Sections 1-3 of the draft integrated FRAV/VMAD guidelines

(Approved by the Integration Group on 30 August 2023 for distribution to FRAV and VMAD)

1. Introduction

1.1. In 2015, the World Forum for Harmonization of Vehicle Regulations (WP.29) established a programme under the Intelligent Transport Systems (ITS) informal working group to focus on automated driving (ITS/AD).

1.2 During its 174th (March 2018) session, WP.29 approved a proposal from the ITS/AD informal group for a "Reference document with definitions of Automated Driving under WP.29 and the General Principles for developing a UN Regulation on automated vehicles".[1]

1.3. In March 2018, ITS/AD established a Task Force on Automated Vehicle Testing (TFAV) "to develop a regulatory testing regime that assesses a vehicle's automated systems so as to realise the potential road safety and associated benefits under real life traffic conditions".[2]

1.4. TFAV established subgroups to consider AV assessment methods:

- Physical certification tests and audit
- Real-world test drive.

1.5. In October 2018, TFAV proposed creating an informal working group on Validation Methods for Automated Driving (VMAD) "to develop methods to assess the safety of driving performance of automated driving systems including safe responses to the environment as well as safe behaviour towards other road users":

- In a controlled environment,
- Via audit of OEM processes,
- Under simulation and virtual testing, and
- Under real-world conditions.

1.6. During its 178th (June 2019) session, WP.29 approved a Framework Document on Automated/ Autonomous Vehicles.[3]

1.6.1. The Framework Document provides "guidance to WP.29 subsidiary Working Parties (GRs) by identifying key principles for the safety and security of automated/autonomous vehicles of levels 3 and higher."[4]

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[1] ECE/TRANS/WP.29/2018/2 as amended by paragraph 31 of the session report ECE/TRANS/WP.29/1137 and consolidated in ECE/TRANS/WP.29/1140.

[2] TFAV-02-12

[3] ECE/TRANS/WP.29/2019/34/Rev.2 and ECE/TRANS/WP.29/1147 Annexes V and VI.

[4] The Framework Document refers back to the Automated Driving definitions provided in the reference document ECE/TRANS/WP.29/1140 noted in para. 1.2. The reference document cites SAE J3016:2016 as its source for establishing levels of driving automation (1-5).

1.7. The Framework Document established a safety vision and identified key issues and principles for work under WP.29:

- System safety
- Failsafe response
- Human Machine Interface/operator information
- Object and Event Detection and Response
- Operational Design Domain
- Validation for System Safety
- Cyber security
- Software updates
- Event Data Recorder and Data Storage System for Automated Driving.

1.8. The Framework Document identified three additional issues not listed in the agreed WP.29 priorities:

- Remote operation
- Safety of in-use vehicles
- Consumer education and training

1.9. Table 1 of the Framework Document allocated work on these WP.29 priorities across several informal working groups:

- Functional Requirements for Automated Vehicles (FRAV)
- Validation Methods for Automated Driving (VMAD)
- Cyber Security and Over-the-Air Software Updates (CS/OTA)
- Event Data Recorders/Data Storage Systems for Automated Driving (EDR/DSSAD).

1.10. Terms of reference mandated FRAV to develop functional (performance) requirements for automated vehicles, addressing:

- System safety
- Failsafe Response
- HMI /Operator information
- OEDR (functional requirements).[5]

1.11. Terms of reference mandated VMAD to develop a new assessment/test method (NATM) "to validate the safety of automated systems based on a multi-pillar approach" including:

- Scenarios
- Audit
- Simulation/virtual testing
- Test track
- Real-world testing.[6]

[5] ECE/TRANS/WP.29/1147/Annex V.
[6] ECE/TRANS/WP.29/1147/Annex VI.

1.12. During its June 2021 session, WP.29 endorsed a draft "New Assessment/Test Method for Automated Driving (NATM) - Master Document" submitted by GRVA that proposed a multi-pillar approach comprised of:

- A scenario catalogue
- Simulation/virtual testing
- Track testing
- Real world testing
- Audit/assessment procedures
- In-service monitoring and reporting.[7]

1.13. Through subsequent revisions to Table 1 of the Framework Document, WP.29 directed FRAV and VMAD to deliver, respectively, for its June 2023 session:

- Guidelines for regulatory requirements and for verifiable criteria for ADS safety validation, and
- Guidelines for NATM.[8]

1.14. WP.29 further directed FRAV and VMAD to collaborate and deliver a consolidated FRAV/VMAD submission (requirements and assessment methods) for its June 2024 session.

1.15. During the June 2023 session, WP.29 reviewed and endorsed documents submitted by GRVA presenting the guidelines prepared by FRAV and VMAD (per para. 1.13).[9]

1.16. Between 2019 and 2023, some 200 experts participated in nearly 80 FRAV and VMAD sessions to develop this document.

2. Scope and purpose.

2.1. This document aims to fulfil the FRAV and VMAD mandates and deliver the consolidated deliverable per the Framework Document described above.

2.2. The document proposes guidelines and recommendations for the establishment of safety requirements and assessment methods applicable to ADS vehicles as defined in Section 3.

2.3. The diversity of ADS vehicle configurations and the characteristics and constraints of their ODD present challenges in establishing harmonized requirements for worldwide use.

2.3.1. These guidelines recommend the establishment of high-level requirements to cope with this diversity.

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[7] ECE/TRANS/WP.29/2021/61 (ECE/TRANS/WP.29/1159)
[8] ECE/TRANS/WP.29/2019/34/Rev.2, ECE/TRANS/WP.29/2021/151, ECE/TRANS/WP.29/2023/43.
[9] WP.29-190-08 (FRAV draft guidelines with pending open issues) and WP.29/2023/44/Rev.1 (VMAD guidelines)

2.3.2. The guidelines propose a framework for applying these high-level requirements to individual ADS use cases.

2.4. The complexity of driving also presents challenges to the assessment of ADS performance across the diversity of possible ODD.

2.4.1. These guidelines recommend a multi-pillar approach to ensure comprehensive and efficient validation of ADS safety.

2.4.2. The guidelines recommend the development of a scenario catalogue for use across five validation pillars:

- Audit and safety-by-design assessment
- Simulation/virtual testing
- Track testing
- Real-world testing
- In-service monitoring and reporting.

2.5. These guidelines and recommendations are intended to support future initiatives that WP.29 may decide to initiate under the 1958, 1997, and/or 1998 Agreements.

2.6. Usage of the verbal forms “shall” (indicating an obligatory provision) and “may” (indicating a permissive provision) in this document should be understood within the context of providing such recommendations.

2.7. The guidelines recommend technology-neutral and evidence-based requirements and methods for objective, repeatable, and reproducible assessments within a framework that can adapt to technological progress.

3. Terms and definitions

This section defines terms used in this document. Use of these terms and their definitions is recommended in the development of legal requirements related to ADS and ADS vehicles.

3.1. *“Abstraction”* means a process of selecting relevant aspects of a source or referent system to be represented in a model or simulation.[10]

3.2. *“Automated Driving System (ADS)”* means the vehicle hardware and software that are collectively capable of performing the entire Dynamic Driving Task (DDT) on a sustained basis.[11]

3.3. *“ADS feature”* means an ADS functionality designed specifically for use within an Operational Design Domain (ODD).

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[10] Any modelling abstraction carries with it the assumption that it should not significantly affect the intended uses of the simulation tool.

[11] This definition is based on SAE J3016 and ISO/PAS 22736 (Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles). These standards define levels of driving automation based on the functionality of the driving automation system feature as determined by an allocation of roles in DDT and DDT fallback performance between that feature and the (human) user (if any). The term “Automated Driving System” is used specifically to describe a Level 3, 4, or 5 driving automation system.

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

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

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

3.7. *"Closed-loop testing*" means testing in an environment in which actions of the ADS hardware, software, or other element(s) in the loop influence the actions of other objects in the simulation.[12]

3.8. *"Open-loop testing*" means testing in an environment in which the actions of the ADS hardware, software, or other element(s) in the loop do not affect the actions of other objects in the simulation.[13]

3.9. *"Stochasti*c" means a process involving or containing a random variable or variables pertaining to chance or probability.

3.10. *"Driver"* means a human user who performs in real time part or all of the DDT and/or DDT fallback for a particular vehicle.

3.11. *"Dynamic Driving Task (DDT)"* means the real-time operational and tactical functions required to operate the vehicle in on-road traffic.

3.11.1. The DDT is always performed in its entirety by the ADS in operation ("the entire DDT" as stated in the definition of an "Automated Driving System" under para. 3.2.) which means the whole of the tactical and operational functions necessary to operate the vehicle. These functions can be grouped into three interdependent categories: sensing and perception, planning and decision, and control.

3.11.1.1. Sensing and perception include:

- Monitoring the driving environment via object and event detection, recognition, and classification.
- Perceiving other vehicles and road users, the roadway and its fixtures, objects in the vehicle's driving environment and relevant environmental conditions.
- Sensing the ODD boundaries, if any, of the ADS feature.
- Positional awareness.

3.11.1.2. Planning and decision include:

- Predicting actions of other road users.
- Response preparation.
- Manoeuvre planning.

3.11.1.3. Control includes:

- Object and event response execution.

[12] For example, evaluating ADS interactions with other objects that respond to the actions of the ADS within a traffic model.

[13] For example, evaluating ADS interaction with a recorded traffic situation.

- Lateral vehicle motion control.
- Longitudinal vehicle motion control.
- Enhancing conspicuity via lighting and signalling.

3.11.1.4. The DDT excludes strategic functions.

3.11.2. *"Strategic function"* means a capability to issue commands, instructions, or guidance for execution by an ADS.[14]

3.11.3. *"Tactical function"* means a capability to perceive the vehicle environment and control real-time planning, decision, and execution of manoeuvres, including conspicuity of the vehicle and its motion.[15]

3.11.4. *"Operational function"* means a capability to control the real-time motion of the vehicle.[16]

3.12. *"Edge Case*" means a low-frequency occurrence that might arise within the ODD of an ADS and warrants specific design attention due to the potential severity of outcomes that might result from encountering such a situation or condition across a full-scale deployed fleet of such ADS vehicles.[17]

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

3.14. *"DDT fallback"* means a response by the user to either perform the DDT or to achieve a minimal risk condition or a response by an ADS to achieve a minimal risk condition:

(1) after the occurrence of one or more DDT performance-relevant system failures, or

(2) upon an ODD exit.

3.15. *"Fallback user"* means a user expected to perform the DDT pursuant to a transition of control.

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

3.17. *"Model*" means a description or representation of a system, entity, phenomenon, or process.

3.18. *"Model calibration*" means a process of adjusting numerical or modelling parameters in a model to improve agreement with a referent.

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[14] Examples include setting the starting point, destination, route, and way points to be used by an ADS during a trip.

[15] Examples include deciding whether to overtake a vehicle or change lanes, signalling intended manoeuvres, deciding when to initiate the manoeuvre, choosing the proper speed, and executing the manoeuvre.

[16] Operational functions involve executing micro-changes in steering, braking, and accelerating to maintain lane position or proper vehicle separation and immediate responsive actions to avoid crashes in critical driving situations.

[17] Examples include a unique road sign or an unusual animal type in the roadway.

3.19. *"Model parameter"* means a numerical value inferred from real-world data and used to characterise a system functionality.

3.20. "*Occurrence*" means a safety-relevant event involving an ADS vehicle.

3.21. "*Non-critical Occurrence*" means an operational interruption, defect, fault, or other circumstance that influenced or may have influenced ADS safety but did not result in a collision or serious incident.[18]

3.22. *"Critical Occurrence*" means an occurrence during which the ADS is performing the DDT and:

(a) at least one person suffers an injury that requires medical attention as a result of being in the vehicle or being involved in the event.

(b) the ADS vehicle, other vehicles or stationary objects sustain physical damage that exceeds a certain threshold.

(c) any vehicle involved in the event experiences an airbag deployment.

3.23. *"Operational Design Domain (ODD)"* means the operating conditions under which an ADS feature is specifically designed to function.[19]

3.24. "*ODD exit*" means:

(a) the presence of one or more ODD conditions outside the limits defined for use of the ADS feature, and/or

(b) the absence of one or more conditions required to fulfil the ODD conditions of the ADS feature.[20]

3.25. *"Other road user (ORU*)" means an entity in the ADS vehicle environment capable of motion and of coordinated interaction with the ADS vehicle.

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

3.27. *"Proving ground"* and "*Test track*" mean a facility closed to public traffic and designed to enable physical assessment of an ADS and/or ADS vehicle performance, including via sensor stimulation and/or the use of dummy devices.

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[18] Examples include minor incidents, safety degradation not preventing normal operation, emergency/complex manoeuvres to prevent a collision, and more generally all occurrences relevant to the safety performance of the in-service ADS (like transfer of control, interaction with remote operator, etc.).

[19] Examples include but are not limited to environmental, geographical, and time-of-day restrictions, and/or the requisite presence or absence of certain traffic or roadway characteristics.

[20] ODD conditions are distinct from ADS capabilities. An ADS may be designed to manage transient changes in the operating environment where such transient changes do not represent an ODD exit.

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

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

3.30. *"Safety case"* means a compelling, comprehensible, and valid argument, supported by a body of evidence, documenting that a system is, or will be, adequately safe for a given application in a given environment.

3.31. *"Sensor Stimulation*" means a technique whereby artificially generated signals are provided to trigger the element under testing in order to produce the result required for evaluation of the element.

3.32. *"Simulation"* means the imitation of the operation of a real-world process or system over time.

3.33. *"Simulation toolchain*" means a combination of simulation tools that are used to support the validation of an ADS.

3.34. *"Test case specification*" means the detailed specifications of what must be done by the tester to prepare for the test.

3.35. *"Test method*" means a structured approach to consistently derive knowledge about the ADS by means of executing tests.[21]

3.36. *"Traffic scenario"* means a description of one or more real-world driving situations that may occur during a given trip.[22]

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

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

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

3.36.4. *"Functional Scenario*" means a basic traffic scenario describing a situation and its corresponding elements at the highest level of abstraction in natural, non-technical language.[23]

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[21] For example, virtual testing in simulated environments, physical, structured testing in controlled test-facility environments, and real-world on-road conditions.

[22] Scenarios include a driving manoeuvre or sequence of driving manoeuvres. Scenarios can also involve a wide range of elements, such as some or all portions of the DDT, different roadway layouts, different types of road users and objects exhibiting static or diverse dynamic behaviours, and diverse environmental conditions (among many other factors).

[23] For example, a description of the ego vehicle's actions, the interactions of the ego vehicle with other road users and objects, and other elements that compose the scenario such as environmental conditions.

3.36.5. *"Logical Scenario"* means a traffic scenario elaborated at a lower level of abstraction to include value ranges or probability distributions for each element of the corresponding functional scenario.[24]

3.36.6. *"Concrete Scenario*" means a traffic scenario at a level of abstraction in which specific values have been selected for each element from the continuous ranges as may be defined in the corresponding logical scenario.

3.36.7. *"Complex Scenario*" means a traffic scenario containing one or more situations that involve a large number of other road users, unlikely road infrastructure, or abnormal geographic/environmental conditions.

3.37. *"Transition of control (TOC)"* means a procedure by which the ADS transfers performance of the DDT to an ADS vehicle user.

3.38. *"TOC request"* means an alert issued by an ADS to an ADS vehicle user prompting the user to intervene in performance of the DDT.[25]

3.39. "*TOC response*" means an ADS vehicle user intervention in performance of the DDT pursuant to a TOC request.

3.40. *"(ADS) User"* means a human user of an ADS vehicle.

3.41. *"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.

3.42. *"Validation of the simulation model*" means the process of determining the degree to which a simulation model is an accurate representation of the real world from the perspective of the intended uses of the tool.

3.43. *"Verification of the simulation model*" means the process of determining the extent to which a simulation model or a virtual testing tool is compliant with its requirements and specifications as detailed in its conceptual models, mathematical models, or other constructs.

3.44. *"Virtual testing*" means the process of testing a system using one or more simulation models.

3.45. *"Driver-In-the-Loop*" *(DIL*) means a driving simulator with components to enable the driver to operate in and communicate with the virtual environment and used to assess the human-automation interaction design.

3.46. "*Hardware-In-the-Loop*" (HIL) means the hardware of a specific vehicle subsystem running the software with input and output connected to a simulation environment to replicate sensors, actuators, and mechanical components in a way that connects all the I/O of the Electronic Control Units (ECU) before the final system is integrated.

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[24] For example, elaborating the lane element to cover possible lane widths.

[25] The TOC request, depending on the ADS design and reason for initiation of the transition of control, may aim to engage the user in performing the DDT (i.e., to the role of driver manually operating the vehicle) or to achieve an MRC.

3.47. *"Model-In-the-Loop*" (MIL) means high-level-of-abstraction software frameworks running on general-purpose computing systems to enable quick algorithmic development without involving dedicated hardware.

3.48. *"Software-In-the-Loop*" (SIL) means a methodology where executable code such as algorithms, an entire controller strategy, or a complete software implementation is assessed within a modelling environment on general-purpose computing systems.

3.49. *"Vehicle -In-the-Loop*" (VIL) means a fusion of real-world and virtual environments to assess the dynamics of a physical ADS vehicle on a vehicle test bed or a test track at the same level as real-world testing.