Consolidation of VMAD-10-14 (Japan) and VMAD-10-15 (France) comments to the VMAD-10-09 submitted by Canada.

Inclusion of OICA/CLEPA comments (in blue)

**Validation Methods of Automated Driving – Scenarios Sub-working Group**

Building off the ‘Next Steps’ section of the SG 1a concept paper, the following document outlines the sub-working groups scope for the short-term. This document also includes a notional list of resources, organized based on workplan items that could be leveraged to establish a methodology for developing scenarios.

**Scope**

At this early stage in the development/implementation of the VMAD safety validation methodology, SG 1a could focus its attention on developing a methodology to identify scenarios in a structured approach. Initially, focusing on a more simple operational design domain (ODD) such as divided-highway driving, and in the longer-term focus on other ODDs, including the possibility of edge cases.

When developing scenarios for this ODD, the group could focus its attention on developing functional scenarios. By limiting the scope of work at this time to functional scenarios, SG 1a would not define specific parameter ranges (logical scenarios) or specific values for the scenario elements (concrete scenarios) that are tested via simulation, track and real-world testing. As the project progresses, SG 1a can work with the other sub-working groups (i.e., SG2a and SG2b) to focus its attention on more detailed/technical scenarios (i.e., logical and concrete scenarios).

**Next Steps**

To inform this work, as a first step, the SG 1a sub-group should perform a literature review to identify and leverage existing materials from groups, such as international standards setting bodies, government departments, industry, and academia, who are active in developing scenarios.

The purpose of the literature review will be to:

1. Identify/leverage areas of prior research/work to prevent duplication and recognize the work of others, which could assist with developing a scenarios catalogue; and
2. Identify gaps in the research/work, including conflicts in previous studies, and/or open questions/next steps raised from previous research that require attention by VMAD.

The following table has been developed to assist with the process of identifying and organizing existing materials in order to perform a literature review. The document has been organized based on the following topics/concepts:

* Methods for identifying scenarios
* Scenario description language
* Definitions
* Levels of Abstraction
* Operational Design Domain and Scenario Elements/Properties
* Measuring Safety/ scenario coverage

Table 1: Resources to Consider as part of a Literature Review

| Title | Author | Description | Website | Notes |
| --- | --- | --- | --- | --- |
| 1. Identifying Scenarios and/or Existing Databases
 |
| Industry is looking into existing scenario databases taken from a literature review and considering the documents highlighted in this section. The aim is to merge existing database and consolidate a list of common scenarios applicable to the highway use-case. Where available, few scenarios will be described in detail using the Pegasus 6-layers approach, in order to provide pragmatic examples to the group. We believe the exercise would help to visualize and appreciate how a highway database would look like and support further regulatory activities from the SG1a.  |
| Streetwise | TNO (the Netherlands)  | The StreetWise methodology provides automatic identification and characterization of scenarios from object level data provided by state-of-the-art sensors for Advanced Driver Assistance and Automated Driving systems (ADAS/AD) and focuses on using such scenario statistics for safety argumentation.  | * StreetWise, scenario-based safety validation of connected and automated driving ( [http://publications.tno.nl/publication/34626550/AyT8Zc/TNO-2018-streetwise.pdf](http://publications.tno.nl/publication/34626550/AyT8Zc/TNO-2018-streetwise.pdf%20) )
* Safety assessment of automated vehicles: how to determine whether we have collected enough field data? (<https://www.tandfonline.com/doi/full/10.1080/15389588.2019.1602727>)
* Automatic identification of critical scenarios in a public dataset of 6000 km of public-road driving (<http://indexsmart.mirasmart.com/26esv/PDFfiles/26ESV-000255.pdf>)
* Scenario Categories for the Assessment of Automated Vehicles (<https://cetran.sg/wp-content/uploads/2020/01/REP200121_Scenario_Categories_v1.7.pdf>)
* A method for scenario risk quantification for automated driving systems (<http://indexsmart.mirasmart.com/26esv/PDFfiles/26ESV-000129.pdf>)
* Ontology for Scenarios for the Assessment of Automated Vehicles. (<https://arxiv.org/abs/2001.11507>)
* Real-World Scenario Mining for the Assessment of Automated Vehicles (<https://arxiv.org/abs/2006.00483>)
 | This methodology is under continuous development with international partners (Germany, Japan, Austria, Netherlands, Singapore). An important ambition is to identify and characterize all highway scenarios out of a significant amount of hours of driving on European highways. In this way a continuously growing scenario data base is set up, from which tests for ADAS and AD functions can be derived. Partners in such collaboration share scenarios and thereby share efforts in determining the important scenarios for testing, however, without sharing sensitive data.Automated scenario identification and characterization has been developed in order to deal with:* The huge number of possible scenarios, and the large variety in scenarios (e.g. different velocities, number of relevant traffic participants, etc.)
* Variations in occurrence of scenarios are captured in automated scenarios to result in parameter distributions for the characteristic scenario parameters. These distributions are used in metrics that quantify the completeness of a scenario database.
* Additionally, such automated methods will show whether all captured data can be applied to known scenario categories. In case a set of data is found that does not fit in an existing scenario category, an additional scenario category is required to be defined. This also relates to the completeness paradigm.
* All scenario statistics are captured in an online accessible database from which test cases can be sampled based on scenario parameter values and tags. These test cases can be used for massive simulation or other (physical) tests
* Automatic scenario extraction has been developed for highway. The method is extended towards urban driving.
 |
| The PEGASUS Method | PEGASUS - Germany | In addition to including methods for how to identify scenarios, this link contains methods, tools, processes within the different elements/concepts required to develop scenarios. | <https://www.pegasusprojekt.de/en/pegasus-method>  | * Safety approval cannot be achieved for highly automated vehicles with available methods and tools within a limited time and budget. PEGASUS project developed a framework for AD assessment using the highway chauffeur as exemplary test object, i.e. a SAE L3 conditional automation system.
* The central element of PEGASUS is a data base and an according data base processing toolchain. The toolchain must be capable to include and use different data sources and therefore heterogenic data and data quality. The proposed data base concept can realise an efficient and effective data processing in a common framework with a common tool chain.
* In the project, scenarios are derived via combining a data driven (main focus) and a knowledge-based approach:
* data driven: using available, not strictly confidential data to determine scenarios that are usually encountered in traffic;
	+ naturalistic driving studies (NDS), field operational tests (FOT), test drives
	+ driving simulator data
	+ German In-Depth Accident Study (GIDAS)
* knowledge-based: using further sources to also cover rare events that are possibly critical scenarios
	+ road traffic regulations
	+ traffic sign catalog
	+ guidelines, laws and standards
	+ expert knowledge
* A first set of scenarios is stored in the PEGASUS database. To allow for this, PEGASUS developed a scenario description language, which is now managed and further developed by ASAM as the freely available standard OpenX.
* PEGASUS project ended in 2019 but work is being continued in the PEGASUS family with projects “VV-Methods” and “SET Level 4 to 5”.
 |
| Identified Crash Scenarios with Probabilities Study in China | China Automotive Technology and Research Centre Co. Ltd. (CATARC) | CATARC, in conjunction with a number of automotive companies, launched the China In-depth Accident Study (CIDAS) on July 15, 2011, to conduct an in-depth investigation of road accidents in order to identify the top crash scenarios in China. | <https://wiki.unece.org/download/attachments/81888491/VMAD-03-07%20Identified%20Crash%20Scenarios%20in%20China%20.pdf?api=v2>  | * Based on China In-Depth Accident Study (CIDAS) data.
* 33 crash scenarios prioritized by frequency of occurrence (including some behavioral scenarios such as speeding).
* SG1a may also wish to consider TFAV SG1-03-11 (Guidelines for Intelligent & Connected Vehicle Autonomous Driving Functionality Tests) and TFAV SG1-03-13 describing 34 scenarios grouped under 14 categories.
* The Guidelines describe functional scenarios for nominal driving events.
* The Guidelines provide a test scenario description, brief description of the test method, and high-level performance requirement.
 |
| Safety Criteria Study on Innovative Safety Validation Methods of Automated Driving Systems  | Japan | In addition to including methods for how to identify scenarios, this link contains methods, tools, processes within the different elements/concepts required to develop scenarios. | <https://wiki.unece.org/download/attachments/87622683/VMAD-04-04%20Japan%20safety%20criteria%20study.pdf?api=v2> | * **New safety validation method for ADS**
* Proposal of a new safety validation method in accordance with the safety vision in GRVA framework document. (safety vision: automated vehicle systems, under their operational domain, shall not cause any traffic accidents resulting in injury or death that are reasonably foreseeable and preventable.)
* Just accumulating and categorizing traffic data cannot assure the future unreasonable risk. In order to overcome this the new derivation process of the holistic safety related concrete scenario is proposed as 3-layer concept. This is the structure of functional scenario in accordance with the physical principle category of ADS such as perception scenario associated with sensor physics, traffic disturbance scenario associated with judgment and vehicle disturbance scenario associated with stability. These 3 layers can cover the root cause of safety risk of DDT.
* The methodology to derive the quantitative parameter range for logical scenario which is reasonably foreseeable and preventable is proposed. The reasonably foreseeable traffic scenario parameter range is derived from traffic monitoring data and the preventable parameter range is calculated by competent and careful human driver model. (The driving culture is different depending on the country and area but the sufficient capability of human drive is harmonized as international driver license.)
* **Case study; Highway system**
* The method that systematizes the position/ behavior of ego vehicle / other vehicle and road geometry for motorways and ensures the completeness of Functional scenarios.
* Proposal to use the Competent & Careful (C&C) Human driver model as a criterion for ADS safety requirements.

Since most of the accidents are caused by the carelessness of the driver, if it is equal to or higher than the "C & C driver model", it is possible to ensure sufficient road traffic safety, and it is considered appropriate as a measurable criterion at the time of introduction ADS.* Extract the trajectory from the real traffic flow data and extract the parameters related to the "Functional scenario."
* Propose a method to analyze the correlation between each parameter (eg. realistic combination parameter) then to derive the Logical scenario parameter.

Propose to build a parameter database that can be owned in each country. |
| Multi-User Scenario Catalogue for Connected and Autonomous Vehicles (MUSICC) | Catapult Transportation Systems - United Kingdom | MUSICC is creating a system to store and share a library of scenarios. | <https://wiki.unece.org/download/attachments/87622683/VMAD-04-11%20UK%20Scenario%20DB%20update.pdf?api=v2>  | * The MUSICC project was led by the UK Department for Transport and Connected Places Catapult;
* MUSICC has produced a system (open library) to store scenarios for use in AV safety tests. Scenarios are stored with metadata that allow them to be searchable and to be used for scenario selection, based on certain criteria:
	+ general properties of the scenario (information about the test case which the scenario describes);
	+ ODD specification (to identify scenarios matching a specified ODD)
	+ admin data (e.g. ownership version control and reference to specifications and regulations)
	+ custom data (user extensible).
* MUSICC supports ASAM OpenSCENARIO v.1.0 for scenario description.
* MUSICC is an open source release

(<https://gitlab.com/connected-places-catapult/musicc>). As a result, developers can store and manage their own test scenarios in a private instance of MUSICC within their own organization and still synchronize with the regulatory scenarios. The whole community will then be able to contribute to the development of an open library for AV certification scenarios. * Next steps include
	+ the development of a more sophisticated language to better match ODD description with all likely use cases and help inform development efforts ([link](https://s3-eu-west-1.amazonaws.com/media.cp.catapult/wp-content/uploads/2020/03/23170028/Design-considerations-for-ODD-ontology.pdf));
	+ development of a framework for assessing an ADS’s behavioral safety in normal operation. The framework will include a highly automated means of evaluating test results ([link](https://s3-eu-west-1.amazonaws.com/media.cp.catapult/wp-content/uploads/2020/05/21113234/Pass-Fail-Criteria-for-Scenario-Based-Testing-of-Autmoated-Driving-Sytems.pdf)).

Linked projects: ASAM OpenSCENARIO v1.0, BSI PAS1883 |
| A Framework for Automated Driving System Testable Cases and Scenarios  | United States National Highway Traffic Safety Administration | This report describes a framework for establishing sample preliminary tests for Automated Driving Systems. The focus is on light duty vehicles exhibiting higher levels of automation, where the system is required to perform the full dynamic driving task, including lateral and longitudinal control, as well as object and event detection and response. | <https://wiki.unece.org/download/attachments/87622238/FRAV-01-14.pdf?api=v2>  | * Risk analysis to prioritize scenario selection, including frequency of occurrence and severity of outcomes (31 events drawn from NHTSA pre-crash scenario analyses).
* Defines seven generic categories of features (based on 24 conceptual features): L4 Highly Automated Vehicle/Transportation Network Company (TNC), L4 Highly Automated Highway Drive, L4 Highly Automated Low Speed Shuttle, L4 Highly Automated Valet Parking, L4 Highly Automated Emergency Takeover, L3 Conditional Automated Highway Drive, L3 Conditional Automated Traffic Jam Drive.
* Lists traffic events for L3 traffic jam and highway drive systems and for L4 highway drive systems.
* Describes six functional scenarios further broken down into 6-12 concrete scenarios.
* Structures test scenarios based on ODD, tactical/OEDR behaviors, parameter values/measurements, and failure/fallback.
* Distinguishes between failsafe (fallback to ready user or MRM) and fail-operational (degradation/redundancy permitting continued ADS operation).
* Provides ODD checklist to define parameters covering physical infrastructure, operational constraints, objects, environmental conditions, connectivity and (operating) zones.
* Covers modeling and simulation, closed track, and open road test methods.
* Performance based on ADS detection of a safety-critical object or event and response with a stable control action or maneuver that allows the ADS to maintain a safe avoidance distance from all relevant obstacles in the immediate vicinity while respecting applicable driving rules and etiquette to the extent possible.
* Notes AdaptIVe and PEGASUS programs, California PATH minimum behavioral competencies, NIST 4D/RCS Reference Model Architecture for Unmanned Vehicle Systems.
 |
| The SAKURA project (Safety Assurance Kudos for Reliable Autonomous vehicles) | JAMA Safety Assurance WG & JARI | Socially acceptable and technically sound safety assurance methodologies | <https://www.sakura-prj.jp/project_info/> | * **Target ; Highway system**
* **Logical scenario parameter derivation method**
* Based on the Functional scenario, the trajectory is extracted from the real traffic flow data and the parameters related to the Functional scenario are extracted.
* The method to analyze the correlation between each parameter (e.g. realistic combination parameter), then to derive the Logical scenario parameter
* **Safety requirements**

Proposal to use the Competent & Careful (C&C) Human driver model as a criterion for ADS safety requirements. For that reason, carried out Driving Simulator experiment evaluation and literature research to determine the validity of C&C Human driver model parameters. |
| ISO34502 | ISO TC22/SC33/WG9 | Road vehicles — Engineering framework and process of scenario-based safety evaluation | <https://www.iso.org/standard/78951.html> | * Scope

(Scenario-based safety evaluation process)This document provides guidance and a state-of-the-art engineering framework for ADS test scenarios and a scenario-based safety evaluation process.* Focus: Highway AD system (upper Level 3/SAE definition)
* Overall

This document specifies the state-of-the-art holistic coverage test scenarios and scenario-based safety assurance process within the product development.* Scenario definition (Based-on Hazardous scenario)

The objectives of this clause are:* to define the state-of-the-art scenario structure to specify a comprehensive range of triggering conditions
* to define the requirements for the determination a set of potential of hazardous scenarios to be tested in compliance with the relevant safety test objectives.
* Scenario structure

Just accumulating and categorizing traffic environment data cannot assure the future unreasonable risk. In order to overcome this the new derivation process of the holistic safety related concrete scenario is proposed as 3 scenario categories. In order to cover the root cause of safety risk of Dynamic Driving Task, the scenario structure in accordance with the physical principle category of ADS Dynamic Driving Task is developed for each following category:* **perception scenario** associated with sensor physics
* **traffic disturbance scenario** associated with judgment and
* **vehicle disturbance scenario** associated with stability.
* Safety target

The engineering framework based on the relevant safety test objectives is developed.The safety test objective can be safety vision in WP29 framework document such that automated vehicle systems under their operational domain shall not cause any traffic accidents resulting in injury or death that are reasonably foreseeable and preventable.* Relation other ISO

ISO34502 is the dedicated standard for methodology and judgement of AD DDT task safety performance and is complementally contents of ISO21448, which is about general safety process and concept of safety of the intended function. |
| Platform for the evaluation of autonomous systems MOSAR | MOSAR – System X (French research institute) | Methods and Tools for the Assessment of Dependability and Robustness Analysis of Autonomous VehiclesSafety relevant scenario library and associated tools to manage it, Use Case Generator, and Virtual Testing. | <https://www.mosar.io/> | * MOSAR “Methods and tools for Safety Assessment and Robustness analysis” is a platform supporting a software application called “Scenario Manager”. In Software As A Service (SaaS) mode, this software offers some features to manage scenarios. Based on a common data model, the Scenario Manager allows partners to describe their scenarios, through a web interface, into a secure and shared Scenario Library. Next, these scenarios can be used for Design, Simulation, Validation and Homologation activities
* MOSAR’s Accident Work Group (WG) leads the accident cases study and transformation into accident scenarios. For each of the 258 accident cases pertaining to the scope of the study (accidents on normal sections of divided roads), Accident WG:
	+ Identifies and builds the relevant parameters list. This specification will serve to build and update the Scenario Manager Data Model;
	+ Builds accident scenario: temporal evolution sequences (with triggers start/end steps definition) and overview pictures;
	+ Imports manually, through the web interface, accident scenarios into the Scenario Manager
 |
| 1. Scenario Description Language
 |
| Industry supports ASAM standardization activities; however, we believe that additional work is needed to meet the expectations of various stakeholders involved in the ASAM project. Therefore, we believe it is still premature to discuss the issue within VMAD and recommend VMAD not to develop a bespoke scenario description language.  |
| OpenDrive | Association for Standardization of Automation and Measuring Systems (ASAM) | ASAM OpenDRIVE defines a file format for the precise analytical description of road networks. Unlike other file formats typically used for navigation systems, ASAM Open-DRIVE's main use is in the area of simulation applications, which require exact road geometry descriptions, including surface properties, markings, signposting and logical properties such as lane types and directions. Road data may be manually created from road network editors, conversion of map data, or originate from converted scans of real-world roads. | <https://www.asam.net/standards/detail/opendrive/>  | **OpenDRIVE: Open Dynamic Road Information for Vehicle Environment** * File format for the description of road networks.
* Used for simulators in the area of

• Drive simulation • Traffic simulation • Sensor simulation * Based upon XML and a hierarchical data model. Basic elements:

• Roads • Junctions • Controller * Not covered: entities acting on or interacting with the road network.

**OpenCRG: Open Curved Regular Grid** * File format and source-code for the detailed description of road surfaces.
* The file format of OpenCRG is integrated in OpenDRIVE.
* Used for the description of patches of road surfaces in a very detailed manner, so that it can be used for:

• Tire simulation • Vibration simulation • Driving simulation, etc. * Source-code included:

• C API for data read and evaluation • MATLAB API for data read/write, evaluation, generation, modification and visualization • Library of sample data |
| Open Scenario | ASAM | ASAM OpenSCENARIO defines a file format for the description of the dynamic content of driving and traffic simulators. The primary use-case of OpenSCENARIO is to describe complex, synchronized maneuvers that involve multiple entities like vehicles, pedestrians and other traffic participants. The description of a maneuver may be based on driver actions (e.g. performing a lane change) or on trajectories (e.g. derived from a recorded driving maneuver). Other content, such as the description of the ego vehicle, driver appearance, pedestrians, traffic and environment conditions, is included in the standard as well. | [https://releases.asam.net/OpenSCENARIO/2.0-concepts/ASAM\_OpenSCENARIO\_2-0\_Concept\_Paper.html#\_measurement\_and\_success\_criteria](https://linkprotect.cudasvc.com/url?a=https%3a%2f%2freleases.asam.net%2fOpenSCENARIO%2f2.0-concepts%2fASAM_OpenSCENARIO_2-0_Concept_Paper.html%23_measurement_and_success_criteria&c=E,1,eTe5AMREAPCpbzCkCZWpbkDtUrgTkqG6bxZ76wMPwMloRXvjUhTCJhH7RUlwMRgBlB6epm9DCQwQ2KBgM-t5CoiOqMT7kV0gXCqz5p1hE4W6KsWXQPk,&typo=1) | * File format for the description of dynamic content in driving simulation applications. Currently: focus on drive maneuver description. Used for driving simulators.
* Description elements:

• Maneuver (complex maneuver descriptions that involve multiple cars) • Trajectory (polyline, clothoid, nurbs) • Vehicle (geometry, type, axes, performance) • Driver (appearance) • Environment (weather, time of day, road condition)* Based upon XML.
 |
| 1. Operational Design Domain (working with FRAV) and Scenario Properties/Elements
 |
| Industry supports following existing standards unless there is a compelling reason not to do so. The reference to existing work will allow VMAD to focus on other essential deliverables and avoid overlapping of work and potential misinterpretations.  |
| AVSC Best Practice for Describing an Operational Design Domain: Conceptual Framework and Lexicon | SAE International | This document, Best Practice for Describing an Operational Design Domain: Conceptual Framework and Lexicon, is a critical first step. It offers a conceptual framework for manufacturers and developers to use when communicating with public agencies and the general public about their ADS’s ODD. It also details a list of potential variables with definitions that manufacturers and developers might use to describe certain aspects of the ODDs of their ADS-operated vehicles. | <https://www.sae.org/standards/content/avsc00002202004/>  | * A common framework and lexicon will reduce confusion, align expectations, and therefore build public trust, acceptance, and confidence.
* ODD with enough specificity to not only satisfy customer expectations, but also the needs of regulators and road operators. Constructing a conceptual ODD framework entails:

• Identifying the road/route network;• Characterizing the fixed-route network and infrastructure;• Identifying operational constraints within the road/route network; and• Formulating a descriptive narrative.* Provides a set of ODD definitions.
 |
| A Framework for Automated Driving System Testable Cases and Scenarios  | United States National Highway Traffic Safety Administration | This report describes a framework for establishing sample preliminary tests for Automated Driving Systems. It also includes a framework for organizing scenario elements. | <https://wiki.unece.org/download/attachments/87622238/FRAV-01-14.pdf?api=v2>  | * ODD will likely vary for each ADS feature, even if there is more than one ADS feature on a vehicle.
* Reviewed more than 50 sources of information
* “Guiding Principles”:
	+ Need for uniform ODD taxonomy
	+ Account for variations in operational environments
	+ Define what constitutes an “operational scenario”
	+ Identify ODD boundaries
	+ Identify “Current ODD State” (system capability to determine whether the vehicle is within the ODD and detect boundaries)
* Proposes an ODD hierarchy with top categories:
	+ Physical infrastructure
	+ Operational constraints (speed limits, traffic conditions)
	+ Objects (signage, roadway users, other obstacles/objects)
	+ Connectivity (V2V, traffic info, remote fleet management, V2I)
	+ Environmental conditions
	+ Zones (geofence, traffic management zones, construction, school, legal jurisdictions, interference such as tunnels)
* Hierarchy extends as far as needed (e.g., environmental conditions 🡪 weather 🡪 rain 🡪 light/moderate/heavy)
* Provides additional explanations for ODD categories/elements
* Proposes an ODD checklist for application to ADS features
 |
| PAS 1883:2020Operational Design Domain (ODD) taxonomy for an automated driving system (ADS) - Specification  | The British Standards Institution (BSI)  | The PAS introduces requirements for specifying an ODD to enable the safe deployment of ADS. The document is intended for trialling organizations developing safety cases for automated vehicle trials and testing. Sponsored by Centre for Connected & Autonomous Vehicles and the UK Department for Transport.  | <https://www.bsigroup.com/en-GB/CAV/pas-1883/> | * The aim is to define ADS capabilities and limitations and clearly communicate them to the end user.
* It introduces requirements for the minimum hierarchical taxonomy for specifying an ODD to enable the safe deployment of an automated driving system:
	+ Scenery (e.g. Zones, Drivable area, Junctions, …);
	+ Environmental Conditions (e.g. Weather, Particulates, Illumination, Connectivity);
	+ Dynamic Elements (e.g. Traffic, Subject Vehicle)
* Intended for trialling organisations developing safety cases for AV trials and testing, manufacturers and developers of Level 3 and 4 ADS and suppliers of components.
* It contains an example checklist for an ODD definition.

Project linked: * PAS 1880 ‘Guidelines for developing and assessing control systems for automated vehicles’;
* PAS 1881 ‘Assuring the safety of automated vehicle trials and testing’,
* PAS 1882 ‘ Data collection and Management for automated vehicle trials’.
 |
| 1. Definitions
 |
| Industry supports following existing standards unless there is a compelling reason not to do so. The reference to existing work will allow VMAD to focus on other essential deliverables and avoid overlapping of work and potential misinterpretations.  |
| Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles J3016 | SAE International | This SAE Recommended Practice describes motor vehicle driving automation systems 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. 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. | <https://www.sae.org/standards/content/j3016_201806/>  | *It should be noted that FRAV has modified certain definitions to meet the needs for terms specific to establishing performance requirements for ADS.** 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). Specifically, an L3+ system.
* ADS feature or application: A level 3-5 driving automation system’s design-specific functionality at a given level of driving automation within a particular ODD, if applicable.
* 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:
	+ Lateral vehicle motion control via steering (operational);
	+ Longitudinal vehicle motion control via acceleration and deceleration (operational);
	+ Monitoring the driving environment via object and event detection, recognition, classification, and response preparation (operational and tactical);
	+ Object and event response execution (operational and tactical);
	+ Maneuver planning (tactical); and
	+ Enhancing conspicuity via lighting, signaling and gesturing, etc. (tactical).
* DDT Fallback: The response by the user to either perform the DDT or achieve a minimal risk condition after occurrence of a DDT performance-relevant system failure(s) or upon operational design domain (ODD) exit, or the response by an ADS to achieve minimal risk condition, given the same circumstances.
* Object and Event Detection and Response (OEDR): The subtasks of the DDT that include monitoring the driving environment (detecting, recognizing, and classifying objects and events and preparing to respond as needed) and executing an appropriate response to such objects and events (i.e., as needed to complete the DDT and/or DDT fallback).
* Operational Design Domain (ODD): Operating conditions under which a given driving automation system or feature thereof is specifically designed to function, including, but not limited to, environmental, geographical, and time-of-day restrictions, and/or the requisite presence or absence of certain traffic or roadway characteristics.

Note deprecated terms: Autonomous, Driving Modes(s), Self-Driving, Unmanned, Robotic |
| ISO 22736 / SAE AWI PAS (Under Development) | ISO TC204  | Intelligent transport systems — Taxonomy and definitions for terms related to driving automation systems for on-road motor vehicles | <https://www.iso.org/standard/73766.html>  | * Produced in cooperation between SAE (see above) and ISO.
* The document does not provide specifications on driving automation systems, although it contains a taxonomy for describing the full range of levels of driving automation and related terms and definitions, with the aim:
	+ Clarifying the role of the (human) driver, if any, during driving automation system engagement.
	+ Answering questions of scope when it comes to developing laws, policies, regulations, and standards.
	+ Providing a useful framework for driving automation specifications and technical requirements.
	+ Providing clarity and stability in communications on the topic of driving automation.
 |
| 1. Levels of Abstraction
 |
| Industry believes the 3 level of abstraction approach (Functional, Logical and Concrete Scenarios) is broadly accepted amongst researchers and developers; however, we will review the literature to confirm this understanding.   |
| The PEGASUS Method | PEGASUS - Germany | Provides a breakdown of the three abstraction levels for automated vehicles: functional, logical, and concrete. | <https://www.pegasusprojekt.de/files/tmpl/PDF-Symposium/04_Scenario-Description.pdf>  | * The term Scenario has different contents and representations in a development process.
* The concept describes scenarios with natural language on a high level of abstraction.
* Technical development and test case generation have demand for a representation with parameter spaces in the physical state space.
* The test case execution and assessment needs distinctively defined scenarios in common data formats.
* Breakdown in three abstraction levels: Functional, Logical and Concrete
* Structure of contents based on a 5 layers model.
	+ Level 1: Description of street layout and condition of the surface.
	+ Level 2: Traffic guidance infrastructure like signs, barriers, and markings.
	+ Level 3: Temporary overlay of topology and geometry for temporal construction sites.
	+ Level 4: Description of traffic participants and objects including interactions based on maneuvers.
	+ Level 5: Modeling of environment conditions like weather and daytime including influence on level 1 to 4.
 |
| Platform for the evaluation of autonomous systems MOSAR | MOSAR – System X (French research institute) | Safety relevant scenario library (functional scenarios, logical scenarios, discrete scenarios, driving scenarios)  | <https://www.mosar.io/> | * Current database focused on highway functions
* The database currently contains:
	+ 34 Functional Scenarios (target under 100);
	+ 117 Logical scenarios (target 200);
	+ 260 discrete scenarios
	+ Driving scenarios by using MOOVE database of 750,000 km – 20,000h
* Discrete scenarios identified from French accidentology:
	+ Annual Accident report from French Motorway Companies Association & VOIESUR databases;
	+ Near crashes from U-DRIVE database
* Database managed by SystemX (French Research Institute)
* Access granted to partners; however discussions on future shared database with read access to all stakeholders involved in the development of AV and authorities, scenario identification from industry/stakeholders or authorities and write access to independent third party after consultation of pool of experts from industry and authorities.
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| 1. Other resources (proprietary)
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| Industry proposes to reword the title to ‘other resources (proprietary)’ as the items included below are proprietary concepts not developed as standards in principle. |
| Coverage Driven Verification | SAFE | The coverage driven verification framework is focused on successfully exercising the scenarios critical for AV safety and extracting the metrics to prove it. The following presentation will focus on describing how AV stakeholders, including suppliers, insurance companies and regulators, can use coverage driven verification to ensure that AVs behave properly in driving scenarios. This includes the scenario coverage metrics required to make a compelling ‘safety case’ to consumers and AV stakeholders.  | <https://wiki.unece.org/download/attachments/92014309/VMAD-05-04%20CDV%20Overview.pdf?api=v2>  | * Usage of Coverage Metrics Supplies:

• Goals for testing • Threshold of quality and safe behaviors • Relative comparison between AVs* PEGAUS Method analyses extracted data and existing [historical] knowledge in order to create and define the required simulations space for AD assessment
* CDV complements and enhances the Pegasus approach:

• CDV Adds the coverage requirements as a data source for the decision process • Introduces constrained-random simulation generation to cover huge simulation and variation space • Provides methods to create unforeseeable scenarios |
| Responsibility- Sensitive Safety (RSS) | Intel/ Mobileye | Intel and Mobileye have proposed a formal, mathematical model to help ensure that an autonomous vehicle (AV) is operated in a safe manner. The Responsibility-Sensitive Safety model provides specific and measurable parameters for the human concepts of responsibility and caution and defines a “Safe State” designed to prevent the AV from being the cause of an accident, no matter what action is taken by other vehicles. | <https://wiki.unece.org/download/attachments/75530396/VMAD-01-08%20Industry-driven%20approach.pdf?api=v2> [RSS, Variability, Uncertainty, and Proving Safety, Philip Koopman, Beth Osyk, Jack Weast, 2019](https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&cad=rja&uact=8&ved=2ahUKEwjf7M-Vru7qAhWOTt8KHTN4CyMQFjABegQIAxAB&url=https%3A%2F%2Farxiv.org%2Fabs%2F1911.01207&usg=AOvVaw1nTmU-Oj9sIfOjiseF1AI1)  | * The RSS model provides a definition of the boundaries of actions of an ADS for safety purposes.
	+ It is technology-neutral.
	+ It does not prevent the use of proprietary driving logic safety strategies.
	+ The goal of the model is to bring a consistent level of safety to ADS operation.
* RSS is based on vehicle and system capabilities, e.g. braking capabilities, system response time, and vehicle acceleration. It does not take into consideration previous human-derived metrics, e.g. 2s time to collision.
* RSS is not ODD-specific and is meant to apply to all driving situations including unforeseen scenarios.
	+ Its parameters can be adapted to ODD or regional particularities.
	+ The parameters may be determined on the basis of statistics and scenarios.

It is possible to derive validation metrics or thresholds from RSS formulas. |