PAS 1883:2020

Operational Design Domain (ODD) taxonomy for an automated driving system (ADS) – Specification

Centre for Connected & Autonomous Vehicles

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Publishing and copyright information

Published by BSI Standards Limited 2020.

ISBN 978 0 539 06735 4

ICS 03.220.20; 35.240.60

Publication history

First published August 2020

Contents

Foreword

This PAS was sponsored by the Centre for Connected and Autonomous Vehicles (CCAV). Its development was facilitated by BSI Standards Limited and it was published under licence from The British Standards Institution. It came into effect on 31 August 2020.

Acknowledgement is given to Siddartha Khastgir of WMG, University of Warwick, as the technical author, and the following organizations that were involved in the development of this PAS as members of the steering group:

- ADA Innovation Lab Limited
- Arup
- AXA XL
- Burges Salmon
- Centre for Connected and Autonomous Vehicles (CCAV)
- Connected Places Catapult
- Five AI
- Loughborough University
- Oxfordshire County Council
- Met Office
- National Physical Laboratory (NPL)
- Nominet
- Ordnance Survey
- TRL
- Wayve Technologies Ltd
- WMG, University of Warwick
- Zenzic

Acknowledgement is also given to the members of a wider review panel who were consulted in the development of this PAS.

This PAS is not to be regarded as a British Standard. It will be withdrawn upon publication of its content in, or as, a British Standard.

The PAS process enables a specification to be rapidly developed in order to fulfil an immediate need in industry. A PAS can be considered for further development as a British Standard, or constitute part of the UK input into the development of a European or International Standard.

Relationship with other publications

PAS 1883 has been developed as part of a wider programme sponsored by CCAV in conjunction with the Department for Transport (DfT), Innovate UK and Zenzic. This PAS is for use by various stakeholders to define the Operational Design Domain (ODD) of the automated driving system (ADS). The ODD definition is an essential step in defining the safe and legal operation of the ADS and in the development of the safety case for the ADS. This PAS, therefore, facilitates the implementation of PAS 1880 and PAS 1881.

Information about this document

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Use of this document

It has been assumed in the preparation of this PAS that the execution of its provisions will be entrusted to appropriately qualified and experienced people, for whose use it has been produced.

Presentational conventions

The provisions of this PAS are presented in roman (i.e. upright) type. Its requirements are expressed in sentences in which the principal auxiliary verb is "shall".

Commentary, explanation and general informative material is presented in smaller italic type, and does not constitute a normative element.

Where words have alternative spellings, the preferred spelling of the Shorter Oxford English Dictionary is used (e.g. "organization" rather than "organisation").

Contractual and legal considerations

This Publicly Available Specification does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

This PAS is not to be regarded as a British Standard. It will be withdrawn upon publication of its content in, or as, a British Standard.

Compliance with a Publicly Available Specification cannot confer immunity from legal obligations.

In particular, attention is drawn to the following specific regulations:

- The Road Traffic Regulation Act 1984 [1];
- The Road Vehicles (Construction and Use) Regulations 1986 [2];
- The Road Traffic Act 1988 [3];
- The General Data Protection Regulation [4];
- The Data Protection Act 2018 [5];
- The Automated and Electric Vehicles Act 2018 [6]; and
- The Road Vehicles (Approval) Regulations 2009 [7].

Introduction

The move towards an automated driving system (ADS) 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.

There has been significant industry and UK government investment in the development of automated vehicle technology, demonstrating the UK's intention of becoming a leader in this field. The UK government is committed to:

- ensuring that the introduction of an ADS 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). The ODD represents the operating environment within which an ADS can perform the dynamic driving task (DDT) safely and this PAS focuses on a taxonomy for the definition of the ODD for a given ADS.

It is intended that this PAS is read in conjunction with PAS 1880, which describes how the control system design in an ADS is influenced by the ODD definition, and PAS 1881, which specifies requirements for safety cases for automated vehicle trials and development testing, and which outlines the relationship between the ODD definition and the safety case requirements. Test scenarios used for the evaluation of the ADS as part of the safety evidence may be derived from the ODD definition of the ADS.

The ODD taxonomy specified in this PAS for the ODD definition will enable ADS manufacturers to specify and implement minimum safety requirements in their designs, and allow end users, 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 appropriate test and verification activities.

While there are a number of different testing and trialling environments within the UK, with varying levels of controllability, this PAS provides a generic taxonomy for defining all environments where an ADS is being tested, trialled or deployed.

1 Scope

This PAS provides requirements for the minimum hierarchical taxonomy for specifying an Operational Design Domain (ODD) to enable the safe deployment of an automated driving system (ADS). The ODD comprises the static and dynamic attributes within which an ADS is designed to function safely.

This PAS is applicable to Level 3 and Level 4 ADS.

NOTE 1 *For more information on Level 3 and Level 4 ADS see SAE J3016:2018.*

NOTE 2 *This PAS may also be relevant for Level 1 and Level 2 ADS.*

This PAS is intended for trialling organizations developing safety cases for automated vehicle trials and testing, manufacturers and developers of Level 3 and Level 4 ADS and suppliers of components and subcomponents.

This PAS is also of interest to insurers, regulators, service providers, and national, local and regional government to enable them to understand possible ADS deployments and capabilities.

This PAS does not cover:

- the basic test procedures for attributes of the ODD;
- the monitoring requirements of the ODD attributes; and
- the format of the ODD definition.

2 Normative references

There are no normative references in this PAS.

3 Terms, definitions, and units

3.1 Terms and definitions

For the purposes of this PAS, the following terms and definitions apply.

3.1.1 automated driving system (ADS)

hardware and software that are collectively capable of performing the entire dynamic driving task (DDT) on a sustained basis, regardless of whether it is limited to a specific Operational Design Domain (ODD)

***NOTE** This term is used specifically to describe a Level 3, 4, or 5 driving automation system.*

3.1.2 automated vehicle (AV)

vehicle fitted with an automated driving system (ADS) that uses both hardware and software to perform dynamic driving tasks associated with moving the vehicle within a defined ODD

3.1.3 dispatcher

user(s) who dispatches an ADS-equipped vehicle(s) in an automated operation

3.1.4 dynamic driving task (DDT)

all of the real-time operational and tactical functions required to operate a vehicle in on-road traffic

***NOTE 1** This excludes the strategic functions, such as trip scheduling and the selection of destinations and waypoints.*

***NOTE 2** This includes, without limitation, the following subtasks:*

a) lateral vehicle motion control via steering (operational);

b) longitudinal vehicle motion control via acceleration and deceleration (operational);

c) monitoring the driving environment via object and event detection, recognition, classification and response preparation (operational and tactical);

d) object and event response execution (operational and tactical);

e) manoeuvre planning (tactical); and

f) enhancing conspicuity via lighting, sounding the horn, signalling, gesturing (tactical).

***NOTE 3** DDT consists of both a tactical driving task and an operational driving task.*

3.1.5 dynamic elements

all movable objects and actors in the ODD within the DDT timeframe

{SOURCE: Ulbrich et al., 2015 [8], modified}

3.1.6 environmental conditions

weather and other atmospheric conditions

3.1.7 minimal risk condition (MRC)

stable and stopped condition to which a user or an ADS brings a vehicle after performing the DDT fallback, in order to reduce the risk of a crash when a given trip cannot be continued

[SOURCE: SAE J3016:2018, **3.17**, modified]

3.1.8 minimal risk manoeuvre (MRM)

tactical or operational manoeuvre triggered and executed by the user or the ADS to achieve the minimal risk condition

3.1.9 operational design domain (ODD)

operating conditions under which a given driving automation system or feature thereof is specifically designed to function

***NOTE 1** This includes, but is not limited to, environmental, geographical, and time-of-day restrictions, and/or the requisite presence or absence of certain traffic or roadway characteristics.*

***NOTE 2** Driving automation system, for the purpose of this PAS, is the automated driving system (ADS).*

3.1.10 operational driving task

dynamic driving task that involves split-second reactions that can be considered pre-cognitive or innate

***NOTE** Examples include making micro-corrections to steering, braking and accelerating to maintain lane position in traffic or to avoid a sudden obstacle or hazardous event in the vehicle's pathway.*

3.1.11 scenery

non-movable elements of the ADS-equipped vehicle's operating environment

3.1.12 subject vehicle

automated vehicle, the behaviour of which is of primary interest in testing, trialling or operational scenarios

NOTE *Subject vehicle can be used interchangeably with ego vehicle and vehicle under test (VUT).*

3.1.13 tactical driving task

dynamic driving task which involves drivers or an ADS exercising manoeuvre control, allowing them to negotiate the directly prevailing circumstances

{SOURCE: Michon, 1985 [9], modified}

3.1.14 V2X

wireless communication between a vehicle and any entity including other vehicles and infrastructure

3.1.15 vulnerable road user (VRU)

road user who is more vulnerable to injury than a typical driver or passenger of a car, lorry, bus or coach

NOTE *Vulnerable road users can include pedestrians, cyclists, horse riders, motorcyclists and people using mobility scooters.*

3.2 Units

K	Kelvin
km	kilometre
lx	lux
mm/h	millimetre per hour
m/s	metre per second
okta	unit of measurement describing cloud cover

4 ODD requirements and application

Based on the taxonomy in Clause **5**, an ODD definition shall be developed and agreed by stakeholders, either individually or in consultation, for the safe operation of the ADS.

NOTE 1 *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 may vary.*

NOTE 2 *Stakeholders might include local authorities, regulators, service providers, manufacturers, developers of an ADS or suppliers of components and subcomponents. A city council, for example, might develop an ODD definition as part of a procurement specification for an ADS mobility service, while a manufacturer might develop an ODD definition in order to convey the ADS' capabilities and limitations and create the corresponding safety case.*

NOTE 3 *Different stakeholders may develop their ODD definition with varied level of detail.*

The ODD definition shall be extensible in a way that allows new attributes or details to be added as a result of stakeholder consultation.

The abstraction hierarchy used for the ODD definition shall be at the discretion of the stakeholder. Irrespective of the abstraction level chosen, stakeholders shall specify the ODD attributes used for informing the safety case for the ADS.

A stakeholder who defines an ODD choosing a higher abstraction level shall comply with all the sub-attributes, even if they have not been explicitly mentioned in the ODD definition.

While performing the DDT, the ADS shall monitor itself and the ODD attributes for the safe operation within the defined ODD, which includes performing the minimal risk manoeuvre (MRM).

NOTE 4 *During trials, the monitoring of the ODD attributes may be performed by the safety operator or dispatcher.*

NOTE 5 *ODD attributes may have interdependence and their relationship may be defined in a prescribed format; for example, an ADS may have a maximum allowable speed of 70 mph in the absence of rainfall, and a reduced maximum allowable speed of 40 mph in the presence of rainfall.*

NOTE 6 *The dispatcher or the ADS itself may decide, for example, to reduce the maximum allowable speed when it is raining as compared to sunny conditions.*

NOTE 7 *The ADS or the dispatcher should monitor current ODD attributes so that they remain within the designed and defined ODD attribute definition. In case of an imminent change or significant deviation of the ODD attribute values, the ADS may trigger a MRM to reach a minimal risk condition (MRC) or change the operating mode to a degraded mode. Alternatively, the ADS may trigger a take-over request for the driver/dispatcher to take back control (in case of SAE Level 3 automation).*

NOTE 8 *For a Level 1 and Level 2 ADS, meeting the ODD conditions enables the availability of the Level 1 or Level 2 feature. When the ODD conditions are not met, drivers should not be able to activate the Level 1 or Level 2 feature.*

NOTE 9 *While the human driver/dispatcher is not part of the ODD definition, they should take into account the ODD limits for the safe use of the ADS feature.*

As part of the process to show compliance with the defined ODD, ADS developers shall demonstrate test procedures for the defined ODD attributes.

NOTE 10 *As part of the ADS development cycle, the ODD definition may be an iterative process with a gradual increase in ODD attributes and attribute value coverage.*

NOTE 11 *An ODD definition is one of the steps in developing a safety case for an ADS. As part of the scenario-based testing process of an ADS, test scenarios may be derived from the ODD definition.*

5 ODD taxonomy

*COMMENTARY ON CLAUSE **5***

Stakeholders may extend attributes (and their sub-attributes) over and above those specified if they do not adequately represent their operating environment.

While the taxonomy is extensible, any extensions to the taxonomy which conflict with attributes specified should be avoided.

5.1 Top level

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

a) "scenery" (see **5.2**);

b) "environmental conditions" (see **5.3**);

c) "dynamic elements" (see **5.4**).

The "scenery" attribute shall consist of the non-movable elements of the operating environment, e.g. roads or traffic lights.

The "environmental conditions" attribute shall consist of weather and atmospheric conditions.

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

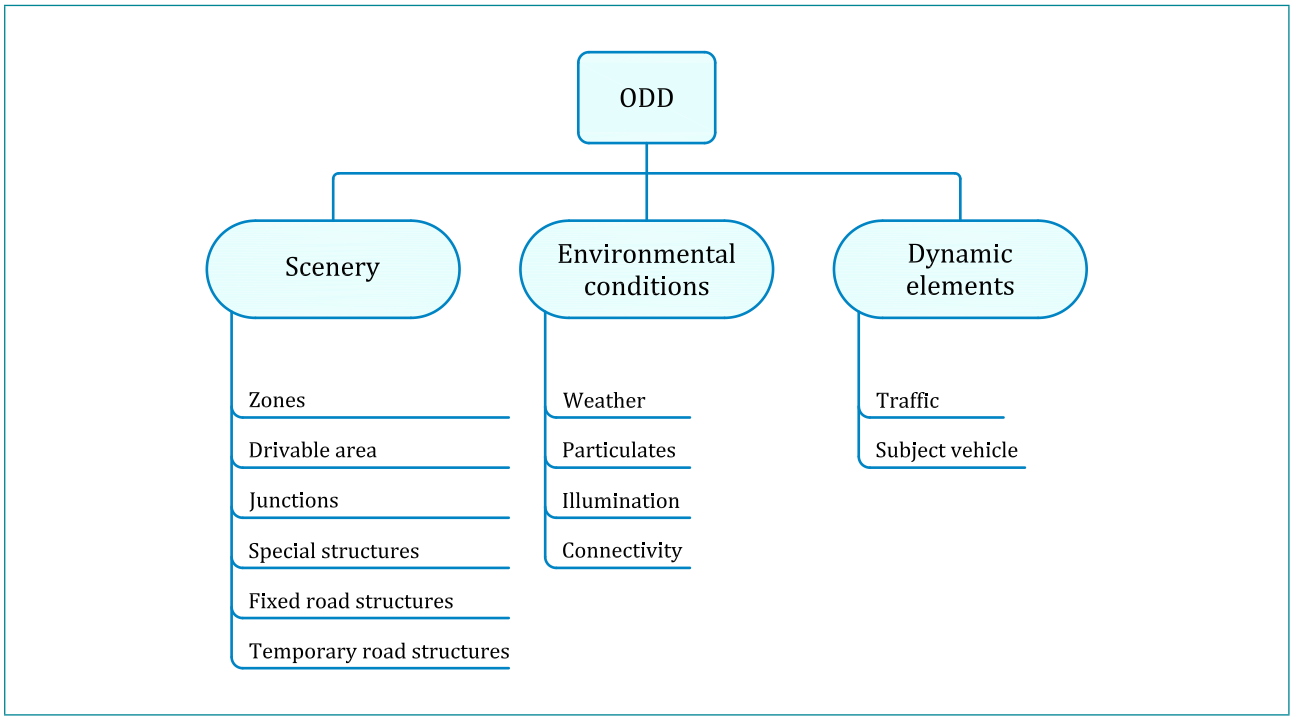
***NOTE 1** Figure 1 illustrates a top-level taxonomy of the ODD attributes.*

***NOTE 2** Environmental conditions play an important role in influencing the safe operation of ADS-equipped vehicles. They also tend to pose one of the biggest challenges to deployment, particularly early deployment or real-world trials. The environmental conditions have the potential to impact all ADS functions from perception and planning to actuation control, as they might impact visibility, sensor fidelity, vehicle manoeuvrability due to changing road surface conditions, and communication systems.*

***NOTE 3** Annex A provides example formats of ODD definitions using the ODD taxonomy specified in Clause **5**.*

***NOTE 4** All attributes are considered to have equal importance.*

Figure 1 – Top level taxonomy with ODD attributes



5.2 Scenery

5.2.1 General attributes

"Scenery" shall be classified into the following attributes:

a) zones;
b) drivable area;
c) junctions;
d) special structures;
e) fixed road structures;
f) temporary road structures.

5.2.2 Zones

Zones shall be classified into the following attributes:

a) geo-fenced areas;
b) traffic management zones;
c) school zones;
d) regions or states;
e) interference zones, e.g. dense foliage or loss of positioning signal due to tall buildings.

NOTE 1 *Zones include special road configurations which may differ from typical conditions for driving, or areas with specific driving regulations or environmental conditions.*

NOTE 2 *Some ADS applications may be restricted to specific zones where the ADS can operate safely.*

5.2.3 Drivable area

5.2.3.1 General attributes

Drivable area shall 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.

NOTE *Many ADS applications may operate on a non-road surface (e.g. low-speed shuttles in shared spaces or pedestrian pathways). Drivable area refers to all applications of the ADS.*

5.2.3.2 Drivable area type

Drivable area type shall be classified into five main attributes:

a) motorways;

NOTE 1 *Motorways are high-traffic roads where non-motorized vehicles and pedestrians are prohibited.*

b) radial roads;

NOTE 2 *Radial roads (A-roads) are high density traffic roads which connect motorways to distributor roads or urban centres.*

c) distributor roads;

NOTE 3 *Distributor roads (B-roads) connect A-roads with minor or local roads and generally have low to moderate capacity.*

d) minor roads;

NOTE 4 *Minor roads or local roads provide access to residential areas and other local developments.*

e) slip roads;
f) parking;
g) shared space.

Motorways shall be classified into those:

1) with active traffic management (smart motorways);
2) without active traffic management.

Each of the road types shall have an associated speed limit(s).

NOTE 5 *A shared space may be shared between subject vehicle and other actors, for example, pedestrians or cyclists.*

5.2.3.3 Drivable area geometry

The drivable area geometry shall be described by viewing the road layout in three attributes:

a) horizontal plane;
b) transverse plane;
c) longitudinal plane.

In horizontal plane, two main attributes shall be included: straight lines and curves. Curves shall be measured by the radius of the curvature of the road.

NOTE 1 *Horizontal alignment can be seen when the road layout is projected on a horizontal plane.*

In transverse plane, the main attributes shall include:

1) divided;
2) undivided;
3) pavements;
4) barriers on edges;

5) types of lanes together.

NOTE 2 Cross section plane is the drivable area configuration in the transverse profile. The cross section shown in Figure 2 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 shall be included:

i) up-slope (positive gradient);

ii) down-slope (negative-gradient);

iii) level plane.

NOTE 3 Longitudinal alignment can be seen in a vertical configuration of the drivable area in a longitudinal section.

5.2.3.4 Drivable area lane specification

The drivable area lane specification shall be classified into the following attributes:

a) lane dimensions;

b) lane marking;

c) lane type;

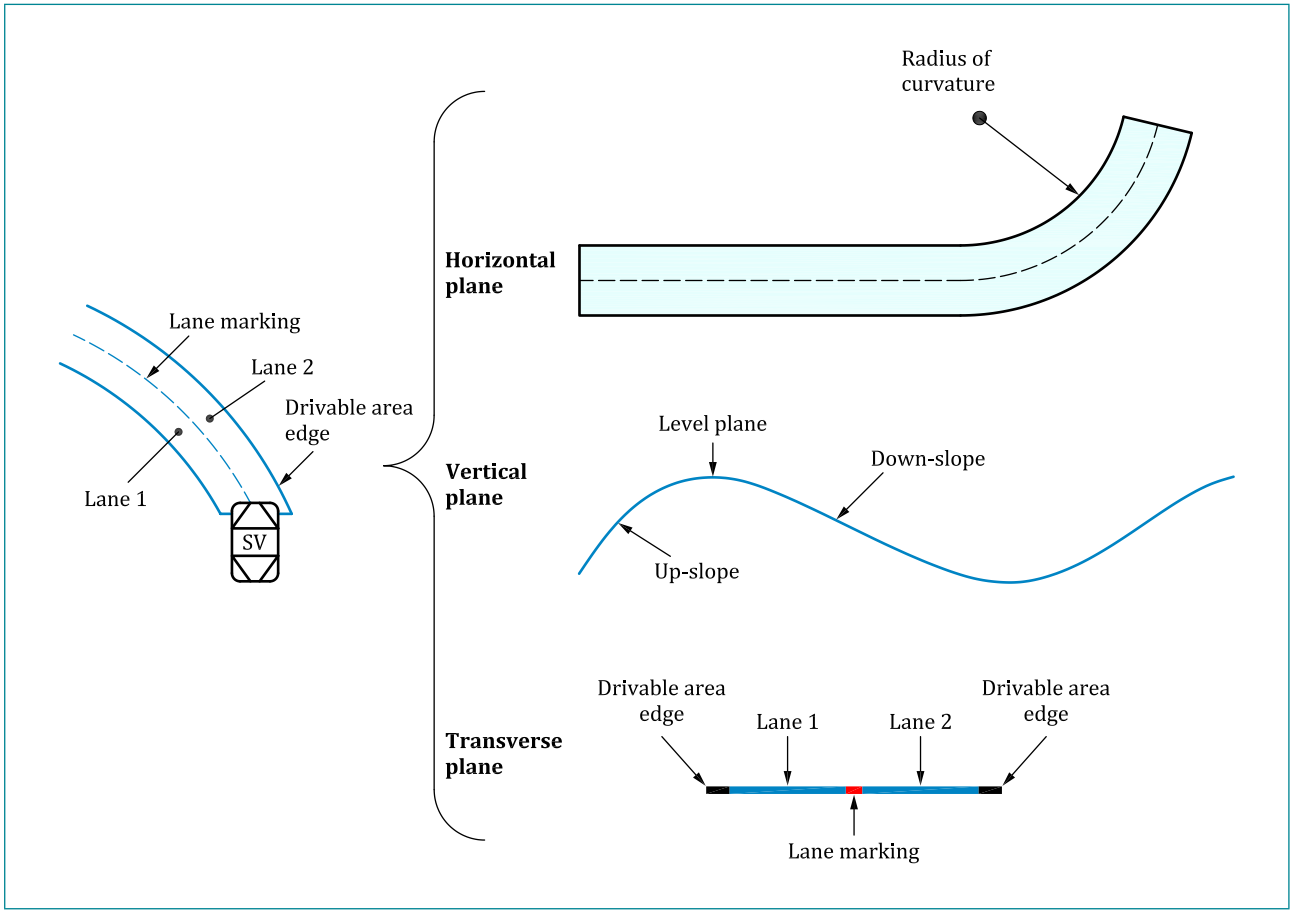
d) number of lanes;

e) direction of travel.

Lane type shall include bus lane, traffic lane, cycle lane, tram lane, emergency lane or other special purpose lanes.

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

Figure 2 – Drivable area geometry configurations



5.2.3.5 Drivable area signs

Drivable area signs shall be classified into the following attributes:

a) information signs;
b) regulatory signs;
c) warning signs.

Each of the above attributes shall be further classified into variable or uniform.

NOTE *For example, smart highways or motorways may change their speed limits depending on external factors.*

Additionally, each of the attributes shall be classified by their operation duration into:

1) full-time;
2) temporary (e.g. due to road construction).

5.2.3.6 Drivable area edge

The drivable area edge shall be classified into the following attributes:

a) line markers;
b) shoulder (paved or gravel);
c) shoulder (grass);
d) solid barriers (e.g. grating, rails, curb, cones);
e) temporary line markers;
f) none.

NOTE *Edge is the outermost edge of the roadway in which a vehicle travels.*

5.2.3.7 Drivable area surface

The drivable area surface shall be classified into the following attributes:

a) drivable area surface type;
b) drivable area surface features;
c) drivable area induced road surface conditions.

Drivable area surface type shall be classified into:

1) loose (e.g. gravel, earth, sand);
2) segmented (e.g. concrete slabs, granite setts, cobblestones);
3) uniform (e.g. asphalt).

Drivable area surface features shall include damage caused by traffic and weather. Any road damage (and the resulting different surface features) shall be classified into cracks, potholes, ruts or swells.

Drivable area induced surface conditions shall be classified into:

i) icy;
ii) flooded roadways;
iii) mirage;
iv) snow on drivable area:
v) standing water;
vi) wet road;
vii) surface contamination.

NOTE 1 *Manoeuvrability and perception capability of the ADS might be affected by road and/or weather conditions. Moreover, road capacity might be reduced due to flooding or lane obstruction/closure caused by snow or wind-blown debris.*

NOTE 2 *Flooded roads result when the amount of water arriving on the road 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 road.*

NOTE 3 *The presence of mirage can affect the perception sensors due to the reflectivity from the drivable area surface.*

NOTE 4 *Surface contamination might include the presence of leaves, oil, mud or rocks.*

5.2.4 Junctions

Junctions shall be classified into roundabouts or intersection attributes.

Roundabouts shall be classified into the following attributes:

a) normal;
b) compact;
c) double;
d) large;
e) mini.

Each roundabout attribute shall be classified into the following:

1) signalized;
2) non-signalized.

NOTE 1 *For more information on roundabouts, see the Design manual for roads and bridges: Road layout design – CD 116: Geometric design of roundabouts [10].*

Intersections shall be classified into the following attributes:

i) T-junctions;
ii) staggered;
iii) Y-junction;
iv) crossroads;
v) grade separated.

NOTE 2 *Junctions are areas on the map where two or more roads meet. Roundabouts are a special type of intersection.*

5.2.5 Special structures

Special structures shall be classified into the following attributes:

a) automatic access control;
b) bridges;
c) pedestrian crossings;
d) rail crossings;
e) tunnels;
f) toll plaza.

5.2.6 Fixed road structures

Fixed road structures shall be classified into the following attributes:

a) buildings;
b) street lights;
c) street furniture (e.g. bollards);
d) vegetation.

5.2.7 Temporary road structures

Temporary road structures shall be classified into the following attributes:

a) construction site detours;
b) refuse collection;
c) road works;
d) road signage.

NOTE *Temporary road structures might be placed on the road due to local requirements or accidents, which include temporary emergency signage which obstruct or impact normal driving.*

5.3 Environmental conditions

*COMMENTARY ON **5.3***

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.

5.3.1 Weather

*COMMENTARY ON **5.3.1***

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).

5.3.1.1 Wind

Wind speed shall be specified in the unit of m/s. It shall 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.

NOTE 1 *Stakeholders may 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 the World Meteorological Organisation's (WMO) Guide to meteorological instruments and methods of observation [11]). 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) calm: 0–0.2 m/s;
b) light air: 0.3–1.5 m/s;
c) light breeze: 1.6–3.3 m/s;
d) gentle breeze: 3.4–5.4 m/s;
e) moderate breeze: 5.5–7.9 m/s;
f) fresh breeze: 8.0–10.7 m/s;
g) strong breeze: 10.8–13.8 m/s;
h) near gale: 13.9–17.1 m/s;
i) gale: 17.2–20.7 m/s;
j) strong gale: 20.8–24.4 m/s;
k) storm: 24.5–28.4 m/s;
l) violent storm: 28.5–32.6 m/s;
m) hurricane force: ≥ 32.7 m/s.

NOTE 2 *Stakeholders may choose a different categorization of wind.*

5.3.1.2 Rainfall

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

NOTE 1 *Rainfall can demonstrate significant natural variability over time (seconds) and distance (tens of metres to thousands of metres) and the degree of impact on connected and autonomous vehicle (CAV) systems might also be dependent on how the volume of rain water is distributed across a range of rain drop sizes. Therefore, the specification of rainfall thresholds within an ODD definition should 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 km".*

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 CAV.

***NOTE 2** 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.*

***NOTE 3** Stakeholders may classify rainfall intensity as follows:*

i) *light rain: when the precipitation rate is < 2.5 mm/h;*

ii) *moderate rain: when the precipitation rate is between 2.5 mm/h and 7.6 mm/h;*

iii) *heavy rain: when the precipitation rate is between 7.6 mm/h and 50 mm/h;*

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

v) *cloudburst: when the precipitation rate is > 100 mm/h.*

***NOTE 4** Stakeholders may choose a different categorization of rain.*

5.3.1.3 Snowfall

Snowfall intensity shall be determined by human-inferred visibility, where it is clear that the visibility is affected by snow alone, and shall be classified as follows:

a) light snow, where visibility is greater than 1 km;

b) moderate snow, where visibility restrictions are between 0.5 km and 1 km;

c) heavy snow, where visibility is less than 0.5 km.

***NOTE** Defining meaningful snowfall rates is challenging both from a direct measurement perspective and also because the pathway to impact might be more directly related to the rate of accretion on surfaces. For this PAS, therefore, qualitative guidance is suggested.*

5.3.2 Particulates (obscuration by non-precipitating water droplets and other particulates)

Particulates shall be classified into the following attributes:

a) marine (coastal areas only);

b) non-precipitating water droplets or ice crystals (i.e. mist/fog);

c) sand and dust;

d) smoke and pollution;

e) volcanic ash.

***NOTE 1** 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 **5.3.2** b) "non-precipitating water droplets", it might be useful to employ a meteorological visibility parameter as it will relate more closely to impacts on optical systems.*

***NOTE 2** The meteorological optical range (MOR) should be 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 2700 K) to 5% of its original value. The luminous flux is evaluated by the photometric luminosity function of the International Commission on Illumination (CIE).*

5.3.3 Illumination

*COMMENTARY ON **5.3.3***

Illumination impacts can be both beneficial (e.g. improving the visibility of targets) or detrimental (e.g. due to rapid changes in shadowing or glare).

Illumination shall be classified into the following attributes:

a) day, where attributes are classified based on:

   1) elevation of the sun above the horizon (as a range in degrees);

   2) position of the sun.

   ***NOTE 1** Daytime is referred to as a condition where the ambient illuminance is greater than 2000 lx.*

   ***NOTE 2** The sun can be in front, behind, at the right side or left side.*

b) night or low-ambient lighting condition;

   ***NOTE 3** Night time is referred to as a condition where the ambient illuminance is less than 1 lx. Low-ambient lighting condition is when ambient light is between daytime and night time.*

c) cloudiness, 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 CAV between clouds;
   3) overcast – there are no breaks.

   NOTE 4 *Stakeholders may classify cloud cover into the following levels (based on the unit of okta):*

   a) clear: sky clear: 0–1 oktas;

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

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

   d) partly cloudy: broken clouds: 5–7 oktas;

   e) overcast: 8 oktas.

   NOTE 5 *Cloud cover is the amount of sky covered by cloud and can affect the illumination during any time of the day/night.*

   NOTE 6 *Stakeholders may choose a different banding for clear sky or overcast.*

d) artificial illumination.

   NOTE 7 *This can be streetlights or oncoming vehicle lights.*

NOTE 8 *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.*

5.3.4 Connectivity

*COMMENTARY ON **5.3.4***

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.

Connectivity is increasingly viewed as a key enabler for autonomy. Certain ADS implementations may use connectivity from off-board sensors to communicate the value of certain ODD attributes to the ADS. For example, some ADS, in order to perform their DDT, are dependent on positional signals or control command from a dispatcher via I2V 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 shall be classified as communication and positioning attributes.

Connectivity shall be classified into the following attributes:

a) communication, which shall be classified into:
   1) vehicle to vehicle communication (V2V);
   2) vehicle to infrastructure communication (V2I).

b) positioning, which shall be classified into:
   1) Galileo;
   2) GLObal NAvigation Satellite System (GLONASS);
   3) Global Positioning System (GPS).

V2X (which includes V2V and V2I) shall be classified into the following attributes:

i) cellular, e.g. 2G, 2.5G, 3G, 4G, 5G;

ii) satellite;

iii) 802.11p-based WiFi, e.g. dedicated short-range communications (DSRC); intelligent transport systems (ITS-G5).

NOTE *Signal strength and interference may be used as sub-attributes of each of the communication and positioning attributes. Interference factors may include electromagnetic (EM) signals present in the environment (e.g. road side emitters).*

5.4 Dynamic elements

"Dynamic elements" shall be classified into the following attributes:

a) traffic, which shall be classified into:
   1) density of agents;
   2) volume of traffic;
   3) flow rate;
   4) agent type;
   5) presence of special vehicles (e.g. ambulances or police vehicles).

   NOTE 1 *Traffic might include vehicles, two-wheelers or bicycles.*

b) subject vehicle.

The subject vehicle's speed shall be an additional ODD attribute.

NOTE 2 *Additionally, the subject vehicle may have an attribute for pre-defined routes.*

NOTE 3 *Stakeholders may include additional behaviour capability of the subject vehicle (e.g. ability to change lanes, turn right, turn left) as part of their ODD definition. This might be useful for defining reduced or degrade mode capability due to the influence of external factors (e.g. environmental, traffic) or internal system fault.*

Traffic shall include parked/stationary vehicles.

Traffic agent type shall include vulnerable road users and animals.

Annex A (informative)
Examples of ODD definitions

A.1 Overview

While this PAS provides a taxonomy for an ODD definition, the definition itself can be presented in various formats or languages to define the ODD. An ODD definition may be in the form of a tabular checklist (see the examples in **A.2** and **A.4.1**) or a textual guide (see the examples in **A.3** and **A.4.2**). While a tabular format might be easy to complete, it might fall short in capturing the dependencies between ODD attributes; for example, "motorway road type" is an acceptable ODD attribute but only when there is no rainfall. In a textual format, it is possible to capture the conditional dependencies of the ODD attributes.

A.2 Checklist for the ODD definition

The following is an example checklist for an ODD definition.

Attribute	Sub-attribute	Sub-attribute	Capability
Drivable area type	Motorways (M)	—	Yes
	Radial roads (A-roads)		Yes
	Distributor roads (B-roads)		Yes
	Minor roads		No
Lane specification	Number of lanes	—	Yes, minimum of two lanes
	Lane dimensions		Minimum 3.7 m
	Lane type	Bus lane	No
		Traffic lane	Yes
		Cycle lane	No
		Tram lane	No
		Emergency lane	No
		Other special purpose lane	No
	Direction of travel	Right-hand traffic	No
		Left-hand traffic	Yes

A.2 Checklist for the ODD definition *(continued)*

Attribute	Sub-attribute	Sub-attribute	Capability
Drivable area geometry	Horizontal plane	Straight roads	Yes
	—	Curves	Yes – up to 1/500 m (radius of curvature)
	Vertical plane	Up-slope	Yes
		Down-slope	Yes
		Level plane	Yes
	Cross-section	Divided/undivided	Divided
		Pavement	Yes
		Barrier on the edge	No
		Types of lanes together	Only traffic lane
Drivable area surface type	Asphalt	—	Yes
	Concrete		Yes
	Cobblestone		No
	Gravel		No
	Granite setts		No
Drivable area signs	Type	Regulatory	Yes
		Warning	Yes
		Information	Yes
	Time of operation	Part-time	No
		Full-time	Yes
	State	Variable	Yes
		Uniform	Yes

A.3 Textual ODD definition

Corresponding to the tabular description for the ODD in **A.2**, below is an example textual description, with the additional ability to capture dependencies between the ODD attributes.

Drivable area

For drivable area type, we allow [motorways, radial roads, distributor roads].

We do not allow [minor roads].

Drivable area lane specification

For lane specification we allow at least [two] lanes with at least [3.7 m] width.

For lane type we allow [traffic lane].

We do not allow [bus lane, cycle lane, tram lane, emergency lane].

For direction of travel, we allow [left hand traffic].

Drivable area geometry

For horizontal plane, we allow [straight roads, curved roads].

For curved roads, we allow radius of curvature [< 1/500 m].

For vertical plane, we allow [up-slope, down-slope, level plane].

For transverse plane, we allow [divided roads, pavements].

For transverse plane, we do not allow [barriers on the edges].

For type of lanes together, we allow [traffic lanes].

Drivable area

For drivable area signs, we allow [regulatory, warning, information].

Drivable area surface

For drivable area surface type, we allow [asphalt, concrete].

For drivable area surface type, we do not allow [cobblestone, gravel, granite setts].

Drivable area signs

For traffic information signs, we allow traffic lights [full-time].

For traffic information signs, we allow traffic lights [variable traffic signs].

Exceptions

In rainfall we do not allow [motorways].

A.4 Capri Project Case Study

*COMMENTARY ON **A.4***

The examples provided here relate to the Capri Project, more specifically to an off-road trial held at Queen Elizabeth Olympic Park.

A.4.1 Checklist for the ODD definition

Attribute	Sub-attribute	Sub-attribute classification	Capability
Drivable area type	Public roadways	Motorways (M)	No
		Radial roads (A roads)	No
		Distributor roads (B roads)	No
		Minor roads	No
		Slip roads	No
		Parking	No
		Shared space	Yes
Drivable area geometry	Horizontal plane	Straight lines	Yes
		Curves	Yes
	Transverse plane	—	Not applicable
	Vertical plane	Up-slopes	Yes
		Down-slopes	Yes
		Level plane	Yes
Lane specification	Lane dimensions	—	Not applicable
	Lane markings	—	Not applicable
	Lane type	Bus lane	Not applicable
		Traffic lane	Not applicable
		Cycle lane	Not applicable
		Tram lane	Not applicable
		Emergency lane	Not applicable
		Other special purpose lane	Not applicable
	Number of lanes	—	Not applicable
	Direction of travel	Left/right hand drive	Not applicable

A.4.1 Checklist for the ODD definition *(continued)*

Attribute	Sub-attribute	Sub-attribute classification	Capability
Drivable area signs	Type	Regulatory	Not applicable
		Warning	Not applicable
		Information	Not applicable
	Time of operation	Part-time/full-time	Not applicable
	State	Variable/uniform	Not applicable
Drivable area edge	Line markers	Permanent/temporary	Not applicable
	Shoulder	Paved/gravel/grass	Not applicable
	Barriers	—	Not applicable
Drivable area surface	Drivable area surface conditions	Icy	No
		Flooded	No
		Mirage	Yes
		Snow	Small depths only
		Standing water	Small depths only
		Wet road	Yes
	Drivable area surface features	Cracks	Yes
		Potholes	No
		Ruts	No
		Swells	Yes
	Drivable area surface type	Loose	No
		Segmented	Yes
		Uniform	Yes

A.4.2 Textual ODD definition

Drivable area

For drivable area type, we allow [shared space].

Drivable area geometry

For horizontal plane, we allow [straight lines, curves].
For vertical plane, we allow [up-slope, down-slope, level plane].

Drivable area surface

For drivable area surface conditions, we allow [mirage, snow, standing water, wet road].
For drivable area surface features, we allow [cracks, swells].
For road surface type, we allow [segmented, uniform].

Environmental

For wind, we allow [up to 15 m/s].
For rainfall, we allow [up to 10 mm/h].
For snowfall, we allow [light snow, moderate snow].
For illumination, we allow [day, night, cloudiness, artificial illumination].

Dynamic elements

For agent types, we allow [vulnerable road users, animals, non-motorized agents].

Bibliography

Standards publications

For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

PAS 1880*, Guidelines for developing and assessing control systems for automated vehicles*

PAS 1881, *Assuring the safety of automated vehicle trials and testing – Specification*

SAE J3016:2018, *Taxonomy and definitions for terms related to driving automation systems for on-road motor vehicles*

Other publications

[1] GREAT BRITAIN. The Road Traffic Regulation Act 1984. London: The Stationery Office.

[2] GREAT BRITAIN. The Road Vehicles (Construction and Use) Regulations 1986. London: The Stationery Office.

[3] GREAT BRITAIN. The Road Traffic Act 1988. London: The Stationery Office.

[4] EUROPEAN COMMUNITIES. Regulation (EU) 2016/679. Regulation on the protection of natural persons with regard to the processing of personal data and on the free movement of such data, and repealing Directive 95/46/EC (Data Protection Directive). Luxembourg: Office for Official Publications of the European Communities, 2018. AT BRITAIN. The General Data Protection Regulation. London: The Stationery Office.

[5] GREAT BRITAIN. The Data Protection Act 2018. London: The Stationery Office.

[6] GREAT BRITAIN. The Automated and Electric Vehicles Act 2018. London: The Stationery Office.

[7] GREAT BRITAIN. The Road Vehicles (Approval) Regulations 2009. London: The Stationery Office.

[8] Ulbrich, S., Menzel, T., Reschka, A., Schuldt, F., and Maurer, M. Defining and substantiating the terms scene, situation, and scenario for automated driving. In: IEEE 18th International Conference on Intelligent Transportation Systems, 2015: 982–988.

[9] Michon, J.A. A critical view of driver behavior models: What do we know, What should we do? In: L. Evans, and R.C Schwing, eds. *Human Behavior and Traffic Safety. Boston: Springer, 1985.*

[10] HIGHWAYS ENGAND. *Design manual for roads and bridges: Road layout design - CD 116: Geometric design of roundabouts*. London: Highways England, 2020.

[11] WORLD METEOROLOGICAL ORGANIZATION. *Guide to meteorological instruments and methods of observation*. Geneva: WMO, 2018.

Further reading

BS EN 1991-1-4:2005+A1:2010, *Eurocode 1: Actions on structures – Part 1–4: General actions – Wind actions*

PAS 1882, *Data collection and management for automated vehicle trials – Specification*[1]

Czarnecki, K. *Operational world model ontology for automated driving systems – Part 1: Road structure.* University of Waterloo, Canada: Waterloo Intelligent Systems (WISE) Lab, 2018.

DEPARTMENT FOR TRANSPORT. *Code of practice: Automated vehicle trialling*. London: DfT, 2019.

DEPARTMENT FOR TRANSPORT. *Highway Code*. London: DfT, 2015.

1) In preparation.

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