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Road Vehicles — Test scenarios for automated driving systems — Specification for operational design domain

Véhicules routiers — Scénarios d'essai pour les systèmes de conduite automatisée — Spécification du domaine de conception opérationnelle

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ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Email: copyright@iso.org
Website: www.iso.org

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 33, *Vehicle dynamics, chassis components and driving automation systems testing*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

The move towards automated driving systems (ADSs) is being driven by the many potential benefits of the technology, such as increased safety, reduced traffic congestion, lowered emissions and potentially increased mobility for those unable to drive. In order to realize these benefits, it is essential that the ADS technology is introduced safely.

The development of automated vehicle technology has received wide public attention, with countries worldwide focusing on:

— ensuring that the introduction of ADSs for testing/trialling purposes and for commercial operations is done safely, securely and legally; and

— building public and consumer trust and acceptance of the technology.

A key aspect of the safe use of automated vehicle technology is defining its capabilities and limitations and clearly communicating these to the end user, leading to a state of "informed safety". The first step in establishing the capability of an ADS is the definition of its operational design domain (ODD). In addition to safe operation, the ODD definition is also important for conformity with laws and regulations and compliance with vehicle goals, e.g. mobility and comfort needs.

The ODD represents the operating conditions within which an ADS can perform the dynamic driving task (DDT) safely during a trip. This document focuses on a taxonomy and format for the ODD definition for a given ADS to create a common understanding of the ODD.

The ODD taxonomy and definition format specified in this document will enable ADS manufacturers to specify, implement and communicate minimum safety requirements in their designs, and allow end users (e.g. insurers, national, local, and regional government), operators and regulators to reference a minimum set of ODD attributes and performance requirements in their procurements. It will also enable ADS manufacturers, developers and suppliers of components and subcomponents to define the operating capability and assemble sets of evidence that will improve confidence in the safety of the resulting product (such as component specifications) and in the data obtained from test and verification activities.

While there are a number of different testing, trialling and deployment environments, this document provides a generic taxonomy for defining each of these environments. For a scenario-based verification methodology for ADS, a hierarchical taxonomy for ODD definition and a definition format also enables an efficient scenario creation and scenario parametrisation. Such a definition format standard is in development – ASAM OpenODD.

Road Vehicles — Test scenarios for automated driving systems — Specification for operational design domain

1 Scope

This document specifies the requirements for the hierarchical taxonomy for specifying operating conditions which enable the definition of an operational design domain (ODD) of an automated driving system (ADS). This document also specifies requirements for the definition format of an ODD using the taxonomy. The ODD comprises specific conditions (which include the static and dynamic attributes) within which an ADS is designed to function.

This document is mainly applicable to level 3 and level 4 ADS. An ODD for level 5 ADS is unlimited (i.e. operation is possible everywhere).

This document can be used by organizations taking part in developing safety cases for automated vehicles, in particular, for organizations conducting trials, testing and commercial deployment. This document can also be used by manufacturers of level 3/4 ADS to define the ADS' operating capability. It may also be of interest to insurers, regulators, service providers, national, local and regional governments to enable them to understand possible ADS deployments and capabilities.

This document does not cover the basic test procedures for attributes of the ODD. It does not cover the monitoring requirements of the ODD attributes.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO/SAE PAS 22736, *Taxonomy and definitions for terms related to driving automation systems for on-road motor vehicles*

ISO 34501, *Road vehicles — Test scenarios for automated driving systems — Vocabulary*

ISO 34502, *Road vehicles — Test scenarios for automated driving systems — Scenario based safety evaluation framework*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO/SAE PAS 22736 and ISO 34501 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
dynamic element
movable object or actor in the ODD within the DDT timeframe

Note 1 to entry: Adapted from Reference [5].

3.2
environmental condition
weather or another atmospheric condition and other conditions of the environment which are not defined as *scenery elements* (3.4) (as well as information technology connectivity)

3.3
minimal risk manoeuvre
MRM
tactical or operational manoeuvre triggered and executed by the ADS to achieve the minimal risk condition (MRC)

3.4
scenery element
non-movable element of the ADS-equipped vehicle's operating environment

Note 1 to entry: This definition is to be used only in the context of an ODD.

Note 2 to entry: Non-movable element is not restricted to static elements. For example, traffic lights, movable bridges.

3.5
vulnerable road user
non-protected road user such as motorcyclists, cyclists, pedestrians, horse riders and persons with disabilities or reduced mobility and orientation

3.6
traffic agent
anyone who uses a road including sidewalk and other adjacent spaces

3.7
target operational domain
TOD
set of operating conditions in which an ADS will be expected to operate, 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 1 to entry: While the ODD defines of the operating conditions that an ADS is designed to operate in, the TOD is the area (describing location) where the ADS will be deployed (expected to operate in). As such a TOD may have conditions outside the ODD of the ADS. For further clarification, see Clause 5.

3.8
current operational domain
COD
specific set of operating conditions which exists presently in the immediate vicinity of an ADS, 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

3.9
operational domain
OD
set of operating conditions, 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 1 to entry: This set can be used to describe real-world conditions in certain environments, geography, synthetic conditions for testing, and other various purposes.

4 Abbreviated terms

ADS Automated Driving Systems

ASAM	Association for Standardization of Automation and Measuring Systems
AV	Automated Vehicle
COD	Current Operational Domain
DDT	Dynamic Driving Task
MRC	Minimal Risk Condition
MRM	Minimal Risk Manoeuvre
OD	Operational Domain
ODD	Operational Design Domain
TOD	Target Operational Domain
V2I	Vehicle to Infrastructure

5 Operational design domain (ODD) and target operational domain (TOD)

An ODD defines the operating conditions under which an ADS is designed to operate safely. However, the target operational domain (TOD) defines the real-world conditions that an ADS may experience and is required to safely operate in. Often, the TOD will be a superset of the ODD properties.

In real world deployment of ADS, the difference between an ODD and TOD highlights the limitations of the ADS. In all practical cases, an ODD definition will not be exhaustive enough to cover all attributes or occurrences in a TOD. Therefore, it is important to ensure the boundary between ODD and TOD is defined objectively and to have design mechanisms in the ADS to execute fallback manoeuvres when an ODD exit is encountered to ensure safe operation of the ADS in a TOD. Current operational domain (COD) refers to the real-time operational domain, i.e. real-time real-world conditions that the ADS is experiencing.

The key difference between ODD and TOD is that ODD expresses a specification of the ADS, whereas TOD is a description/specification of an environment in which various ADSs will be expected to operate. In general, one can expect that an ODD of any ADS operating within the TOD, is a superset (i.e. including all aspects) of the TOD. Another perspective is that the TOD can be viewed as a requirement to be met by all ADS's ODD – if these ADS are to operate within the environment described by the TOD.

Depending on the design and requirements for an ADS, the TOD may be a superset of the ODD or the other way round. If the TOD is a superset of the ODD, it implies appropriate risk mitigation measures will be required as part of the ADS safety measures.

6 ODD and scenario relationship

As an ODD definition needs to be testable, ODD attributes and the definition of the attributes play a key role in scenario-based testing. It is important to highlight that ODD and scenarios are two distinct but related constructs. While ODD describes the operating conditions of the ADS in which it is designed to operate, a scenario along with parts of the scenery elements and environmental conditions, describe the behaviour of the traffic participants and may also define the desired behaviour of the ego vehicle in an instantiation (part) of an ODD or outside of an ODD.

NOTE See Annex A for the overall ADS-constraining factors apart from the ODD.

The ODD definition shall be used as one of the inputs for scenario-based safety evaluation framework in accordance with ISO 34502. Therefore, one of the first steps in a verification and validation process of an ADS would be to analyse the designed ODD of the ADS to create a set of test scenarios. The second step would involve testing the desired behaviour of the ADS by choosing a set of behaviours from a

behaviour library. The choice of the behaviours may include undesired behaviours to test the ADS' response. An instantiation of the ODD together with a desired behaviour and the description of the traffic participants' behaviour according to events and triggers will provide a scenario definition for the ADS. Such a qualitative scenario can then be further detailed into functional, abstract, logical and concrete scenarios to create a scenario library (Figure 1).

Furthermore, the ODD definition can be used as criteria for deciding whether individual test scenarios are inside, outside or at the boundary of an ODD. Such scenarios also enable the test for activation and deactivation of the ADS depending on ODD. It is important to test against scenarios outside the ODD in order to ensure that the ADS is not misused in situations for which it is not designed. Also, a comparison between a test scenario set and the ODD definition shall be performed to analyse the test space coverage.

As a centralised scenario library will potentially have a large number of scenarios for different ODDs, ODD attributes (see Clause 8) and behaviour labels (ASAM OpenLabel[4]) can play a key role in enabling an efficient scenario search for an ADS. Every scenario will have a relationship with an ODD. In ISO 34502, three types of scenarios are mentioned: perception-, traffic- and vehicle control. For example, a perception related scenario focused on blind spot detections may exist on a motorway or on a road in a city centre, where motorway and city centre roads are ODD instantiations. Compared to an ODD definition, a scenario has additional constructs like events, triggers and other dynamically changing behaviours. Such scenario attributes may be classified according to ASAM OpenLabel[4].

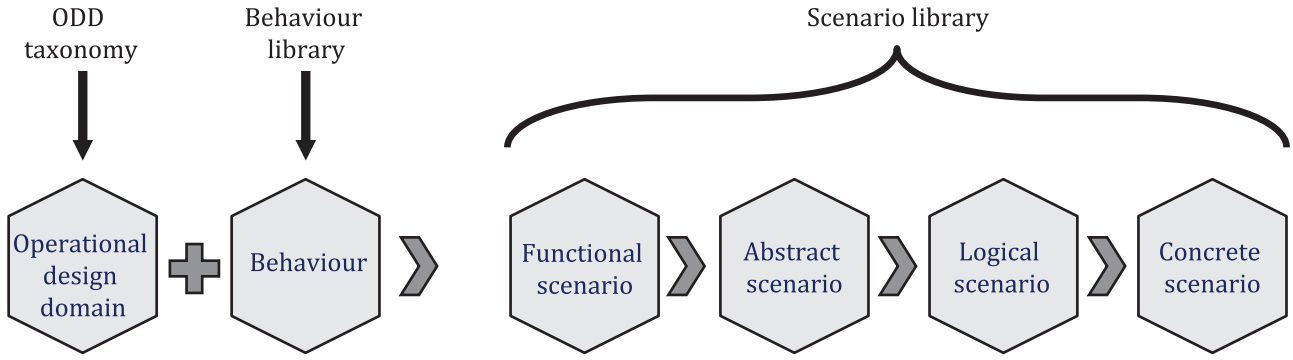

Figure 1 — An example relationship between ODD, behaviour and scenarios

7 ODD requirements and application

7.1 Abstraction of ODD definition

Based on the taxonomy and definition format in this document (Clauses 8-12), an ODD definition shall be developed by an ADS developer and before deployment should be compared with the stakeholders' requirements of the operational domain (OD), either individually or in consultation, for the safe operation of the ADS in the operational domain.

An ODD can be defined from the perspective of an end user or a system specifier. Depending on the perspective, the abstraction of the ODD definition can vary.

Although the end user and specifier can have different abstractions of ODD, the ODD definition should be done objectively to avoid any misunderstandings.

Stakeholders or end users may include, but are not limited to, local authorities, regulators, ADS system users, service providers, manufacturers, developers of an ADS or suppliers of components and subcomponents. A city council, for example, can develop an ODD definition as part of a procurement specification for an ADS mobility service, while a manufacturer can develop an ODD definition in order to convey the ADS' capabilities and limitations and create the corresponding safety case. Different stakeholders can develop their ODD definition with varied level of detail.

The abstraction hierarchy to be used for the ODD definition, see Clauses 8 to 11, shall be at the discretion of the stakeholder. Irrespective of the abstraction level chosen, stakeholders shall specify the ODD attributes used to inform the scenario-based testing of the ADS.

A stakeholder who defines an ODD by choosing an attribute at a higher abstraction level shall ensure that all the predefined subattributes are also within the ODD definition, even if they have not been explicitly mentioned in the ODD definition. In case it is necessary for a specific defined system to have a detailed ODD, the ODD definition shall be described with a greater level of detail. For example, if an ADS is designed to be able to handle light rain only (<2,5 mm/h) and is not able to operate in higher intensity of rainfall, the defined ODD should be specified at this granularity (i.e. with additional subattributes).

The ODD attributes shall be extensible in a way that allows new attributes or subattributes to be added as a result of stakeholder consultation and ensuring consistency with the existing attributes.

7.2 Monitoring ODD attributes

While performing the DDT, ADS will perceive the operating environment, i.e. will be aware of the near real-time ODD attributes' values, so that the ADS can compare the external conditions (i.e. the COD) with the defined ODD. This is essential for the ADS to be able to decide on triggering the minimal risk manoeuvre (MRM) or issuing a transition demand by the ADS. During trials, the monitoring of the ODD attributes may be performed by the safety operator or dispatcher.

ODD attributes may have interdependence and their relationship shall be defined in a prescribed format (Clause 12). For example, an ADS may have a maximum allowable speed of 70 km/h in the absence of rainfall, and a reduced maximum allowable speed of 40 km/h in the presence of rainfall. The ADS or the dispatcher shall be able to compare the defined ODD with the COD. The dispatcher or the ADS need to decide, for example, to reduce the maximum allowable speed when it is raining as compared to sunny conditions in order to ensure operation within ODD boundaries.

Defining an ODD boundary is up to the manufacturers' discretion and may involve subattributes or qualifiers, such as temporal elements. For example, an ODD boundary may be defined as up to 2 min of heavy rainfall by adding a relevant subattribute. ODD attributes shall be defined in such a way to allow the ADS to be aware if it remains within the designed and defined ODD attribute definition. The ODD monitoring is needed for forecasting an upcoming ODD boundary with sufficient time buffer. In case of an imminent ODD exit, the ADS should be designed to trigger a transition to a minimal risk condition (MRC) or issue a transition demand to the fall-back ready user or change the operating mode to a degraded mode, i.e. lower performance capability mode.

While the role of the human driver/dispatcher is not part of the ODD definition, the ODD is to be defined in a way that it is understandable to the user (driver/dispatcher) to enable them to take into account the ODD limits for the safe use of the ADS feature (see Clause 12).

7.3 Implication to scenario-based testing

As part of the ADS development cycle, the ODD definition may be an iterative process with a gradual increase or decrease in ODD attributes and attribute value coverage. An ODD definition is an essential work product contributing to the safety case of an ADS. As part of the scenario-based testing process of an ADS as defined in ISO 34502, constraints given by the ODD definition shall be used to define test scenarios. As part of the process to show compliance with the defined ODD, test procedures shall be demonstrated for the specific defined ODD attributes. Testing should cover correct ADS operation within the ODD, across ODD boundary and responses outside ODD boundary (e.g. reject attempts to engage outside ODD).

8 ODD taxonomy

8.1 General

ODD attributes (and their subattributes) are specified below in 8.2 and Clauses 9 to 11. If they do not adequately represent a specific operating environment, stakeholders may extend them, including the introduction of relevant measurement units (which might reflect temporal or other aspects). While the taxonomy is extensible, any extensions to the taxonomy which conflict with attributes specified shall be avoided. Furthermore, while extending the attributes, stakeholders shall ensure that the additional attributes are placed at the correct hierarchy and group in the taxonomy while providing justification for the same. For all attributes, the specifier shall provide the objective measurement for the attribute. In case any of the attributes are not relevant for the operating condition of the ADS, such attributes may be ignored from the ODD definition (depending on the format definition, see Clause 12). Stakeholders may add additional layers of attributes between parent and child attributes in order to aid grouping of the attributes.

NOTE For examples of ODD descriptions from different use cases, see Annex B.

8.2 Top level ODD classification

At the top level, the ODD shall be classified into the following attributes:

— scenery elements;

— environmental conditions;

— dynamic elements.

The “scenery elements” attribute (in the context of defining an ODD) shall consist of the spatially fixed elements of the operating environment (e.g. roads, traffic lights, etc.), relative to the ego vehicle (in terms of position of the elements).

The “environmental conditions” attribute shall consist of weather and atmospheric conditions (including information technology connectivity).

The “dynamic elements” attribute shall consist of the movable elements of the ODD, e.g. traffic, subject vehicle.

Figure 2 illustrates a top-level taxonomy of the ODD attributes. All attributes are considered to have equal importance.

While scenery elements ODD attributes (Clause 9) consist of spatially fixed objects, flow of traffic may change with time on or around scenery elements attributes. For example, traffic flow direction on some roads (drivable area) may change with time of the day or day of the week. Similarly, some bridges may close and open to let boats and ships to pass. While the state of the bridge changes, the location of the bridge itself does not change. Therefore, all attributes with fixed location are considered to be part of scenery elements attributes, while their state may change with time.

Environmental conditions (Clause 10) play an important role in influencing the safe operation of ADS-equipped vehicles. The environmental conditions have the potential to impact all ADS functions from perception and planning to actuation control, as they can impact visibility, sensor fidelity, vehicle manoeuvrability due to changing drivable area surface conditions, and communication systems.

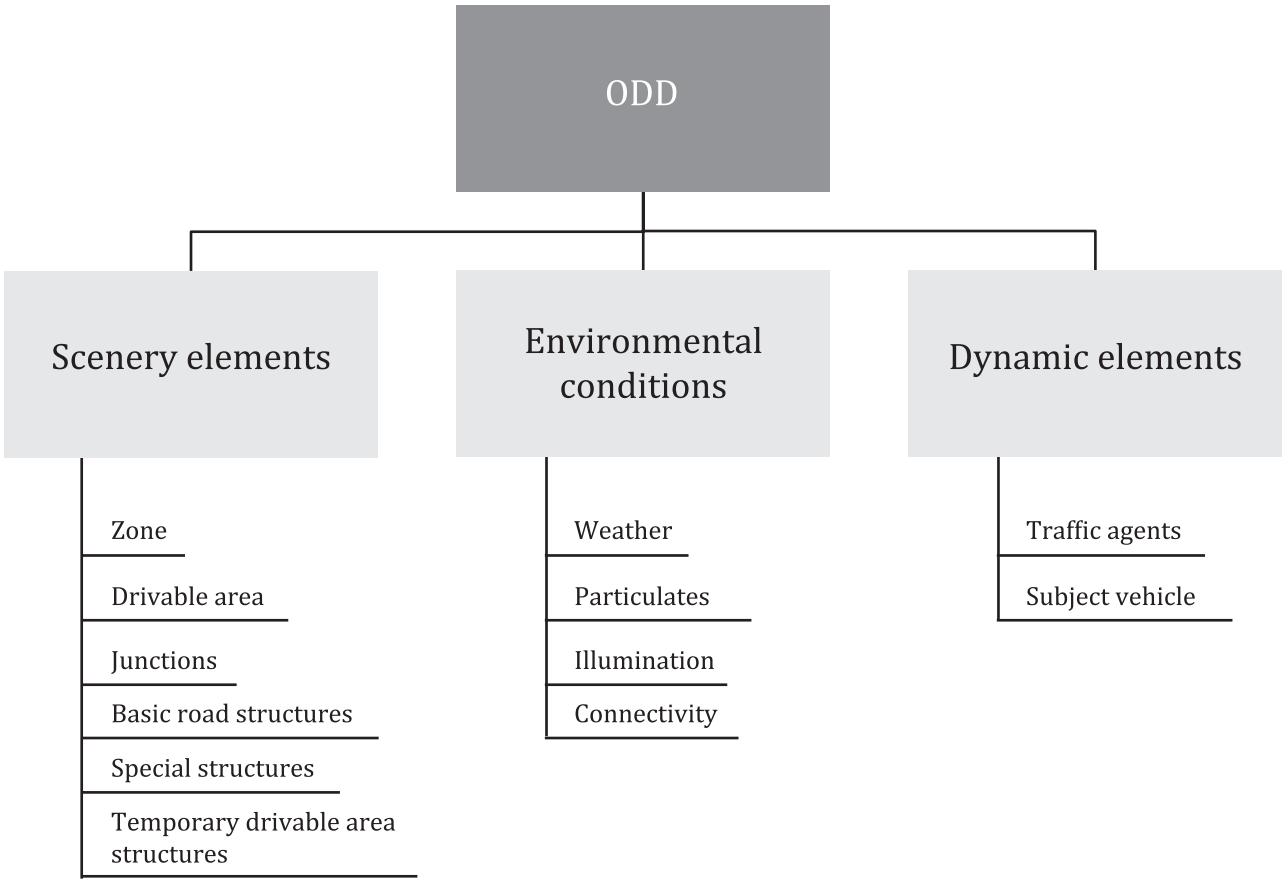

Figure 2 — Top level taxonomy with ODD attributes

Similarly, dynamic elements (Clause 11) add complexity to the operating environments due to their diverse nature, and their predictable and unpredictable behaviour.

Annex B provides examples of ODD definitions using the ODD taxonomy and format specified in Clauses 8 to 11 and Clause 12 respectively.

9 Scenery elements

9.1 General

At the top level, “scenery elements” shall at least be classified into the following attributes or have additional attributes:

a) zones;

b) drivable area;

c) junctions;

d) special structures;

e) basic road structures;

f) temporary drivable structures.

9.2 Zones

Zones include special road configurations which may differ from typical conditions for driving, or areas with specific driving regulations or environmental conditions. Some ADS applications may be restricted to specific zones where the ADS can operate safely. Zones attributes should at least be classified into the following attributes:

a) geo-fenced areas;

b) zone type:

   1) fixed zone: school zone, environmental zone, industrial zone, parking lot;

   2) dynamic zone: traffic management zone, mobile work zone, ;

   3) interference zone: urban canyon, overhead wires, dense foliage;

   4) port zone;

   5) freight distribution centre;

c) regions or states.

By defining a geo-fenced zone, one may already imply some of the other attributes in 9.3 to Clause 11. However, it may be possible that the entire geo-fenced zone is excluded from the ODD definition, and any exceptions shall be defined using the taxonomy and the format defined in this document.

In case a zone is defined as an ODD attribute, it shall imply that everything inside the zone is a part of the ODD unless explicitly excluded.

9.3 Drivable area

9.3.1 General attributes

A drivable area refers to the area on which the ADS equipped vehicle may operate. Drivable area should at least be classified into the following attributes:

a) drivable area type;

b) drivable area geometry;

c) drivable area lane specification;

d) drivable area signs;

e) drivable area edge;

f) drivable area surface.

9.3.2 Drivable area type

A drivable area type should at least be classified into the following attributes:

a) motorways or highways or interstates;

b) primary roads (e.g. dual-carriage ways, single carriage ways);

c) radial roads;

d) distributor roads;

e) minor or local roads;

f) slip roads or off-ramps;

g) parking space;

h) shared space.

Motorways or highways or interstates are high-traffic roads where non-motorized vehicles and pedestrians are prohibited.

Radial roads are high density traffic roads which connect the motorways to distributor roads or urban centres.

Distributor roads connect radial roads with minor or local roads and generally have low to moderate capacity.

Minor roads or local roads provide access to residential areas and other local developments. These roads carry low volumes of traffic.

A slip road is a road which is used to drive on to and off a motorway or highways or interstates.

A parking space is the physical space where one vehicle is parked.

A shared space may be shared between subject vehicle and other actors, for example, pedestrians or cyclists.

When stakeholders use the above attributes for driveable area type, stakeholders shall define each of the attributes used as part of the ODD definition. It may be possible that in certain regions the above attributes are given vernacular names. In such cases, stakeholders shall define each term to enable mapping to the above attributes.

Each of the drivable area types should at least be further classified into those:

1) with active traffic management; and

2) without active traffic management.

Each of the drivable area types should have associated speed limit(s).

9.3.3 Drivable area geometry

A drivable area geometry should be described by viewing the drivable area layout in three planes:

a) horizontal plane;

b) transverse plane;

c) longitudinal plane.

In case any of the attributes are not relevant for the operating condition of the ADS, such attributes may be ignored from the ODD definition (depending on the format definition, see Clause 12).

In a horizontal plane, two main attributes should be included:

1) straight lines; and

2) curves.

Curves should be measured by the radius of curvature of the road. Horizontal alignment can be seen when the road layout is projected on a horizontal plane.

In a transverse plane, the main attributes should at least be classified into the following attributes or have additional attributes:

i) type: divided, undivided, pavement

ii) barriers on road edges;

v) types of lanes together;

vi) superelevation / banking.

A cross section plane is the road configuration in the transverse profile. The cross section below (see Figure 3) provides information about the features on or adjacent to the road, e.g. pavement or divided drivable area. Transverse plane attributes may include banking and camber.

In a longitudinal plane, three main attributes should be included:

1. up-slope (positive gradient);
2. down-slope (negative-gradient);
3. level plane.

Longitudinal alignment can be seen in a vertical configuration of the road in a longitudinal section.

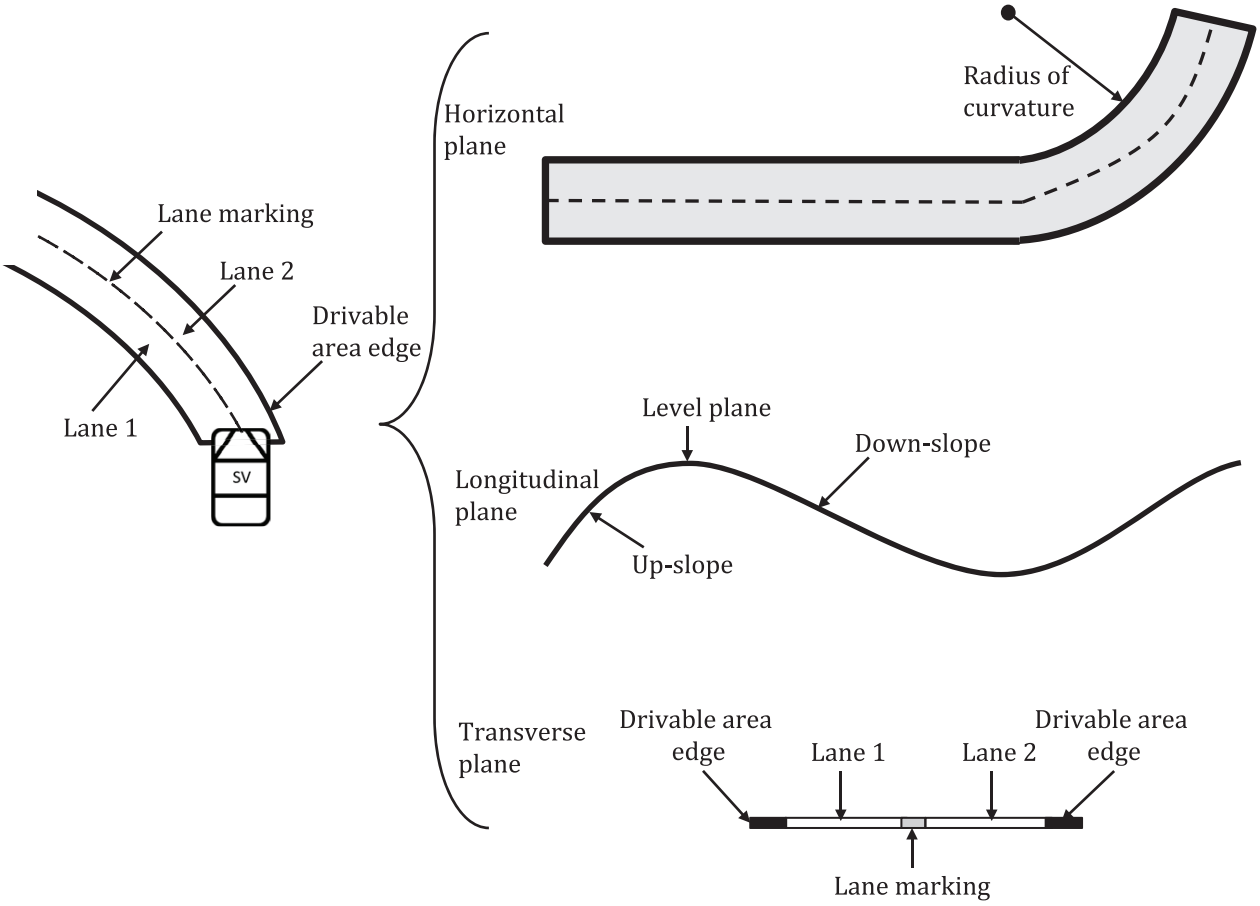

Figure 3 — Road geometry configurations

9.3.4 Drivable area lane specification

A drivable area lane is the drivable area that a vehicle would be expected to travel along in the absence of any obstruction without the driver's or ADS' desire to change the path of travel (adapted from ISO 11270). The drivable area lane specification should at least be classified into the following attributes:

a) lane dimensions;

b) lane marking;

c) lane type;

d) direction of travel;

e) speed limit;

f) lane usage.

A drivable area lane type should include bus lane, traffic lane, cycle lane, tram lane, emergency lane, shared lane or other special purpose lanes.

Drivable area lane markings are delineators intentionally placed on the borderline of the lane (adapted from ISO 11270). Drivable area lane marking may include clear lane marking, blurred lane marking, no lane marking and temporary lane marking.

Direction of travel should include right hand and left-hand travel.

9.3.5 Drivable area signs

Drivable area signs should at least be classified into the following attributes:

a) sign type: regulatory signs (e.g. traffic lights), warning signs, information signs;

b) sign feature: movable signs, fixed signs.

Regulatory signs are used to indicate or reinforce traffic laws, regulations or requirements. They are intended to instruct drivable area users on what they must or should do (or not do) under a given set of circumstances.

Warning signs provide advance notice of hazardous situations or conditions on the drivable surface. These are advisory signs.

Information signs provide directions and information about services which may be of interest to the driver, or the ADS equipped vehicle.

Each of the above drivable area signs should be further classified into variable or uniform messaging. For example, smart highways or motorways may change their speed limits depending on external factors.

Additionally, each of the attributes should be classified by their operation duration into full-time or temporary (e.g. due to road construction or road incidents).

Each of the attributes may also be classified based on the language used in the sign in case textual information is displayed on the sign.

Quality of signs may be defined by the stakeholders.

9.3.6 Drivable area edge

A drivable area edge is the outermost edge of the drivable area in which a vehicle travels. The drivable area edge should at least be classified into the following attributes:

a) line markers;

b) shoulder:

   1) paved or gravel;

   2) grass;

c) snowbanks;

d) solid barriers (e.g. grating, rails, curb, cones);

e) temporary line markers;

f) none.

Shoulders are clear of main line traffic, are situated adjacent to a road and offer a place for vehicles to stop in emergencies.

A hard shoulder should be considered as a drivable area when it is opened as a driving lane.

9.3.7 Drivable area surface

The driveable area surface should be classified into the following attributes:

a) drivable area surface type;

b) drivable area surface features;

c) drivable area induced surface condition.

A drivable area surface type should be classified into at least:

— asphalt,

— cement concrete,

— pavers,

— cobblestone,

— granite setts and

— gravel.

Drivable area surface features should include damage caused by traffic and weather. Any road damage (and the resulting different surface features) should be classified into:

— cracks,

— potholes,

— ruts or

— swells.

Driveable area surface features should include artificial features like speed bumps and intentional speed reduction obstacles.

Drivable area induced surface conditions should at least be classified into the following attributes:

1) icy;

2) flooded;

3) standing water;

4) snow on surface;

5) wet;

6) surface contamination.

A flooded drivable area results when the amount of water arriving on the drivable area is greater than the capacity of the drainage facilities that take it away.

Standing water tends to occur if there is a depression in the drivable area.

Surface contamination may be due to oil spills, sand on surface, etc.

9.4 Junctions

9.4.1 General

Junctions are areas where two or more drivable area types meet. Junctions should be classified into roundabout or intersection attributes. Roundabouts are a special type of intersection (a circular intersection).

9.4.2 Roundabout

A roundabout should at least be classified into the following attributes:

a) mini;

b) compact;

c) normal;

d) large;

e) double;

f) multiple.

A mini roundabout is a small roundabout in low-speed environments and with an inscribed circle diameter (ICD) of less than 28 m. ICD is the diameter of the largest circle that can be inscribed within the roundabout kerbs.

A compact roundabout is a roundabout with a central island of at least 4 m diameter and an ICD between 28 m and 36 m. A compact roundabout has a single drivable area lane entry and exit on each arm.

A normal roundabout is a roundabout with a central island of at least 4 m diameter, and inscribed circle diameter (ICD) between 28 m and 100 m and has more than one drivable area lane entry and exit on at least one of the arms.

A large roundabout is a roundabout with a central island, and ICD in excess of 100 m and with multiple drivable area lane entry and exits at all or some of the approaches.

A double roundabout comprises of two roundabouts which are separated by a short link.

A multiple roundabout complex is an arrangement where multiple roundabouts are linked together to form a roundabout complex. Vehicles can travel around the periphery of the complex in a similar fashion to a single large roundabout or they can treat each mini roundabout as a separate entity.

It may be possible that in certain regions the above attributes are given vernacular names. In such cases, stakeholders should define each term to enable mapping to the above attributes.

Each roundabout attribute should be further classified into:

1) signalised;

2) non-signalised: non-signalised roundabout should be further classified into:

   i) non-signalised roundabout with yielding traffic;

   ii) non-signalised roundabout without yielding traffic.

9.4.3 Intersection

Intersections should at least be classified into the following attributes:

a) T-junction;

b) Y-junction;

c) cross road;

d) staggered;

e) grade separated.

While classifying intersections, stakeholders should consider the number of roads meeting at the intersection and may extend the attributes as per their requirement.

A T-junction is a three-way intersection where one road joins another road at a right angle without crossing it.

A Y-junction is a three-way intersection where one road joins another road at an acute angle without crossing it.

A cross road junction is where two roads cross each other to form a junction. A crossroad may be comprised of the two roads with equal rights or a major road (i.e. traffic has the right of way) and a minor road (i.e. traffic has to yield to the traffic on the major road).

Staggered junction is a junction arrangement where the major road (i.e. traffic has the right of way) is continuous through the junction and two opposing minor roads (i.e. traffic has to yield to the traffic on the major road) form priority junctions that are offset from one another.

Grade separated junction is a junction that has at least two road links at different levels to keep conflicting traffic flow apart, and usually involves the provision of a structure (e.g. bridge or a tunnel) to accommodate road crossing.

Each intersection attribute should be further classified into: signalised or non-signalised.

9.5 Basic road structures

Basic road structures are structures that are present on the drivable area surface or near the edge of the drivable area surface. Basic road structures should at least be classified into the following attributes or have additional attributes:

a) building;

b) streetlight;

c) street furniture (e.g. bollards);

d) vegetation.

9.6 Special structures

Special structures should at least be classified into the following attributes:

a) type: automatic access control barrier, bridge, pedestrian crossing, rail crossing, tunnel, toll plaza;

b) dimension: length, width, height, shoulder width

c) usage: driving on, driving under

9.7 Temporary drivable area structures

Temporary drivable area structures should at least be classified into the following attributes:

a) construction site detour;

b) refuse collection;

c) road work;

d) signage.

Temporary drivable area structures may be placed on the drivable area due to local requirements or accidents, which include temporary emergency signage which obstruct or impact normal driving. Signage (as part of temporary road structures) are different from drivable area signs (9.3.5), as they include new physical structures being temporarily put in place as compared to fixed signs which are part of drivable area signs.

10 Environmental conditions

10.1 General

Many of the environmental elements that impact the ADS will demonstrate high degrees of variability over time and distance, therefore traditional meteorological reports of weather parameters require some degree of interpretation to be truly applicable to the ADS. The following environmental attributes represent many of those with the highest expected impact.

10.2 Weather

10.2.1 General

While individual weather attributes (e.g. wind, rainfall, snowfall) are mentioned in this taxonomy, ADS developers should also take into account the effect of a combination of attributes (e.g. high rainfall rate and strong breeze).

10.2.2 Ambient air temperature

Ambient air temperature may have a significant effect on ADS system performance. It is necessary for the ADS to detect the ambient air temperature in order to ensure safe performance. The temperature should be given in °C or °F.

10.2.3 Wind

Wind speed should be specified in the unit of m/s. It should be characterized as an average over a specified time interval (recommended 2 min to 10 min) and a gust value in m/s, which is the peak value of a 3 s rolling mean wind speed.

Stakeholders may additionally choose to use the Beaufort scale to categorize wind on the basis of its speed as outlined in the list below (noting that these speeds strictly refer to measurements made at 10 m above open flat ground and are drawn from Reference [6]). The values are to the nearest 0,1 m/s due to the natural variability of wind, and the typical precision of these measurements and the definitions are for ease of use only):

a) no wind;

b) calm: < 0,2 m/s;

c) light air: 0,3 m/s to 1,5 m/s;

d) light breeze: 1,6 m/s to 3,3 m/s;

e) gentle breeze: 3,4 m/s to 5,4 m/s;

f) moderate breeze: 5,5 m/s to 7,9 m/s;

g) fresh breeze: 8,0 m/s to 10,7 m/s;

h) strong breeze: 10,8 m/s to 13,8 m/s;

i) near gale: 13,9 m/s to 17,1 m/s;

j) gale: 17,2 m/s to 20,7 m/s;

k) strong gale: 20,8 m/s to 24,4 m/s;

l) storm: 24,5 m/s to 28,4 m/s;

m) violent storm: 28,5 m/s to 32,6 m/s;

n) hurricane force: ≥ 32,7 m/s.

Stakeholders may choose a different categorization of wind such as: no wind, low wind (less than 5,4 m/s), medium wind (5,5 m/s to 17,1 m/s), and high wind (greater than 17,1 m/s).

In addition to the wind speed, according to its direction of travel, wind may also be classified as head wind, tail wind and cross wind. Head wind is when wind is blowing against the direction of travel. Tail wind is when wind is blowing in the direction of travel. Cross wind is when wind is blowing perpendicular to the direction of travel.

10.2.4 Rainfall

Rainfall intensity should be specified in the units of mm/h. The interval and spatial scale over which the intensity has been defined should also be stated.

Rainfall may demonstrate significant natural variability over time (seconds) and distance (tens of metres to thousands of metres) and the degree of impact on the ADS may also be dependent on how the volume of rainwater is distributed across a range of rain drop sizes. Therefore, the specification of rainfall thresholds within an ODD definition may include information that supports appropriate interpretation.

Examples for describing the time and space scales include:

a) the average rainfall intensity measured by a meteorological rain gauge over a period of a minute;

b) the average rainfall in a rainfall radar pixel of specified size in kilometres.

Due to the natural variability, instantaneous rainfall values that are potentially significantly higher than this headline value might occur at the precise location of the ADS.

In addition to the average rainfall intensity, the type of rainfall may also be categorized to inform the degree of spatial variability and the rate of onset as well as the relative abundance of smaller or larger drop sizes. Rainfall may be described as:

1) dynamic (commonly “frontal”) – associated with large scale weather systems;

2) convective – typically showery and potentially very intense;

3) orographic (commonly “relief”) – associated with hilly/mountainous terrain.

As well as quantitative rainfall intensity, stakeholders may classify rainfall intensity as follows:

i) no rain;

ii) light rain: when the precipitation rate is <2,5 mm/h;

iii) moderate rain: when precipitation rate is between 2,5 mm/h and 7,6 mm/h;

iv) heavy rain: when precipitation rate is between 7,6 mm/h and 50 mm/h;

v) violent rain: when precipitation rate is between 50 mm/h and 100 mm/h;

vi) cloudburst: when precipitation rate is > 100 mm/h.

Stakeholders may choose a different categorization of rain such as: no rain, light rain (less than 2,5 mm/h), medium rain (2,5 mm/h to 7,6 mm/h), and extreme rain (greater than 7,6 mm/h).

10.2.5 Snowfall

Snowfall intensity refers to precipitating snow in the air and should be determined by human-inferred visibility, where it is clear that the visibility is affected by snow alone, and may be classified as follows:

a) no snow;

b) light snow: visibility greater than 1 km;

c) moderate snow: visibility restrictions between 0,5 km and 1 km;

d) heavy snow: visibility less than 0,5 km.

Defining meaningful snowfall rates is challenging from a direct measurement perspective and also because the pathway to impact might be more directly related to the rate of accretion on surfaces.

10.3 Particulates

Particulates which cause obscuration by non-precipitating water droplets and other particulates should be classified into the following attributes:

a) type (e.g. sand, dust, smoke and pollution, volcanic ash, water spray, non-precipitating water droplets, blowing debris);

b) intensity;

c) size.

The impact of small airborne particulates on sensory perception is commonly expressed in terms of "visibility". As visibility is related to human perception it is only directly applicable to sensors operating at human-visible wavelengths. The degree of obscuration will be dependent on the amount of particulate matter, the sensor wavelength and also the composition and size distribution of the particles in question. In the particular case of 10.4 b) "non-precipitating water droplets", it may be useful to employ a meteorological visibility parameter as it will relate more closely to impacts on optical systems.

The meteorological optical range (MOR) is measured in metres (m). The MOR is the length of path in the atmosphere required to reduce the luminous flux in a collimated beam from an incandescent lamp (at a colour temperature of 2 700 K) to 5 % of its original value. The luminous flux is evaluated by the photometric luminosity function of the International Commission on Illumination (CIE).

10.4 Illumination

Illumination (both visible and non-visible) impacts may be both beneficial (e.g. improving the visibility of targets) or detrimental (e.g. due to rapid changes in shadowing or glare) to the ADS performance.

Illumination should be classified into the following attributes.

a) Natural illumination:

   1) Daytime: daytime is referred to as a condition where the ambient illuminance is greater than 2 000 lx. The sun can be in front, behind, at the right side or left side.

   2) Night time: night-time is referred to as a condition where the ambient illuminance is less than 1 lx.

   3) Low-ambient lighting condition: low-ambient lighting condition is when ambient light is between day-time and night-time.

b) Artificial illumination: this can be streetlights or oncoming vehicle lights or indoor lights (e.g. parking facilities).

c) Cloudiness, may be expressed as:

   1) clear – no possibility of cloud fully or partially obscuring the sun;

   2) partly cloudy – some possibility of a direct path of sunlight to the ADS-equipped vehicle between clouds;

   3) overcast – there are no breaks.

   Stakeholders may classify cloud cover into the following levels (based on the unit of oktas):

   i) clear: sky clear: 0–1 oktas;

   ii) partly cloudy: few clouds: 1–2 oktas;

   iii) partly cloudy: scattered clouds: 3–4 oktas;

   iv) partly cloudy: broken clouds: 5–7 oktas; and

   v) overcast: 8 oktas.

   Cloud cover is the amount of sky covered by cloud and can affect the illumination during any time of the day/night. Stakeholders may choose a different banding for clear sky, overcast, etc.

   While time of the daytime/night-time is expressed in illuminance in the units of lux, cloudiness (or cloud cover) is expressed using oktas. It is important to highlight that cloud cover is possible during daytime or night-time and thus is independent from the time of the day. Cloud cover may affect visibility or sensor perception due to camera washout while the ADS equipped vehicle travels from an area with cloud cover to an area without cloud cover (i.e. partly cloudy condition) exposing the sun intermittently.

d) Position of the sun: elevation of the sun above the horizon (as a range in degrees).

Other weather attributes, such as temperature, humidity, air pressure, surface temperature, hail, freezing rain, or solar flares, may be taken into account as part of the ODD definition.

10.5 Connectivity

Connectivity indicates the ability of a vehicle to receive data from and/or transmit data to an external system to determine positioning or to communicate with other vehicles and the wider infrastructure.

Certain ADS implementations may use connectivity from off-board sensors to communicate the value of certain ODD attributes to the ADS. For example, some ADSs, in order to perform their DDT safely, may be dependent on positional signals or control command from a dispatcher via V2I communications. Alternatively, in certain ADS configurations, the ADS may be dependent on off-board weather data sensing to be communicated to the ADS via V2I communications. For safe operation of such systems, data quality and latency are essential.

If connectivity is required for the ADS to perform its DDT safely, connectivity attributes should be classified as communication and positioning attributes.

Connectivity should at least be classified into the following attributes or have additional attributes:

a) communication: communication attribute should be classified into:

   1) Type: (e.g. fleet management, traffic management, V2X);

   2) Technology (e.g. cellular (e.g. 2G, 2.5G, 3G, 4G, 5G), Satellite, WLAN, DSRC, intelligent transport systems (ITS-G5), Sidelink PC5 etc.);

   3) Downlink: throughput, latency;

   4) Uplink: throughput, latency;

   V2X includes vehicle to vehicle communication (V2V), vehicle to infrastructure communication (V2I); vehicle to pedestrian communication (V2P); Vehicle to network communication (V2N).

b) positioning: positioning attribute should be classified into:

   1) satellite based global positioning:

      i) Galileo;

      ii) GLObal NAvigation Satellite System (GLONASS);

      iii) Global Positioning System (GPS);

      iv) RTK;

      v) BeiDou;

   2) local positioning:

      i) NavIC;

      ii) Quasi-Zenith Satellite System (QZSS);

      iii) Indian Regional Navigation Satellite System (IRNSS);

c) RTK correction:

   1) country specific;

   2) site specific;

   3) global specific (NovAtel satellite).

Signal strength and interference may be used as subattributes of each of the communication and positioning attributes. Interference factors may include electromagnetic (EM) signals present in the environment (e.g. roadside emitters). Stakeholders may specify signal strength and interference ranges as part of their ODD specification.

11 Dynamic elements

Dynamic elements shall be further classified into the following attributes:

a) traffic agents;

b) subject vehicle.

11.1 Traffic agents

Traffic agents should be classified into the following attributes:

a) agent type;

b) presence of special vehicles: special vehicles should at least be classified into or have additional attributes:

   1) ambulance ;

   2) police vehicle;

   3) work vehicle;

   4) traffic management vehicle;

   5) fire engine/appliance vehicle.

Agent type may include:

1) motor vehicle;

2) non-motor vehicle;

3) vulnerable road users (pedestrians two-wheelers, bicycles, e-scooters);

4) animals;

5) horse riders.

Additionally, each traffic agent may be classified into stationary (or parked for vehicles) and moving.

Each traffic agent may be classified using two of the following three attributes:

i) density of agents;

ii) volume of traffic;

iii) flow rate.

The choice of two of the three attributes can enable the specifier to define a unique specification. Density of agents is expressed in terms of number of agents per unit distance. Volume is the number of agents passing a reference point for a specified period of time (e.g. volume for 15 min). Flow rate is the rate at which agents pass a given point and is generally expressed as agents per hour. Volume may be extrapolated to obtain traffic flow. Stakeholders shall specify the unit distance or unit time for measurement based on their information source.

Additionally, each traffic agent may also have a position (relative to subject vehicle) attribute, e.g. presence of lead vehicle.

11.2 Subject vehicle

The subject vehicle's maximum allowable speed should be defined as an ODD attribute based on the designed or capability limitation of the vehicle or the roadway. Additionally, the subject vehicle may have an attribute for pre-defined routes and weight of vehicle.

12 ODD definition format

12.1 General

An operational design domain definition (ODD) shall be valid throughout the ADS' lifetime for a particular hardware and software configuration. The ODD may change with an update of the vehicle software. The definition of an ODD is part of the safety concept of an ADS. In order to enable stakeholders to share, compare and re-use ODD definitions, it is not only essential to use a standard set of ODD attributes, but also a standard format, especially for a non-technical audience.

As per ISO 34502, the ODD definition has a key role to play in the simulation-based testing. However, this document focuses on ODD definition at a functional level to be used by stakeholders like regulators, system engineers, local authorities etc. An ODD definition format for use in simulation-based testing or other computer-based analysis of an ODD at a simulation execution level will be defined in ASAM OpenODD[13].

Example ODD definitions using the taxonomy and format specified in this document are illustrated in Annex B.

12.2 Type of definition mode

Due to the large number of attributes needed for defining an ODD, an ODD definition could potentially become cumbersome. In order to make the ODD definition concise, a permissive or a restrictive definition mode or default definition mode shall be used. Stakeholders may choose any definition mode for their definition. However, they shall state which mode is being used for that attribute.

All three modes are actually an ODD definition, which is specifying values and ranges for a sub-set of the attributes in the full taxonomies. The mode supplies guidance on the interpretations of attributes which are included in the taxonomy, and are not explicitly stated in the ODD definition.

An ODD definition in a "permissive" mode shall list only the attributes that are inside or outside ODD definition. The remaining attributes (unspecified) shall be considered to be inside of the ODD definition.

An ODD definition in a "restrictive" mode means only the attributes that are explicitly stated inside or outside of the ODD will be listed in the ODD definition. The remaining attributes (unspecified) shall be considered to be outside the ODD definition.

An ODD definition in a "default" mode means the attributes of interest that are listed in the ODD definition are explicitly stated inside or outside the ODD and will be monitored during ADS operation. The remaining attributes (unspecified) shall be considered not to be affecting the ADS performance and may not be monitored. However, unspecified attributes in "default" mode are also considered to be inside the ODD.

NOTE In restrictive and permissive mode, there is a defined reference behaviour derived from each and every taxonomy attribute. For default mode, defined behaviour can be derived only from attributes explicitly stated in the ODD definition itself.

For any ODD definition, stakeholder shall define the definition mode: permissive or restrictive or default. It may be reasonable to use permissive definition for some sections of the ODD definition and restrictive for other sections (for ease of readability) or default mode. In such a case, the type of definition mode shall be explicitly mentioned in the relevant section of the ODD definition.

12.3 Human readability

An ODD definition is one of the first steps in the safety assurance process. Therefore, ODD definitions need to be shared and agreed between a wide range of stakeholders such as ADS developers, regulators and test engineers, but at the same time to be used by humans for purposes of specification, communications, analysis and debug. This implies that an ODD specification shall be understandable to both technical and non-technical users.

12.4 Inclusion, exclusion, and conditional

For each of the ODD attribute defined in Clauses 8 to 11, the attribute may be included in the ODD definition or excluded from the ODD definition or may have a conditional nature to its inclusion/exclusion.

For example, the velocity in which an ADS system is operating is defined to be between 0 km/h and 80 km/h. However, in the case of heavy fog, the ADS system is constrained to operate in velocity range of 0 km/h to 40 km/h.

In the design of an ADS, it will be reasonable to expect the ADS to have a reduced or degraded capability in severe operating conditions (e.g. heavy rainfall or heavy fog) in order to maintain safe operation of the system. In such situations, an ODD definition format shall allow the designers to specify conditional statements or reduced ODDs. The reduced or degraded capability definition shall be achieved by using constraints to the ODD definition.

Therefore, three keywords as specified in Table 1 shall be used as qualifiers to specify inclusion, exclusion and conditional nature of the attributes. Each ODD statement with a qualifier shall tackle one parent class (or higher-level ODD attribute) and shall perform the classification of its subattributes into the three categories. Upon covering all the parent classes a complete ODD description may be produced.

Table 1 — Qualifiers for inclusion, exclusion and conditional

Qualifiers	Meaning
Inclusion	Included in the ODD
Exclusion	Excluded from the ODD
Conditional	Inclusion/exclusion of attributes have dependencies

Depending upon the permissive and restrictive nature of the ODD definition (as chosen by the stakeholder), the ODD can be detailed by use of either “Include” or “Exclude” keyword as a qualifier.

For example, “drivable area type” contains “motorway”, “radial road”, “distributor road”, “minor road”, “slip road”, “parking” and “shared space” attributes. In order to write a statement for the drivable area type such that only motorway is suitable, one may state: “Include” road type is “motorway”. Alternatively, one may also state “Exclude” road type are radial road, distributor road, minor road, etc. Both approaches are valid, however the first one is the more efficient approach and has better readability.

12.5 Extensibility and expressing relationships between ODD attributes

The ODD attributes are governed by the defined class hierarchy or taxonomy (Clauses 8 to 11) which enables the illustration of relationships between attributes. The relationship between ODD attributes may be underpinned by a domain ontology description.

While stakeholders may extend attributes (and their subattributes) in order to define their required operating conditions, the inclusion or exclusion of attributes in the ODD definition shall be coherent with the existing set of attributes and the relationship between the attributes. Stakeholders may add additional layer of attributes as parent attributes to other attributes in order to aid grouping of the attributes.

12.6 Objective boundaries

The ODD shall be defined in a way that its boundaries are objectively specified. This shall be achieved by identifying the boundaries for the value for each ODD attribute.

12.7 Statement composition

For each ODD attribute statement, the following components shall be defined (Table 2):

— qualifier (include, exclude, conditional);

— attribute;

— attribute value.

Table 2 — Example composition of ODD definition statement

Qualifier	Attribute	Attribute value
Include	Driveable area type	Motorway
Exclude	Driveable area type	Shared space

When the “conditional” qualifier is used, the statement composition shall have the following components:

— qualifier 1: conditional;

— qualifier 2: (include or exclude);

— attribute metric: (e.g. rainfall rate);

— influencing attribute: (e.g. rainfall);

— influenced attribute: (e.g. motorway);

— influencing attribute value: (e.g. light rain).

EXAMPLE Conditional Include rainfall rate of rainfall for motorway is light rain.

Annex A
(informative)

Operational design conditions (ODC): including vehicle internal aspects to the ODD

In order to define the overall design of an automated driving system (ADS), it is important to define aspects other than the ODD. The other potentially necessary attributes for the overall design of an ADS include (see Figure A.1):

a) vehicle status and behaviour;

b) driver and passenger status;

c) other necessary conditions, e.g. behaviour of other road users.

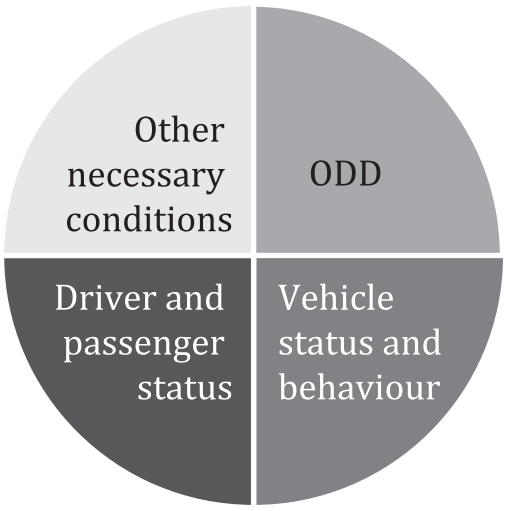

Figure A.1 — Relationship between ODD and other vehicle characteristics

Vehicle status refers to the system self-checks to confirm no failure affects the safe operation of the desired ADS functionality. This further includes checks like ensuring roadworthiness of the vehicle, doors are properly shut, no tyre punctures exist, etc. Vehicle behaviour refers to the behaviour competencies that the ADS may be designed to execute safely.

Vehicle status may be classified into the following attributes:

— vehicle motion status (real time);

— ADS status;

— non-ADS system status.

Driver and passenger status refers to establishing that the driver is in the driving position (especially for a level 3 ADS to ensure the driver is able to perform the fallback ready user role). Additionally, it also includes whether the drivers and passengers have fastened their safety belts.

Driver and passenger status may be classified into:

— status of driver/DDT fallback ready user;

— passenger status.

Status of driver/DDT fallback ready user may be further classified into the following attributes:

— distraction status;

— posture status;

— safety belt status.

Passenger status may be further classified into the following attributes:

— posture status;

— safety belt status;

— child safety seat.

Table A.1 provides an example of a level 3 ADS on how all the above attributes (in addition to ODD) can be used to determine whether an ADS can be activated or not.

Table A.1 — Factors influencing ADS design

	Situation A	Situation B	Situation C	Situation D
ODD	Sunny day on a motorway	Night-time on a motorway	Sunny day on a motorway	Sunny day on a motorway
Driver and passenger state	Driver state monitoring detects attentive driver	Driver state monitoring detects attentive driver	Safety belt not fastened	Driver state monitoring detects attentive driver
Vehicle status	Vehicle status OK	Vehicle status OK	Vehicle status OK	Perception system cannot work properly
Can ADS be activated?	Yes	No	No	No

Annex B
(informative)

Examples of ODD definition (for various regions)

B.1 General

Examples in this Annex are illustrated using the ODD definition format illustrated in Clause 12. Other definition formats (e.g. ASAM OpenODD) can also be used for ODD definition for simulation purposes.

B.2 Canada

End user for this ODD definition in Figure B.1 are regulators, local authorities, system engineers.

```
#Composition statements
Include geofenced areas is [predefined route]
Include regions or states is [Ottawa Canada]
Include zones are [regions or states, geofenced areas]
Cond_1 Conditional drivable area type are [minor roads, parking, shared space]
Cond_2 Conditional horizontal plane is [curved roads]
Exclude transverse plane is [divided]
Include types of lane together is [traffic lane]
Include lane dimension is [3.7,∞]
Include lane marking is [2,∞]
Include lane type is [traffic lane]
Include number of lanes is [2,∞]
Include direction of travel is [right hand travel]
Exclude drivable area signs is [variable]
Include drivable area edge is [line markers, solid barriers]
Exclude induced drivable area surface conditions are [flooded roadways, mirage]
Include drivable area surface type is [uniform]
Include roundabout is [normal]
Include normal is [non signalised]
Exclude intersection is [staggered, grade separated]
Include special structures is [pedestrian crossing]
Exclude temporary road structures is [construction site detours]
Exclude wind are [near gale, gale, strong gale, storm, violent storm, hurricane-
force]
Exclude rainfall is [violent rain, cloudburst]
Include temperature is [-30,40 C]
Include particulates is [non precipitating water droplets]
Include vehicle to infrastructure is [cellular]
Include positioning is [global positioning]
Include subject vehicle speed is [0,15 km/h]

#Conditional statements
Cond_1 Include speed of subject vehicle for [minor roads] is [0,15 km/h]
Cond_1 Include speed of subject vehicle for [parking, shared space] is [0,10 km/h]
Cond_2 Exclude radius of curved road is [0,5 m]
```

Figure B.1 — ODD definition using Clauses 8 to 12 for the LSAD on pilot test in Ottawa in permissive mode

B.3 USA

In certain commercial, industrial, or residential areas, the driver cannot perform a traditional left-turn. Using an indirect left-turn manoeuvre reduces the number and severity of collisions or injuries, enhances traffic flow, and accommodates large (commercial or recreational) vehicles. For human

operators, Reference [13] from the Michigan Department of Transportation (MDOT) defines the manoeuvre to drive a Michigan left as follows.

— "Highway A traffic is prohibited from making a direct left turn onto Highway B at the intersection. Instead, drivers must continue past the intersection and turn left into the median crossover. When traffic clears, the driver will make a left turn onto Highway A and continue straight or move to the far-right lane and turn right onto Highway B.

— Highway B traffic is prohibited from making a direct left turn onto Highway A at the intersection. Instead, drivers must turn right onto Highway A, move to the far-left lane and turn left into the median crossover. When traffic clears, the driver will make a left turn onto Highway A and continue straight."

— The MUTIT is also referenced as an indirect U-turn or a Michigan left turn.

```
#Composition statements
Cond_1 Conditional drivable area type is [motorway, radial roads, distributor roads]
Cond_2 Conditional drivable area type is [median crossover]
Included number of lanes is [1,∞]
Included lane dimension is [3.7,∞]
Excluded roundabouts are [all]
Excluded intersections are [grade separated]
Cond_3 Conditional horizontal plane is [curved roads]
Excluded special structures are [all]
Included direction of travel is [right hand drive]
Included lane type is [traffic lane]
Included drivable area surface type is [asphalt, concrete]
Excluded fixed road structures are [buildings]
Excluded drivable area edge is [None]
Excluded transverse plane is [pavements]
Included temporary road structures are [road signage]
Cond_4 Conditional temporary road structures are [refuse collection, road works]
Excluded rainfall is [heavy rain]
Excluded snowfall is [heavy snow]
Excluded particulates are [mist and fog]

#'Conditional' statements
Cond_1 Included speed of subject vehicle for [motorway, radial roads, distributor roads] is
[0,15 km/h]
Cond_2 Included drivable area signs for [median crossover] are [yield, stop, one-way, do not
enter]
Cond_3 Excluded radius of curved_road is [0,13 m]
Cond_4 Excluded location of [refuse collection, road works] is [in lane]
```

Figure B.2 — ODD definition using Clauses 8 to 12 for the Michigan left-turn in permissive mode

End user for this ODD definition in Figure B.2 are regulators, local authorities, system engineers.

B.4 Germany

Using the definition format, various definition modes can also be illustrated in a tabular format. Table B.1 depicts a definition in default mode, Table B.2 in permissive mode and Table B.3 in restrictive mode.

Table B.1 — Tabular ODD definition using Clauses 8 to 12 in default mode

Top level attribute	Sub-attribute	Qualifier	Attribute	Attribute value
Scenery	Zones	Include	Region	Germany
	Drivable area	Include	Drivable area type	Motorways
	Temporary road structures	Exclude	Temporary road structures	Road works
Dynamic elements	Subject vehicle	Include	Maximum speed	130 km/h

Table B.2 — Tabular ODD definition using Clauses 8 to 12 in permissive mode

Top level attribute	Sub-attribute	Qualifier	Attribute	Attribute value
Scenery	Zones	Exclude	Region	all
		Include	Region	Germany
	Drivable area	Exclude	Drivable area type	all
		Include	Drivable area type	Motorways
	Junctions			not applicable
	Temporary road structures	Include	Temporary road structures	all[a]
		Exclude	Temporary road structures	Road works
	Connectivity			not applicable
Dynamic elements	Subject vehicle	Include	Maximum speed	130 km/h

[a] All means here, all reasonably foreseeable in the context of: Region=Germany AND Drivable area=Motorways AND Subject max- speed=130 km/h.

Table B.3 — Tabular ODD definition using Clauses 8 to 12 in restrictive mode

top level attribute	Sub-attribute	Qualifier	Attribute	Attribute value
scenery	Zones	Include	Region	Germany
	Drivable area	Include	Drivable area type	Motorways
		Include	Drivable area geometry	all[a]
		Include	Drivable area signs	all[a]
		Include	Drivable area edge	all[a]
		Include	Drivable area surface	all[a]
	Junctions			not applicable
	Special structures	Include		all[a]
	Fixed road structures	Include		all[a]
	Temporary road structures	Include	Temporary road structures	all[a]
		Exclude	Temporary road structures	Road works
Environmental conditions	Weather	Include	Outside air temperature	all[a]
		Include	Wind speed	all[a]
		Include	Rainfall intensity	all[a]
		Include	Snowfall intensity	all[a]
	Particulates	Include		all[a]
	Illumination	Include		all[a]
	Connectivity			not applicable
Dynamic elements	Traffic agents	Include		all[a]
	Subject vehicle	Include	Maximum speed	130 km/h

[a] All means here, all reasonably foreseeable in the context of: Region=Germany AND Drivable area=Motorways AND Subject max. speed=130 km/h.

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