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Recommendations concerning Safety Requirements for the Assessment of Automated Driving Systems and ADS Vehicles

Submitted by the Working Party on Automated/Autonomous and Connected Vehicles*

The text reproduced below was approved by the Working Party on Automated/Autonomous and Connected Vehicles (<mark>GRVA) during its sixteenth session</mark> (see ECE/TRANS/WP.29/GRVA/16, para. xx). The text provides interim draft recommendations concerning common safety requirements for Automated Driving Systems (ADS) and vehicles equipped with ADS that can be adapted for use under the 1958, 1997, and 1998 Agreements. This text was prepared pursuant to the Terms of Reference (see ECE/TRANS/WP.29/1147, Annex V) establishing the Informal Working Group on Functional Requirements for Automated and Autonomous Vehicles (FRAV). It is submitted to the World Forum for Harmonization of Vehicle Regulations (WP.29) and to the Administrative Committee (AC.1) for consideration at their <mark>June 2023</mark> sessions.

> *This document has been prepared solely to support FRAV deliberations on preparations for drafting an interim submission to the June 2023 WP.29 session. Its contents are designed to highlight editorial issues, including formatting, that may arise in drafting the submission based on the contents of Document 5. This document is for discussion purposes and should not be understood as a proposal for specific provisions.*

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* In accordance with the programme of work of the Inland Transport Committee for 2022 as outlined in proposed programme budget for 2022 (A/76/6 (part V sect. 20) para 20.76), the World Forum will develop, harmonize and update UN Regulations in order to enhance the performance of vehicles. The present document is submitted in conformity with that mandate.

Recommendations concerning Safety Requirements for the Assessment of Automated Driving Systems and ADS Vehicles

I.   Introduction

1.   This section provides background information concerning the deliberations on safety requirements for Automated Driving Systems (ADS).

2.   ADS present challenges to the safety regulator that require new concepts, tools, and methodologies in addition to those historically used for previous vehicle technologies and systems.

3.   This section explains the considerations behind the recommendations for ensuring ADS safety presented in this document.

A.   Driving

4.   Driving is a complex activity with traffic laws and codes of behaviour based upon human cognitive strengths and weaknesses.

5.   Driving involves three behavioural levels: strategic, tactical, and operational.[1]

6.   The strategic level concerns general trip planning such as determination of trip goals, the route to be used, the modal choice, and evaluation costs and risks associated with these decisions.

7.   The tactical level concerns assessment of the real time driving environment and decisions on driving responses to negotiate the directly prevailing circumstances within the constraints of the general strategic goals.

8.   The operational level concerns vehicle-control capabilities and the application of the capabilities to execute the tactical choice.

9.   For example, a decision to drive from home to a workplace involves a strategic assessment of the current conditions, the risks involved in driving under those conditions, and the probability for arriving at work on time. While driving, the driver makes tactical decisions based on conditions encountered along the way such as to change lanes or turn onto another street. In changing lanes, the driver makes a tactical assessment that the lane change is feasible and actuates the direction indicators before operationally steering the vehicle while maintaining an appropriate speed, often with micro adjustments in response to changes in the behaviour of other vehicles relevant to executing the change of lane.

10.   These behavioural levels relate to perception, information processing, and decision making under uncertainty.[2] Driving can be considered an exercise in risk management within the context of achieving strategic goals. Drivers assess and respond in real time to perceived risks in the road environment.

11.   The real-time tactical and operational functions required to operate a vehicle in on-road traffic are collectively known as the Dynamic Driving Task (DDT). As noted above, these functions may be performed within the context of strategic goals, but the DDT itself excludes such strategic functions. These functions may overlap or operate in combination such as in a tactical decision in response to road conditions to deviate from the original strategy to follow a particular route.

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

[2]   Michon, J.A., 1979 (update 2008). "Dealing with Danger", Summary Report of the Workshop on Physiological and Psychological Factors in Performance under Hazardous Conditions with Special Reference to Road Traffic Accidents, Gieten, Netherlands, May 23-25, 1978.

12. Although the DDT comprises individual functions (in some research, broken down into thousands of subtasks), the DDT itself refers to the whole of the functions required to operate the vehicle. In this aspect, performance of the DDT cannot be split or allocated. Either the ADS or the driver performs the DDT. A system that cannot perform the entire DDT can only assist the driver's performance of the DDT.

13. Tactical functions include but are not limited to manoeuvre planning, enhancing conspicuity (lighting, signalling, gesturing, etc.), and managing interactions with other road users. Tactical functions generally occur over a period of seconds.

14. Operational functions include but are not limited to lateral vehicle motion control (steering) and longitudinal vehicle motion control (acceleration and deceleration). This operational effort involves split-second reactions, such as making micro-corrections while driving.

15. The DDT cannot be apportioned because these functions are interdependent and operate as a whole. Operational and tactical functions are inherent in monitoring the driving environment (object and event detection, recognition, classification, and response preparation) and in object and event response execution.

B. Automated driving

16. While the previous section concerns driving in general, human and automated driving have notable differences.

17. Unlike human drivers broadly licensed to operate a vehicle on all roadways under all conditions, ADS may be designed for specific purposes and to operate under specific conditions.

18. The diversity of ADS and ADS vehicle configurations requires attention to the roles, if any, that a vehicle user may play in the use of the vehicle. ADS vehicles may, or may not, be designed to carry human occupants. They may, or may not, be designed for use by a driver. They may permit or prohibit driver activation of the ADS while the vehicle is moving.

19. Safety requirements must account for the role(s) a user may have in the use of the ADS and/or ADS vehicle such as driver or passenger. These human-user roles may involve vehicle occupants, or they may be external to the vehicle.

20. Roles may change during the course of a trip. For example, in some configurations, when a driver activates the ADS while the vehicle is moving, the ADS becomes the sole vehicle operator (i.e., performing the DDT) and the driver shifts to the role of fallback user. For safety reasons, this fallback-user role entails an obligation to remain receptive and responsive to ADS requests to assume control over the vehicle (i.e., to return to the role of driver).

21. The requirements recommended in this document address misuse prevention and the safety of user interactions such as transitions of vehicle control; however, the fallback-user role also suggests traffic laws to codify obligations of fallback users to maintain their readiness to drive the vehicle during a trip.

22. The conditions under which an ADS is designed to operate are known as the Operational Design Domain (ODD), including aspects such as roadway speed limits, road designs (surface, geometry, infrastructure, etc.), weather conditions, and traffic densities. The ODD may include constraints or limitations on ADS use such as maximum vehicle speed, maximum rate of rainfall, or road type.

23. The ADS requirements must address the diversity of driving conditions that may arise singly and in combination within the ODD.

24. In addition, the requirements must address ADS that may be designed to operate in more than one ODD. As long as the ADS safely performs the DDT within each ODD, there is no reason to limit the definition of sets of ADS capabilities designed to operate the vehicle under separate sets of ODD conditions.

25.   Driver performance of the DDT is based on human physical, sensory, and cognitive capabilities. ADS performance of the DDT is based on hardware and software. Therefore, the definition of DDT as applied to an ADS must be understood in these terms.

26.   For an ADS, the operational and tactical functions of the DDT can be logically grouped under three general categories:

Sensing and perception

27.   ADS sensing and perception includes monitoring the driving environment via object and event detection, recognition, and classification. These functions include perceiving other vehicles and road users, the roadway and its fixtures, objects in the vehicle's driving environment, and relevant environmental conditions, including sensing ODD boundaries, if any, of the ADS feature and positional awareness relative to driving conditions.

Planning and decision

28.   Planning and decision includes anticipation and prediction of actions that other road users may take, response preparation, and manoeuvre planning.

Control

29.   Control refers to object and event response execution via lateral and/or longitudinal motion control and enhancing vehicle conspicuity via lighting and signalling.

C. Automated Driving Systems

30.   Based on the above, ADS need to be understood in terms that cover the DDT (tactical and operational functions required to operate the vehicle in traffic) and the ODD (conditions under which such ADS capabilities are made available to a user).

31.   An ADS consists of hardware and software that are collectively capable of performing the entire DDT on a sustained basis within one or more ODD.

32.   Driving automation systems that require human support to fulfil aspects of the DDT fall below the level of an ADS.

33.   In order to cover the diversity of ADS configurations, uses, and limitations on use, these recommendations define ADS in terms of functions and features.

D.   ADS functions

34.   ADS integrate subsets of hardware and software (i.e., functions) designed to perform aspects of the DDT.

35.   ADS functions, in general, correspond to system-level capabilities integrated into the ADS design.

36.   A function enables the ADS to perform one or more elements of the DDT.

37.   In addition to DDT-specific functions, an ADS function may contribute to ensuring the safe operational state of the ADS and/or preventing use when the ADS is not in a safe operational state.

38.   ADS functions may also ensure the correct use of the ADS and safe interactions with a user such as in transitions of control.

39.   Functions represent the first level of safety that an ADS must fulfil. These functions correspond to essential capabilities without which an ADS cannot be deemed safe for use in traffic.

40.   However, functions that enable performance of the DDT and functions that ensure safe use, including the safety of user interactions, involve distinctly different objectives and requirements.

Safe ADS performance of the DDT

41.   Requirements to ensure safe ADS performance of the DDT address the functional and behavioural objectives described by the WP.29 Framework Document on Automated Vehicles: ADS operation of the vehicle shall not cause crashes or disrupt traffic and ADS shall avoid crashes where preventable.

42.   The requirements recommended in this document aim to ensure that each ADS is capable of performing the entire DDT to the extent necessary to operate the vehicle within its ODD. Because the performance of tactical and operational functions is dependent on the prevailing traffic conditions, these DDT requirements specify that the ADS must demonstrate behavioural competencies across traffic scenarios covering its ODD. The behavioural competencies inherently require functional capabilities to perform the DDT.

43.   These recommendations intentionally omit specifications for individual DDT functions. As noted above, performance of the DDT is dependent on traffic conditions where such functions cannot be limited to representative specifications. For example, a representative crash test at 56 kph ensures safety at lower speeds. This approach cannot be applied to driving where safety involves real time tactical and operational adaptation to dynamic road conditions. Tactical and operational functions are interdependent where the complexity of their interactions needs to be assessed under diverse traffic conditions.

44.   By ensuring that an ADS will be subjected to traffic scenarios covering its ODD, the assessment of the behavioural competencies demonstrated by the ADS under those scenarios verifies the capability of the ADS to perform the entire DDT necessary to navigate its ODD.

Safe use of ADS and ADS vehicles

45.   Ensuring the safety of interactions between ADS and their users demands a human-centred focus on user needs, strengths, and weaknesses.

46.   Trust often determines automation usage. Operators may not use a reliable automated system if they believe it to be untrustworthy. Conversely, they may continue to rely on automation even when it malfunctions.[3] ADS should be designed to foster a level of trust that is aligned with their capabilities and limitations to ensure proper use.

47.   These recommendations address user understanding of the ADS configuration, intended uses, and limitations on use, simplicity in defining and communicating user roles and responsibilities, clarity and commonality across ADS controls, requests, and feedback, and both misuse prevention as well as safeguards in the event of misuse.

48.   The recommendations encourage Safety Management Systems that integrate Human-Centred Design Processes to ensure safe interactions between ADS and their users.

49.   These human-centred processes should include analyses by qualified personnel of user needs and risk, setting safety and usability objectives, specifying user requirements and ensuring user understanding and context to produce design solutions that meet the requirements.

50.   ADS should be evaluated, particularly under real-world testing on real users (i.e., not the people who are developing the products).

51.   ADS performance should be monitored in the field and this information should be used to set future design targets and evaluate designs against these requirements.

52.   These recommendations for user safety align with this human-centred approach to identify functions that must be integrated into ADS designs to ensure safe interactions and prevent misuse.

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[3] Raja Parasumaran and Victor Riley. Humans and Automation: Use, Misuse, Disuse, Abuse. Human Factors, 1997, 39(2), 230-253.

E. ADS features

53. Although an ADS performs the entire DDT on a sustained basis, an ADS may be designed to operate within more than one ODD.

54. Each set of ODD-specific capabilities has a unique set of constraints defining the conditions under which the ADS may be used.

55. An ADS feature refers to an application of ADS capabilities designed for use within a defined ODD. In the case of an ADS designed to operate within a single ODD, the ADS and the ADS feature are synonymous.

56. ADS functions enable each ADS feature to operate the vehicle within the ODD of the feature. ADS functions may be used by more than one ADS feature and ADS features may use some or all of the ADS functions.

57. This document recommends a feature-based assessment of ADS. In cases where an ADS has more than one feature (i.e., is designed to operate in more than one ODD), each feature should be assessed to ensure that the ADS provides the functions necessary for performance of the entire DDT within the ODD of each feature.

II.   Purpose

58. This document provides recommendations for ADS safety requirements intended to inform WP.29 discussions on future initiatives that may be proposed under the 1958, 1997, and/or 1998 Agreements.

59. Usage of the verbal forms "shall" and "may" should be understood within the context of providing recommendations per the preceding paragraph.

III.   Terms and Definitions

60. This section defines terms used in this document.

61. Use of these terms and their definitions is recommended in the development of legal requirements related to ADS and ADS vehicles.

62. *"Automated Driving System (ADS)"* means the hardware and software that are collectively capable of performing the entire DDT on a sustained basis.

63. *"(ADS) feature"* means an application of ADS hardware and software designed specifically for use within an ODD.

64. *"(ADS) function"* means an ADS hardware and software capability designed to perform a specific portion of the DDT.

65. *"ADS vehicle"* means a vehicle equipped with an ADS.

66. *"Behavioural competency"* means an expected and verifiable capability of an ADS feature to operate a vehicle within the ODD of the feature.

67. *"Critical scenario"* means a traffic scenario representing unusual and/or unexpected object behaviours and/or road conditions.

68. *"Dynamic Driving Task (DDT)"* means the real-time operational and tactical functions required to operate the vehicle in on-road traffic. (See Section I.A. for general background and especially Section I.B., paragraphs 25-29, for application to ADS.)

69. *"Failure scenario"* means a traffic scenario representing a system failure that compromises the capability of the ADS to perform the entire DDT.

70. *"(ADS) fallback response"* means an ADS-initiated transition of control or an ADS-controlled procedure to place the vehicle in a minimal risk condition.

71. *"Fallback user"* means a user designated to assume the role of driver upon completion of a transition of control.

72.   *"Fallback-user response"* means the response of a fallback user to a request for fallback-user intervention in vehicle control by the ADS.

73.   *"Minimal Risk Condition (MRC)"* means a stable and stopped state of the vehicle that reduces the risk of a crash.

74.   *"Nominal scenario"* means a traffic scenario representing usual and/or expected object behaviours and/or road conditions.

75.   *"Operational Design Domain (ODD)"* means the operating conditions under which an ADS feature is specifically designed to function.

76.   *"Operational functions"* refer to basic capabilities such to control lateral and longitudinal motion of the vehicle.

77.   "Other *road user (ORU)"* means any entity using a roadway and capable of safety-relevant interaction with an ADS vehicle.

78.   *"Priority vehicle"* means a vehicle subject to exemptions, authorizations, and/or right-of-way under traffic laws while performing a specified function.

79.   *"Real time"* means the actual time during which a process or event occurs.

80.   *"Road-safety agent"* means a human being engaged in directing traffic, enforcing traffic laws, maintaining/constructing roadways, and/or responding to traffic incidents.

81.   *"Tactical functions*" refer to the real-time planning, decision, and execution of manoeuvres.

82.   *"Traffic scenario"* means a description of one or more real-world driving situations that may occur during a given trip.

83.   *"Transition of control (TOC)"* means a procedure by which the ADS hands over dynamic control of the vehicle to the fallback user such that the fallback user is given the role of driver upon completion.

84.   *"(ADS) User"* means a human being using an ADS where dynamic control of the vehicle is entirely maintained on a sustained basis by the ADS performance of the DDT.

85.   *"Useful life (of an ADS vehicle)"* means the duration during which an ADS vehicle is in an operational state under which it may be driven on public roads regardless of the operational state of the ADS.

IV.   ADS Documentation

86.   This section concerns the availability and/or provision of information regarding an ADS and/or ADS vehicle. Unless otherwise specified, "documentation" should be understood as agnostic regarding the form or format for substantiation of such information.

87.   The manufacturer shall provide written information on the ADS configuration and the intended uses and limitations on the use of its feature(s).

88.   The manufacturer shall describe means made available to the public to promote a correct understanding of the intended uses and limitations on the use of the ADS and its feature(s).

89.   The manufacturer shall establish terms for the correct use of the ADS and its feature(s).

90.   The manufacturer shall provide written information on the roles and responsibilities of the ADS vehicle user(s), including on permissible user activities while the ADS is performing the DDT.

91.   The manufacturer shall provide written instructions for the activation and deactivation of the ADS.

92.   The manufacturer shall provide written information on ADS responses to ADS vehicle user interventions in the dynamic control of the vehicle.

93.   The manufacturer shall provide written descriptions of the transfer of control procedures, including ADS notifications and fallback user responses.

94.   The manufacturer shall provide information detailing the human-machine interactions, including HMI tell-tales, indicators, and displays.

95.   The manufacturer shall establish the ODD conditions and boundaries of each ADS feature in measurable and/or verifiable terms in accordance with Appendix A.

96.   The manufacturer shall list the potential faults identifiable by the diagnostic system(s) of the ADS.

V.   ADS Safety Requirements

97.   The following subsections recommend criteria for validating the safety of ADS and/or ADS vehicles.

98.   Subsections A, B, and C concern ADS performance of the DDT. The recommended requirements have been drafted for worldwide application. These requirements, therefore, do not specify technical performance limits due to the diversity of ODD-specific conditions and requirements that may influence safe performance of the DDT.

99.   Driving fundamentally involves real-time risk management under prevailing traffic conditions. Therefore, safe ADS performance of the DDT depends upon the conditions presented under each individual scenario.

100.   Annex A provides a recommended approach to scenario generation and to the establishment of ADS behavioural competencies to be demonstrated under these scenarios. Each scenario is associated with one or more behavioural competencies.

101.   The ODD-based approach to scenario generation provides analytical methods to ensure that the scenarios cover the ODD of the ADS feature(s). These scenarios address nominal, critical, and failure situations to enable assessments in accordance with the WP.29 Framework Document on Automated Vehicles (FDAV)[4].

102.   The behavioural competencies define ADS responses that comply with the following global requirements (Subsections A, B, and C) within the bounds of a relevant safety model quantifying dimensions for assessment of ADS performance (as described in Annex A). The behavioural competencies align with the layer of abstraction of the scenario to provide verifiable criteria at the functional layer down to measurable criteria at the concrete layer of abstraction.

103.   Compliance with the recommended requirements under Subsections A, B, and C is determined by verifying that the ADS demonstrates the behavioural competencies associated with the scenarios relevant to the ODD of its features.

104.   These requirements shall be applied in the definition of behavioural competencies to be demonstrated under traffic scenarios.

A.   ADS Performance of the DDT under Nominal Traffic Scenarios

105.   The following recommendations address the Framework document on automated/autonomous vehicles (ECE/TRANS/WP.29/2019/34/Rev.2) guidance that ADS vehicles shall not cause traffic accidents or disrupt traffic.

106.   Compliance with this broad objective can be verified by subjecting the ADS and/or ADS vehicle to nominal traffic scenarios representing usual and expected traffic conditions and behaviours. By minimizing risk factors outside the ADS nominal performance of the DDT, the impact of the ADS driving behaviour on other road users and the flow of traffic can be isolated.

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[4] ECE/TRANS/WP.29/2019/34/Rev.2

107.   This section recommends functional and behavioural requirements for assessing the ADS performance of the DDT under normal operational and driving conditions.

Functional Requirements

108.   The ADS shall be capable of performing the entire DDT within the ODD of its feature(s).

109.   The ADS shall recognize the conditions and boundaries of the ODD of its feature(s) pursuant to the manufacturer's declaration under Section IV.

110.   The ADS shall be able to determine when the conditions are met for activation of each feature.

111.   The ADS shall detect and respond when one or more ODD conditions are not or are no longer fulfilled.

112.   The ADS shall be able to anticipate foreseeable exits from the ODD of each feature.

113.   The ADS shall detect and respond to objects and events relevant to its performance of the DDT. See Appendix B.

114.   The ADS shall detect objects in and around its path of travel that exceed a minimum size.

115.   The ADS shall recognize objects as static or mobile.

116.   The ADS shall recognize markings and signals used to indicate priority vehicles within the ODD of its feature(s).

117.   The ADS shall classify priority vehicles within the ODD of its feature(s) in accordance with the relevant traffic law(s).

Behavioural Requirements

118.   The driving behaviour of the ADS shall not disrupt the flow of traffic.

119.   The driving behaviour of the ADS shall not require other road users to take evasive action to avoid a collision with the ADS vehicle.

120.   The driving behaviour of the ADS shall not cause a collision.

121.   The ADS shall operate the vehicle at safe speeds.

122.   The ADS shall maintain safe lateral and longitudinal distances between the ADS vehicle and other road users.

123.   The ADS shall adapt its driving behaviour to the surrounding traffic conditions (e.g., by avoiding disruption to the flow of traffic).

124.   The ADS shall adapt its driving behaviour in line with safety risks (e.g., by giving all road users and passengers the highest priority).

125.   The ADS shall comply with traffic rules and regulations relevant to its performance of the DDT under each traffic scenario within the ODD of its features. See Annex A for recommendations on converting ODD-specific traffic rules into elements applicable to scenario generation and the establishment of behavioural competencies.

126.   The ADS shall yield the right of way to priority vehicles in service in accordance with the relevant traffic law(s).

127.   ADS shall comply with the traffic laws in nominal conditions, except when in specific circumstances or when necessary to enhance the safety of the vehicle's occupants and/or other road users.

128.   The ADS shall interact safely and smoothly with other road users.

129.   The ADS shall signal intended changes of direction.

130.   The ADS shall signal its intention to place the vehicle in an MRC.

131.   The ADS shall signal its operational status (active/inactive) as needed.

B.   ADS Performance of the DDT under Critical Traffic Scenarios

132.   The following recommendations address the Framework document on automated/autonomous vehicles (ECE/TRANS/WP.29/2019/34/Rev.2) guidance that ADS vehicles shall avoid collisions where preventable.

133..   Compliance with this broad objective can be verified by subjecting the ADS and/or ADS vehicle to critical traffic scenarios representing unusual or unexpected traffic conditions and/or object behaviours that elevate road safety risks. By introducing foreseeable external risk factors into scenarios, the capability of the ADS to manage safety-critical events that may arise within its ODD can be assessed.

134.   This section recommends functional and behavioural requirements for assessing the ADS performance of the DDT under critical driving conditions.

135.   The ADS shall avoid collisions with safety-relevant objects where possible.

136.   In the event of a collision, the ADS shall stop the vehicle and deactivate.

C.   ADS Performance of the DDT under System Failure Scenarios

137.   The following recommendations address the Framework document on automated/autonomous vehicles (ECE/TRANS/WP.29/2019/34/Rev.2) guidance regarding the assurance of system safety and responses to system failures that compromise the capability of the ADS to perform the entire DDT.

138.   The ADS shall detect faults, malfunctions, and abnormalities that compromise its capability to perform the entire DDT within the ODD of its feature(s) per the manufacturer's documentation under Section IV.

139.   The ADS may continue to operate in the presence of [faults/failures] that do not prevent that ADS from fulfilling the safety requirements applicable to the ADS.

D.   Interactions between Users of ADS Vehicles and the ADS

140.   User interaction with and the interface of ADS (features) shall have a high-level commonality of design.

141.   The ADS shall interact safely with the authorized user in the vehicle.

142.   The ADS should be designed to foster a level of trust that is aligned with its capabilities and limitations to ensure proper use of the system.

143.   The operation of the interaction shall use of common sequence of states in the transition/activation/overriding/.

144.   ADS interactions shall have a limited number of user roles.

145.   ADS interactions shall have a limited number of potential transitions.

146.   ADS interactions shall have a limited number of settings.

147.   ADS interactions shall have a limited number of interaction modes.

148.   The ADS HMI shall provide clear and unambiguous information to the user.

149.   The vehicle shall indicate the ADS capabilities in terms of their automated [features] and their ODD.

150.   The ADS shall inform the user on the current ADS status.

151.   The ADS shall inform the user on the availability of the ADS feature(s).

152.   The ADS shall inform the user of the current user role.

153.   The ADS shall inform the user of their responsibilities.

154.   The ADS shall inform the user of permissible non-driving-related activities.

155.   The ADS shall inform the user of potential roles to activate.

156.   The ADS shall inform the user of the vehicle speed, range, and time to fuel.

157.   The ADS shall ensure safe ADS feature activation.

158.   The ADS shall inform the user on the upcoming ODD boundaries.

159.   The ADS shall inform the user of upcoming actions or changes in user role.

160.   The ADS shall inform the user of upcoming decisions/manoeuvres.

161.   The ADS shall inform the user of the estimated time until take-over under normal conditions.

162.   The ADS shall inform the user on TOC-related communications.

163.   The ADS shall prioritise and present safety-related information in a clear and unambiguous manner.

164.   An ADS which permits a TOC shall be designed to ensure safe TOC.

165.   An ADS which permits user takeovers of control shall be designed to ensure safe user-initiated takeovers.

166.   TOC shall follow a verifiable common sequence of actions and states, including changes in the user role.

167.   TOC shall return to a common default user role, normally to a fully engaged driver without any control assistance (conventional driver; safety systems such as ESC will remain activated).

168.   The ADS shall continuously verify whether the user is available for TOC.

169.   The ADS shall adapt the TOC procedure to the state of the user and/or of the ADS, including to the available time budget where feasible.

170.   The ADS shall warn the user when they are not available when required for a TOC.

171.   The ADS shall register the user response indicating readiness for a TOC.

172.   The ADS shall verify that the user is in stable control of the vehicle to complete the TOC.

173.   During a TOC, the ADS shall remain active until the TOC has been completed or the ADS has completed a fallback to an MRC.

174.   The use of the ADS shall be supported by documentation and tools to facilitate user understanding of the functionality and operation of the system.

175.   The ADS shall be designed to prevent misuse and errors in operation.

176.   The ADS shall be designed to prevent inadvertent activation or deactivation.

177.   The controls dedicated to the ADS shall be clearly distinguishable from other controls.

178.   The ADS shall provide feedback when the user attempts to enable unavailable functions.

179.   The ADS shall evaluate the safety of user inputs to vehicle-control functions.

180.   The ADS shall ensure safe ADS feature activation.

181.   The ADS shall inform the user that preconditions for activation are met.

182.   The activation shall follow a verifiable common sequence of actions and states.

183.   The ADS shall provide confirmation that the system is activated.

184.   In the absence or insufficiency of a fallback-user response, the ADS shall initiate a fallback response to place the vehicle in an MRC.

185.   The driver may be permitted to operate the vehicle following completion of a fallback response to place the vehicle in an MRC.

186.   The ADS shall permit the user to assume control over the vehicle at any time subject to ADS safety evaluation of the user inputs to the vehicle-control functions.

187.   An ADS which permits user takeovers of control shall be designed to ensure safe user-initiated takeovers.

188.   The user is allowed to initiate a take-over process of the ADS.

189.   The ADS may momentarily delay deactivation of driving control when immediate human resumption of control could compromise safety.

190.   The ADS shall provide clear and specific feedback of the completion of a user-initiated take over.

191.   The user initiated take over shall return to a common default user role, normally being a fully engaged driver without any control assistance systems with the exception of mandated systems (conventional driver).

192.   The use of the ADS shall be supported by documentation and tools to facilitate user understanding of the functionality and operation of the system.

193.   The ADS manufacturer / vehicle manufacturer (as appropriate) shall create documentation available for audit on its intended educational approach, including theoretical and practical training and how its HMI design aligns with common HMI and interaction.

194.   The ADS manufacturer/ADS vehicle manufacturer shall provide an owner's manual describing in accordance with Appendix C.

195.   The ADS manufacturer / vehicle manufacturer (as appropriate) shall create in-vehicle tools that support the user in correct operation (coaching) and gives prompt feedback on erroneous operation.

196.   The integration of an ADS which permits a TOC with the entire vehicle HMI shall be assured.

197.   The entire HMI design should be defined and the integration with ADS HMI assured by analysis and/or test.

198.   The vehicle and ADS HMI needs to take into account potential impairments of users (such as colour blindness, impaired hearing) which do not require specific hardware adaptations of the vehicle.

199.   Passenger-carrying ADS vehicles that may operate without a fallback user shall provide means for ensuring passenger safety.

200.   The ADS vehicle shall stop in accordance with the designated route.

201.   The ADS vehicle shall open the service doors when at a stop and close them before starting moving again.

202.   The ADS vehicle shall place the ADS vehicle in an MRC upon demand of the vehicle occupants via application of a designated control (button).

203.   The ADS vehicle shall provide a sound notification to the ADS vehicle occupants in the case of emergency braking.

204.   The ADS vehicle shall provide audio messages to the ADS vehicle occupants about approaching a stop and starting the motion after a stop.

205.   The ADS vehicle shall provide voice communication between the occupant compartment and a remote operation dispatcher/assistance personnel.

206.   The ADS shall signal its intention to place the vehicle in an MRC.

207.   The ADS shall signal faults as identified in the manufacturer's documentation under Section IV.

208.   The ADS shall signal required system maintenance if any.

E.   Safety throughout the Useful Life of the ADS Vehicle

209.   This section addresses the safe use of an ADS during the useful life of the ADS vehicle.

210.   The ADS shall detect malfunctions and abnormalities that compromise its capability to perform the entire DDT as provided by the manufacturer under Section IV.

211.   The ADS shall perform self-diagnosis of system integrity in accordance with the manufacturer documentation provided under Section IV.

212.   The ADS shall be accessible for the purposes of maintenance and repair to authorized persons.

213.   The ADS shall be designed to protect against unauthorized access to and modification of the ADS functions.

214.   The ADS shall prohibit activation of an ADS feature in the presence of a fault in an ADS function that compromises the ADS capability to perform the entire DDT within the ODD of the feature.

215.   In response to a fault, the ADS may limit the ODD to enable activation and use of a feature impacted by the fault provided that the ADS continues to provide the functions necessary to perform the entire DDT within the limited ODD.

216.   Remote termination of the availability of the ADS or its feature(s) to the user by an authorized entity shall be possible in ADS vehicles equipped with wireless connectivity enabling access to the ADS (e.g., over-the-air software update capability).

217.   ADS safety shall be ensured in the event of discontinued production, support, and/or maintenance.

218.   Pursuant to vehicle damage, ADS reactivation shall not be possible until the safe operational state of the ADS has been verified.

VI.   Appendices

A.   ODD Descriptions for ADS Features

This appendix provides mandatory guidelines for the documentation of ODD conditions under which an ADS is designed to operate. These guidelines promote consistency across manufacturer descriptions of each ODD to facilitate use of this information in ADS assessments.

ODD Documentation

1.   To the extent provided, the documentation shall use the terms and measurement units provided in the Compendium of ODD Conditions.

2.   The manufacturer may describe additional conditions where not provided for in the Compendium of ODD Conditions.

3.   Each ODD condition and/or boundary shall be defined in measurable and/or verifiable terms.

Compendium of ODD Conditions

1.   *Rain* means water droplets of 0. 5 mm or greater.

2.   *Rainfall rate* means the intensity of rain falling per hour assuming constant intensity during this period. The rainfall rate shall be specified in cm/hour.

B.   Object and Events

This appendix provides a listing of objects and events that may be relevant to ADS performance of the DDT within the ODD of a feature.

1. Motor vehicle

2. Motorcycle

3. Cyclist

4. Pedestrian

5. Stationary obstacle

6. Road accident scene

7. Road safety agent

8. Law enforcement agent

9. Emergency vehicle

C. Material to be Included in the Owner's Manual

This appendix provides a list of information that shall be provided at a minimum in the vehicle owner's manual.

1. An operational description of ADS' (features) capabilities and limitations (the information should also refer to specific scenarios).

2. A description of the roles and responsibility of driver/user and ADS when an ADS (feature) is on/off.

3. A description on the permitted transitions of roles and the procedure for those transitions.

4. A general overview of NDRA allowed when an ADS feature is active.

VII. Annexes

A. Approach to Derive Verifiable Performance