

Ontology and Lexicon for Automated Driving System (ADS)-Operated Vehicle Behaviors and Maneuvers in Routine/Normal Operating Scenarios

RATIONALE

The purpose of this document is to provide an ontology and lexicon for behaviors and maneuvers of on-road automated driving systems (ADSs)¹ under routine/normal operating conditions, as defined in SAE J3016. Defining such behaviors and maneuvers is an important step towards developing validation and verification methods. This document serves to advance a framework and common language for behaviors and maneuvers that can support ADS development and deployment, for example, through reducing use of inconsistent terminology in the literature. Standardizing terms and definitions for ADS behaviors and maneuvers during routine/normal operation serves several purposes, including:

1. Clarifying the expected driving behaviors of an ADS, and the context in which particular expected behaviors are appropriate, while not limiting design or functionality.
2. Support answering questions of scope when it comes to developing laws, policies, regulations, and standards.
3. Providing a useful framework for ADS specifications and technical requirements.
4. Providing clarity and stability in communications on the topic of ADS behaviors and maneuvers.

This document has been developed according to the following guiding principles, namely, it should:

1. Be descriptive and informative and might provide preliminary guidance.
2. Provide functional definitions.
3. Be consistent with current industry practice.
4. Be consistent with prior art to the extent practicable.
5. Be useful across disciplines, including engineering, law, media, and public discourse.
6. Be clear and cogent and, as such, it should avoid using or defining ambiguous terms.

This document does not provide specifications or otherwise impose requirements on ADSs or ADS-equipped vehicles.

¹ While beyond the scope of this document, level 1 and 2 driving automation system features allow for lateral and longitudinal vehicle motion control that are relevant to concepts discussed in this document, but these features importantly still require driver supervision while the feature is engaged, which is not the case for ADS features.

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Documents

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1. SCOPE

This document provides a high-level ontology and lexicon for describing on-road ADS-operated vehicle behavioral competencies and driving maneuvers that comprise routine/normal performance of the complete DDT, as defined in SAE J3016. It provides definitions of behavior, maneuver, scenario, and scene. This initial high-level lexicon and ontology are developed for ADS driving behaviors, including considerations for hierarchy of behaviors, and relationships among maneuvers, operational design domain (ODD) elements, and object and event detection and response (OEDR). Considerations for describing scenarios using this lexicon and ontology are discussed. This document describes ADS-operated vehicle motion control maneuvers during routine/normal operation. Maneuvers of other road users are not evaluated. This document assumes left-hand drive vehicles and road infrastructure. Applicability to right-hand drive vehicles and roadway infrastructure would require adjustment to such vehicles and conditions.

2. REFERENCES

2.1 Applicable Documents

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

2.1.1 SAE Publications

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

SAE J3016	Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles
AVSC00002202004	AVSC Best Practice for Describing an Operational Design Domain: Conceptual Framework and Lexicon
AVSC00008202111	AVSC Best Practice for Evaluation of Behavioral Competencies for Automated Driving System Dedicated Vehicles (ADS-DVs)

2.1.2 ISO Publications

Copies of these documents are available online at <https://webstore.ansi.org/>.

ISO 21448:2022	Road Vehicles - Safety of the Intended Functionality
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2.2 Other Publications

ASAM. (2020). ASAM OpenSCENARIO: Version 2.0.0. ASAM.

C. Nowakowski, S.E. Shladover, and C.-Y. Chan. (2016). Determining the Readiness of Automated Driving Systems for Public Operation. *Transportation Research Record No. 2559*, pp. 65-72.

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Colwell, I., Phan, B., Saleem, S., Salay, R., and Czarnecki, K.. (2018). An Automated Vehicle Safety Concept Based on Runtime Restriction of the Operational Design Domain. *Proceedings, The 2018 IEEE Intelligent Vehicles Symposium, Springer*, pp. 1910-1917.

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Czarnecki, K. (2018c). Operational World Model Ontology for Automated Driving Systems—Part 1: Road Structure. *Waterloo Intelligent Systems Engineering Lab (WISE) Report, University of Waterloo*, DOI: 10.13140/RG.2.2.15521.39568.

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NHTSA. (2015). Critical Reasons for Crashes Investigated in the National Motor Vehicle Crash Causation Survey. *National Highway Traffic Safety Administration*, <https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812115>.

NHTSA. (2021). An Approach for the Selection and Description of Elements Used to Define Driving Scenarios. *National Highway Traffic Safety Administration*, <https://rosap.nhtl.bts.gov/view/dot/55465>.

NHTSA. (n.d.). Voluntary Safety Self-Assessment (VSSA) Disclosure Index (28 VSSA documents as of 8/16/2021). *National Highway Traffic Safety Administration*, <https://www.nhtsa.gov/automated-driving-systems/voluntary-safety-self-assessment>.

PEGASUS. (2019). Requirements and Conditions: Scenario Description. *PEGASUS Project*, https://www.pegasusprojekt.de/files/tmpl/PDF-Symposium/04_Scenario-Description.pdf.

Tellis, L., Engelman, G., Christensen, A., Cunningham, A., Debouk, R., Egawa, K., Green, C., Kawashima, C., Nicols, G., Prokhorov, D., Wendling, B., Yako, S., and Kiger, S. (2016). Automated Vehicle Research for Enhanced Safety: Final Report. *National Highway Traffic Safety Administration*, https://downloads.regulations.gov/NHTSA-2014-0070-0003/attachment_1.pdf.

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3. DEFINITIONS

3.1 [ADS-OPERATED VEHICLE] BEHAVIORAL COMPETENCY

A description of an expected capability(ies) of an ADS feature operating a vehicle within the feature's ODD.

NOTE 1: For a complete definition of “[driving automation system] feature,” including “ADS feature,” refer to SAE J3016.

NOTE 2: Behavioral competency includes routine/normal and fallback ADS operating conditions (refer to SAE J3016).

NOTE 3: Competencies can be attained at different levels of performance and should demonstrate absence of unreasonable risk within the ODD.

For additional information, see Section 4.

3.2 DYNAMIC DRIVING TASK (SAE J3016)

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

1. Lateral vehicle motion control via steering (operational).
2. Longitudinal vehicle motion control via acceleration and deceleration (operational).
3. Monitoring the driving environment via object and event detection, recognition, classification, and response preparation (operational and tactical).
4. Object and event response execution (operational and tactical).
5. Maneuver planning (tactical).
6. Enhancing conspicuity via lighting, signaling and gesturing, etc. (tactical).

Refer to SAE J3016 for complete definition.

3.3 VEHICLE BEHAVIOR

Goal-oriented activities enacted by a vehicle to implement a human driver's or an engaged ADS's performance of the DDT or DDT fallback.

NOTE 1: Maneuvers are a subset of behaviors.

NOTE 2: Vehicle behaviors can occur at the tactical and operational timescales (Michon, 1985).

NOTE 3: The focus of this document is observable and/or measurable vehicle behaviors, such as lane maintenance, speed maintenance, lane changing, and turning.

NOTE 4: Enhancing conspicuity via lighting and signaling and/or gesturing are observable behaviors that can support vehicle motion control behaviors but are not maneuvers. Signaling (when used) is an observable behavior that supports tactical lane change behavior.

NOTE 5: ADS monitoring of the driving environment via object and event detection, recognition, classification, and response preparation and maneuver planning are non-observable functions that can support vehicle motion control behaviors but are not the focus of this document.

NOTE 6: In contrast to “behavioral competencies” (see 3.1 and Section 4), vehicle behaviors may be (judged to be) competent or incompetent.

3.3.1 ADS-OPERATED VEHICLE BEHAVIOR

Goal-oriented activities enacted by a vehicle to implement the engaged ADS's performance of the DDT or DDT fallback.

NOTE 1: The general term "behavior" in the context of road travel can apply to any road user, including motorists, pedestrians, cyclists, and animals. This document, however, is focused on ADS-operated vehicle behaviors, especially actions taken by an ADS when performing the complete DDT in on-road traffic. (ADS performance of the DDT includes tactical and operational behaviors; see 3.2.) In general, behavior can also include uncontrolled actions, such as uncontrolled skidding, but these are not the focus of this document.

NOTE 2: An ADS performs actions in response to states or state changes that are internal or external to the vehicle, and these actions, in turn, cause state changes that are internal or external to the vehicle (e.g., activation of a turn signal).

NOTE 3: As is the case for human-operated vehicles (even when operated by highly-qualified drivers), an ADS-operated vehicle might encounter conditions or circumstances that are so severe or catastrophic as to be beyond its operational capabilities (e.g., some situations involving black ice, landslide occurrence, or during/after a severe crash). Such conditions or circumstances are beyond the scope of this document.

EXAMPLE 1: A "detect and respond to proximate and pertinent vehicles" behavior in which an ADS-operated vehicle detects a cut-in from an adjacent vehicle and responds by decelerating to achieve a comfortable headway.

EXAMPLE 2: An "intersection handling" behavior in which an ADS-operated vehicle approaching a red traffic signal light at an intersection decelerates to a full stop and remains there until the light turns green and traffic clears, whereupon the ADS causes the vehicle to resume motion.

3.3.2 HUMAN-OPERATED VEHICLE BEHAVIOR

Goal-oriented activities enacted by a vehicle to implement the human driver's performance of the DDT or DDT fallback.

NOTE: This is beyond the scope of this document, but important to the definition of scenarios involving human-operated vehicles.

3.4 VEHICLE MANEUVER

Goal-oriented vehicle movement directed by an ADS or human driver in order to achieve a specific result/outcome.

NOTE 1: Maneuvers are a subset of operational and tactical behaviors. Operational and tactical behaviors include vehicle motion control behaviors, such as making a turn, but also signaling behavior—which is not a maneuver—associated with that turn.

NOTE 2: Non-maneuver behaviors may not entail vehicle movement (e.g., activities related to signaling/lighting, adjustment of mirror/sensor field-of-view, gear shifting) and/or may not be goal-oriented (e.g., sliding on ice or snow).