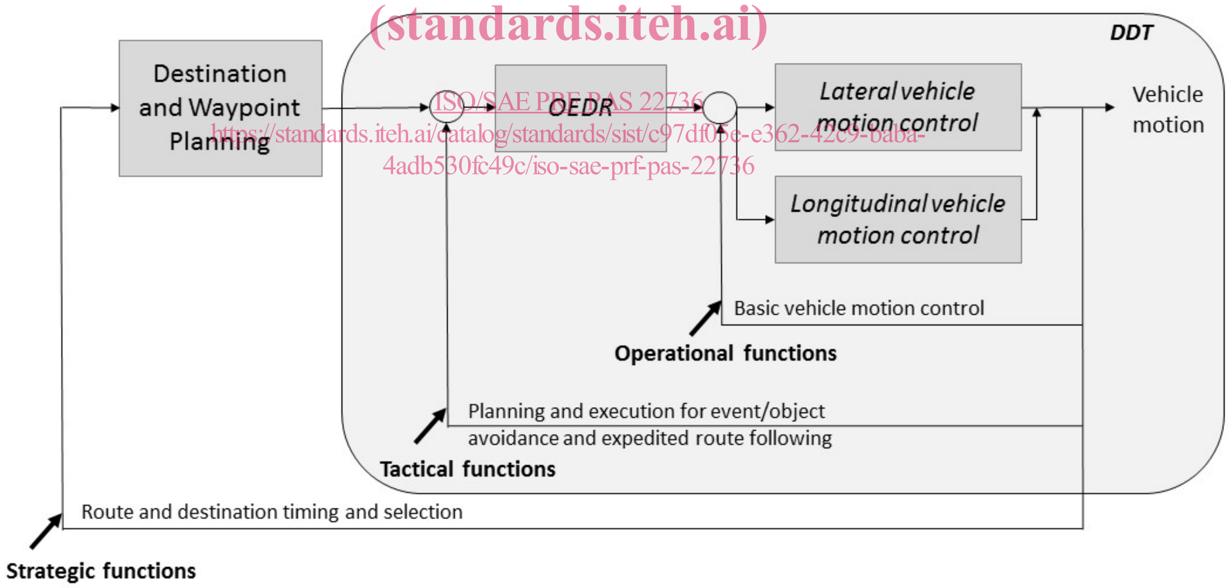

Figure 2 — Schematic (not a control diagram) view of driving task showing DDT portion

For purposes of *DDT* performance, Level 1 *driving automation* encompasses automation of part of the innermost loop (i.e., either lateral *vehicle* motion control functionality or longitudinal *vehicle* motion control functionality and limited *OEDR* associated with the given axis of *vehicle* motion control); Level 2 *driving automation* encompasses automation of the innermost loop (lateral and longitudinal *vehicle* motion control and limited *OEDR* associated with *vehicle* motion control), and Level 3 to 5 *driving automation* encompasses automation of both inner loops (lateral and longitudinal *vehicle* motion control and complete *OEDR*). Note that *DDT* performance does not include strategic aspects of driving (e.g., determining whether, when, and where to travel).

3.11 FAILURE MITIGATION STRATEGY

A *vehicle* function (not an *ADS* function) designed to automatically bring an *ADS*-equipped *vehicle* to a controlled stop in path following either: (1) prolonged failure of the *fallback-ready user* of a Level 3 *ADS feature* to perform the *fallback* after the *ADS* has issued a *request to intervene*, or (2) occurrence of a *system failure* or external event so catastrophic that it incapacitates the *ADS*, which can no longer perform *vehicle* motion control in order to perform the *fallback* and achieve a *minimal risk condition*. (See 8.6.)

NOTE: Some *vehicles* equipped with Level 2 *driver support features* may be designed to brake a *vehicle* to a full stop if the *driver* fails to indicate his/her continued *supervision* of *feature* performance during engagement. Although that is similar in function to a *failure mitigation strategy* as defined above, the term "*failure mitigation strategy*" is reserved for *ADS features* that do not require *driver supervision*.

3.12 [DYNAMIC DRIVING TASK (DDT)] FALLBACK

The response by the *user* to either perform the *DDT* or achieve a *minimal risk condition* (1) after occurrence of a *DDT* performance-relevant *system failure*(s), or (2) upon *operational design domain* (*ODD*) exit, or the response by an *ADS* to achieve *minimal risk condition*, given the same circumstances.

NOTE 1: The *DDT* and the *DDT fallback* are distinct functions, and the capability to perform one does not necessarily entail the ability to perform the other. Thus, a Level 3 *ADS*, which is capable of performing the entire *DDT* within its *ODD*, may not be capable of performing the *DDT fallback* in all situations that require it and thus will issue a *request to intervene* to the *DDT fallback-ready user* when necessary (see Figures 3 to 6).

NOTE 2: Some Level 3 *features* may be designed to automatically perform the *fallback* and achieve a *minimal risk condition* in some circumstances, such as when an obstacle-free, adjacent shoulder is present, but not in others, such as when no such road shoulder is available. The assignment of Level 3 therefore does not restrict the *ADS* from automatically achieving the *minimal risk condition*, but it cannot guarantee automated achievement of *minimal risk condition* in all cases within its *ODD*. Moreover, automated *minimal risk condition* achievement in some, but not all, circumstances that demand it does not constitute Level 4 functionality.

NOTE 3: At Level 3, an *ADS* is capable of continuing to perform the *DDT* for at least several seconds after providing the *fallback-ready user* with a *request to intervene*. The *DDT fallback-ready user* is then expected to resume manual *vehicle operation*, or to achieve a *minimal risk condition* if s/he determines it to be necessary.

NOTE 4: At Levels 4 and 5, the *ADS* must be capable of performing the *DDT fallback* and achieving a *minimal risk condition*. Level 4 and 5 *ADS*-equipped *vehicles* that are designed to also accommodate *operation* by a *driver* (whether in-*vehicle* or remote) may allow a *user* to perform the *DDT fallback*, when circumstances allow this to be done safely, if s/he chooses to do so (see Figures 7 and 8). However, a Level 4 or 5 *ADS* need not be designed to allow a *user* to perform *DDT fallback* and, indeed, may be designed to disallow it in order to reduce crash risk (see 8.9).

NOTE 5: While a Level 4 or 5 *ADS* is performing the *DDT fallback*, it may be limited by design in speed and/or range of lateral and/or longitudinal *vehicle* motion control (i.e., it may enter so-called "limp-home mode").

NOTE 6: While performing *DDT fallback*, an *ADS* may *operate* temporarily outside of its *ODD* (see 3.21 NOTE 1).

EXAMPLE 1: A Level 1 adaptive cruise control (ACC) *feature* experiences a *system failure* that causes the *feature* to stop performing its intended function. The human *driver* performs the *DDT fallback* by resuming performance of the complete *DDT*.

EXAMPLE 2: A Level 3 *ADS feature* that performs the entire *DDT* during traffic jams on freeways is not able to do so when it encounters a crash scene and therefore issues a *request to intervene* to the *DDT fallback-ready user*. S/he responds by taking over performance of the entire *DDT* in order to maneuver around the crash scene (see Figure 4). (Note that in this example, a *minimal risk condition* is not needed or achieved.)

EXAMPLE 3: A Level 4 *ADS-dedicated vehicle* (*ADS-DV*) that performs the entire *DDT* within a geo-fenced city center experiences a *DDT* performance-relevant *system failure*. In response, the *ADS-DV* performs the *DDT fallback* by turning on the hazard flashers, maneuvering the *vehicle* to the road shoulder and parking it, before automatically summoning emergency assistance (see Figure 7). (Note that in this example, the *ADS-DV* automatically achieves a *minimal risk condition*.)

The following Figures 3 through 8 illustrate *DDT fallback* at various levels of *driving automation*.

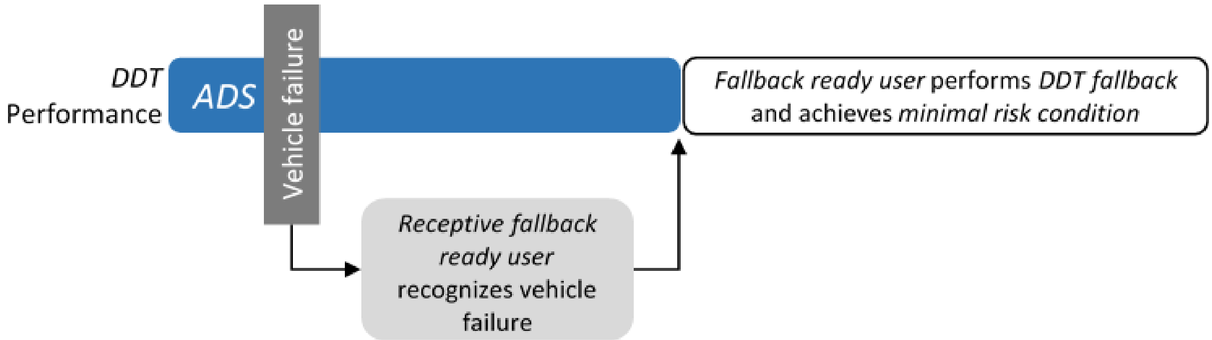

Figure 3

Sample use case sequence at Level 3 showing *ADS* engaged and occurrence of a *vehicle system failure* that prevents continued *DDT* performance. *User* performs *fallback* and achieves a *minimal risk condition*.

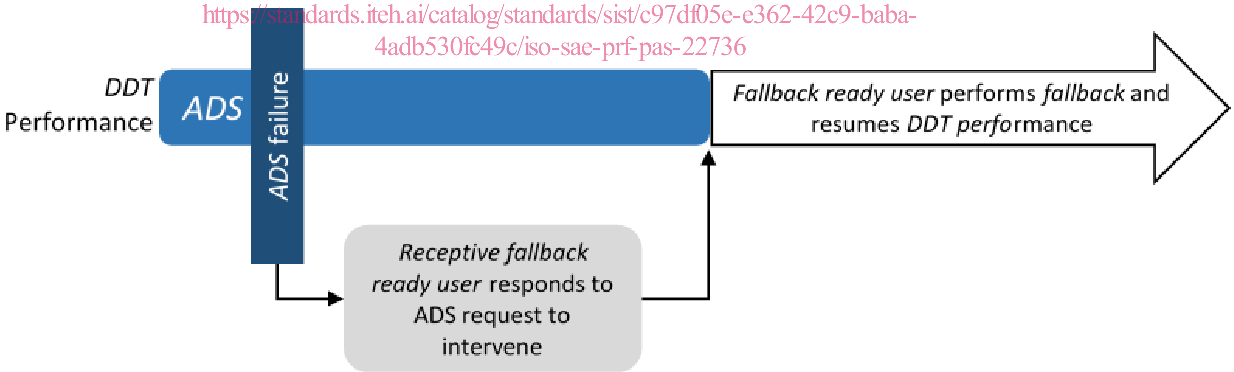

Figure 4

Sample use case sequence at Level 3 showing *ADS* engaged and occurrence of an *ADS system failure* that does not prevent continued *DDT* performance. *User* performs the *fallback* and resumes *DDT* performance.