**New Assessment/Test Method for Automated Driving (NATM)
Master Document**

1. Background
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4. **Applying a Multi-pillar Approach to the NATM**

	1. The purpose of the NATM is to assess, based on the requirements, whether an ADS is able to safely address the various situations it may encounter in the real world Possible rephrasing: The purpose of the NATM is to provide a framework for assessing the ADS against **requirements** in order to demonstrate safe behavior in the real world, where the “safe response” to these situations is specified in the IWG on FRAV.
	2. Validating these capabilities is a highly complex task which cannot be done comprehensively nor effectively through one validation methodology alone. As a result, VMAD has proposed that the NATM adopt a multi-pillar approach for the validation of ADS, composed of a scenarios catalogue and four validation methodologies (pillars) each of which is explored in greater detail in subsequent sections of this document:
		* **A** **scenarios catalogue,** consisting of a series of relevant and critical scenarios that represent real-world traffic situations, will be a tool used by the following three pillars (testing methodologies) to validate the safety of an ADS. The goal of these scenarios is to exercise and challenge an ADS’ capabilities to safely operate. This catalogue will provide a minimum baseline (non-exhaustive inventory) of scenarios that should be considered (and built upon as required) to validate each safety requirement for an ADS;

1. **Scenarios Catalogue**
	1. **Why should scenario-based testing be included in the NATM?** In order to maximize the potential safety of AVs, a robust safety validation framework shall be established. Such a framework shall provide clear direction for assessing functional requirements of AVs in a repeatable, objective, evidence-based and technology neutral manner.
	2. At this relatively early stage in the development of AVs, much of the existing literature that assesses the current state of AV development uses metrics such as miles/kilometers travelled in real-world test situations with the absence of a collision, a legal infraction, or a disengagement by the vehicle’s ADS.
	3. Simple metrics such as kilometers travelled without a collision, legal infraction, or disengagement can be helpful for informing public dialogue about the general progress being made to develop AVs. Such measurements on their own however, do not provide sufficient evidence to the international regulatory community that an AV will be able to safely navigate the vast array of different situations a vehicle could reasonably be expected to encounter.
	4. In fact, some observers have suggested that an AV would have to drive billions of miles in the real-world to experience an adequate number of situations without an incident to prove that it has a significantly better safety performance than a human driver (Kalra & Paddock, 2016). Safety validation through such testing would not be cost and time effective, nor would it be feasible to replicate the testing later on. As validation of AV in various traffic situations is needed, therefore different traffic scenarios shall be considered.
	5. A scenario-based approach helps to systematically organize safety validation activities in an efficient, objective, repeatable, and scalable manner and is a critical part of the NATM for ensuring a holistic and dense coverage of traffic situations.
	6. Scenarios-based validation consists of reproducing specific real-world situations that exercise and challenge the capabilities of an ADS-equipped vehicle to safely operate.
	7. **What is a traffic scenario?** [A traffic scenario (or scenario for short) is a sequence or combination of situations used to assess the functional requirements for an ADS]. . Scenarios can also involve a wide range of elements,; different roadway layouts; different types of road users and objects exhibiting static or diverse dynamic behaviours; and, diverse environmental conditions (among many other factors).
	8. As previously noted, the use of scenarios can be applied to different testing methodologies, such as virtual/simulation, test track, and real-world testing. Together these methodologies provide a multifaceted testing architecture, with each methodology possessing specific strengths and weaknesses. Therefore, some scenarios may be more appropriately tested using certain test methodologies over others.
	9. Going forward, VMAD will establish a catalogue of a minimum baseline/non-exhaustive inventory of scenarios that should be considered (and built upon as required) to validate, using the NATM pillars, each functional requirement – given by FRAV - for an ADS , although it is ideal that scenarios (neutral to vehicle technology) comprehensively reflect the situation on world-wide public roads. In addition, scenarios shall not be limited to scenarios that are deemed preventable by the ADS. [Considering each country has different traffic environment, scenarios should be selective to Contracting Party] This work will be accomplished in consultation with VMAD subgroups.
	10. [Manufacturers are responsible for demonstrating how functional requirements have been assessed. It is recognized that the scenario catalogue will serve only as a minimum baseline on which manufacturers should apply their own scenarios, as necessary, to assess each functional requirement.]
	11. **Identifying Scenarios:** Scenario-based validation methods must include an adequate representation/coverage of relevant, critical, and complex scenarios to effectively validate an ADS. There are a number of approaches for identifying scenarios to validate the safety of an AV. For example, scenarios can be identified based on:
		* + analyzing human driver behaviour, including evaluating naturalistic driving data;
			+ analyzing collision data, such as law enforcement and insurance companies’ crash databases;
			+ analyzing traffic patterns in specific ODD (e.g., by recording and analyzing road user behaviour at intersections);
			+ analyzing data collected from ADS’ sensors (e.g., accelerometer, camera, radar, and global positioning systems);
			+ Using specially configured measurement vehicle, onsite monitoring equipment, drone measurements, etc. for collecting various traffic data (including other road users);
			+ Knowledge/experience acquired during ADS development;
			+ Synthetically generated scenarios from key parameter variations; and
			+ Engineered scenarios based on functional safety requirements and safety of intended functionality. [Importance of HMI scenarios should be also addressed.]
	12. Continued collection of real-world data is important for identifying unexpected scenarios – scenarios that may be uniquely challenging to that vehicle’s specific ADS.
	13. Once a wide range of scenarios has been identified, specific requirements can be tested and validated by virtual, test track, and real-world test validation methods.
	14. **Classifying Scenarios:** The amount of information that is included in a scenario can be extensive. For example, the description of a scenario could contain information specifying a wide range of different actions, characteristics and elements, such as objects (e.g., vehicles, pedestrians), roadways, and environments, as well as pre-planned courses of action and major events that should occur during the scenario. Therefore, it is critical that a standardized and structured language for describing scenarios is established so that AV stakeholders understand the intention of a scenario, each other’s objectives, and the capabilities of an ADS.
	15. One approach that researchers have established for developing a standardized and structured language for describing scenarios, which also incorporates different levels of abstraction/detail, is classifying scenarios according to three categories: functional, logical, and concrete scenarios.
		* + **Functional Scenario:** Scenarios with the highest level of abstraction, outlining the core concept of the scenario, such as a basic description of: the ego vehicle’s actions; the interactions of the ego vehicle with other road users and objects; roadway geometry; and other elements that compose the scenario (e.g. environmental conditions etc.). This approach uses accessible language to describe the situation and its corresponding elements/parameters .
			+ **Logical Scenario**: Building off the elements/parameters identified within the functional scenario, developers generate a logical scenario by selecting value ranges or probability distributions for each element/parameter within a scenario (e.g., the possible width of a lane in meters). The logical scenario description covers all elements and technical requirements necessary to implement a system that solves these scenarios.
			+ **Concrete Scenarios:** Concrete scenarios are established by selecting specific values for each element/parameter. This step ensures that a specific test scenario is reproducible. In addition, for each logical scenario with continuous ranges, any number of concrete scenarios can be developed, helping to ensure a vehicle is exposed to a wide variety of situations.
			+ **Scenario** based test-case

*Figure 2. Examples of a scenario during different stages of its development (Pegasus, 2018).*



**Scenario Properties:** Traffic scenarios are derived by combining a number of relevant properties, taken from disjunct layers describing the scenario space systematically. **This part will be discussed further during highway focused functional scenario development.**