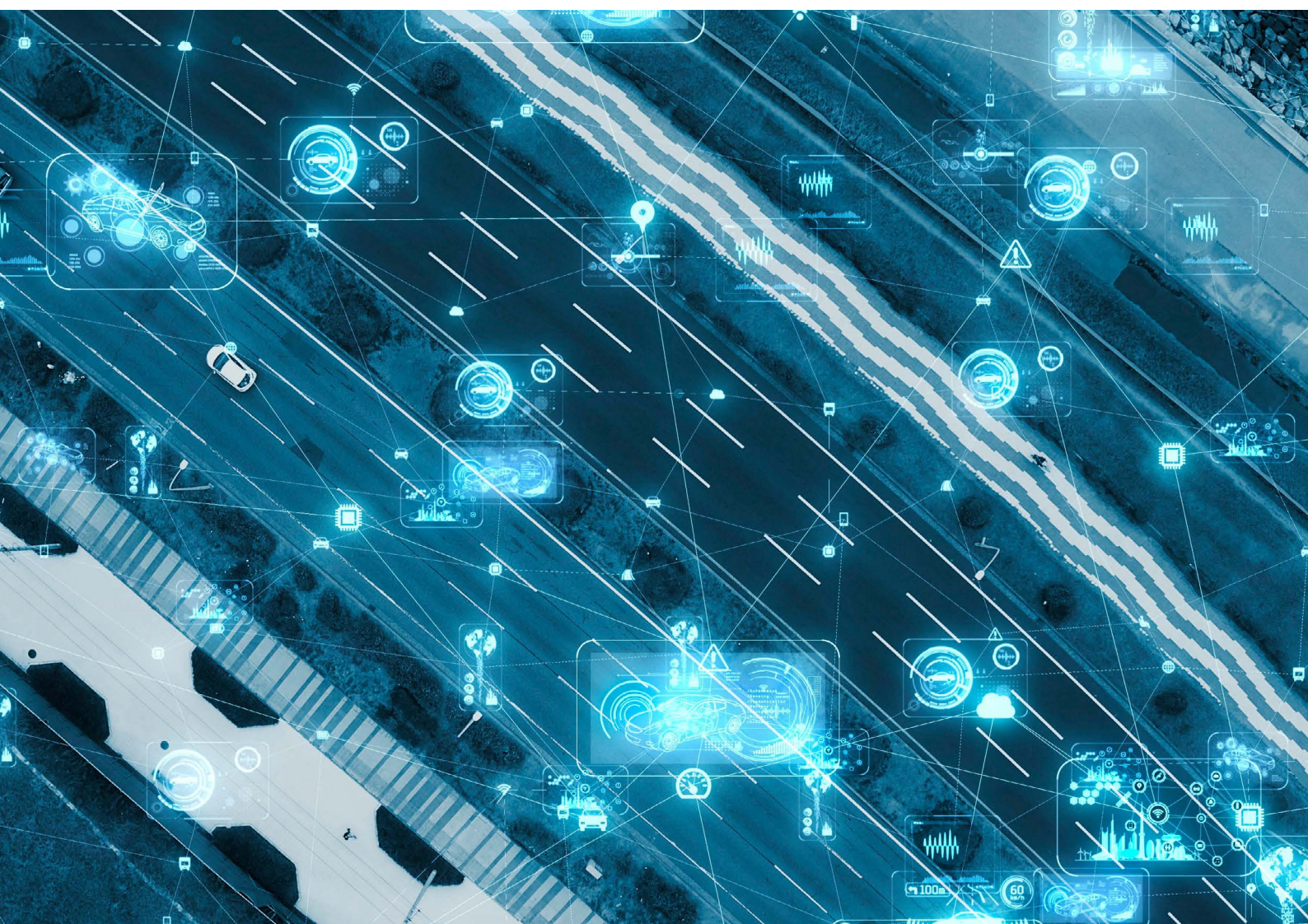


Formalised natural language description of scenarios for automated driving systems – Specification

September 2023 Version 2



BSI Flex 1889 v2.0:2023-09



Centre for Connected
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Foreword

This BSI Flex was sponsored by the Centre for Connected and Autonomous Vehicles (CCAV). Its development was facilitated by BSI Standards Limited and it was released under licence from The British Standards Institution. It came into effect on 30th September 2023.

Acknowledgement is given to Siddhartha Khastgir of WMG, University of Warwick, as the technical author, and the following organizations that were involved in the development of this BSI Flex as members of the Advisory Group:

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- Wayve

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The content in this version is part of an iterative process, it is likely to change from time to time with subsequent iterations.

Supersession

This version of BSI Flex 1889 supersedes BSI Flex 1889 v1.0:2022-07, which is withdrawn.

Information about this document

This is a full update of the document, and introduces the following principal changes:

- addition of an informative annex;
- additional detail in grammar definitions; and
- reordering of scenario elements.

Copyright is claimed on Figure 1. Copyright holders are *Abstract Natural Scenario Language Version 1.0* [1], Technical Disclosure Commons. Copyright is claimed on Figure 2. Copyright holders are *Criticality Analysis for the Verification and Validation of Automated Vehicles* [2], IEEE Access.

This release is Version 2 of BSI Flex 1889 which has been released to enable industry to engage with the initial content and feedback comments. All comments received will be reviewed to inform the future direction of this standard. However, at present there are no plans to develop further versions. Interested parties are encouraged to check the BSI website for any updates regarding future versions.

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Where websites and webpages have been cited, they are provided for ease of reference and are correct at the time of publication. The location of a webpage or website, or its contents, cannot be guaranteed.

Relationship with other publications

This document is part of BSI's Connected and Automated Mobility programme which aims to develop a suite of technical standards and guidance to help promote the design, testing and safe deployment of automated vehicles on UK roads. This document is issued as a vocabulary document that underpins the suite of CAM-related publications. It is intended to be read in conjunction with:

- publications on system safety, including PAS 1881, PAS 1883, PAS 1884, PAS 1885, BSI Flex 1890 and PAS 11281;
- publications on safety critical data, including PAS 1882;
- safety and stakeholder requirements, including the Department for Transport's Code of practice: Automated vehicle trialling, Transport for London's Connected and autonomous vehicles: Guidance for London trials, and National Highways' Safety risk assurance for connected and autonomous vehicle (CAV) trials on the strategic road network (SRN) Guidance Document; and
- existing legislation for UK vehicles and roads.

Presentational conventions

The provisions of this BSI Flex 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").

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0 Introduction

0.1 Vehicles equipped with Automated Driving Systems (ADS) bring many potential benefits such as potentially increased safety, reduced congestion, and more efficient traffic flow. However, due to the complexity of ADS, safety assurance poses challenges.

Figure 1 illustrates the V model for system development; on the right-hand side of the V model are the different levels of testing, whereas on the left side are the system development phases. Using a traditional distance-based approach, *Kalra et al.* [3] suggested that it would take 11 billion miles to demonstrate ADS are 20% better than an average human driver. This has therefore shifted the industry and academia towards a scenario-based approach for the development and testing of the system. Within a scenario-based approach for ADS development, purposely defined scenarios are used throughout the whole V model – from operational concept definition to requirements and architecture definition, to detailed design and development, and finally to the testing phases of the system.

0.2 When incorporating scenarios along the V model, it is important to appreciate the diversity of its end users (e.g. ADS developer, simulation test engineer, regulator, the public, etc.). ADS developers might favour a common format to share across organizations and systems, which raises the need for standardization. Simulation test engineers might favour a highly detailed, machine-readable format for their execution and analysis. Regulators and the public might prefer a higher abstraction level and human readable natural language format. Given these competing requirements, the industry has concluded that different levels of scenarios are needed for the ADS development. As generally applicable terminology, the *PEGASUS* project [4] has defined three different levels of abstraction:

- a) functional scenarios (semantic descriptions);
- b) logical scenarios (including ranges for variable scenario parameters); and
- c) concrete scenarios (with concrete values for each parameter range).

Neurohr et al. [2] have extended that by adding a fourth layer between functional and logical called “abstract” scenarios. The resulting levels with the corresponding descriptions are depicted in Figure 2.

Figure 1 – V model for system development

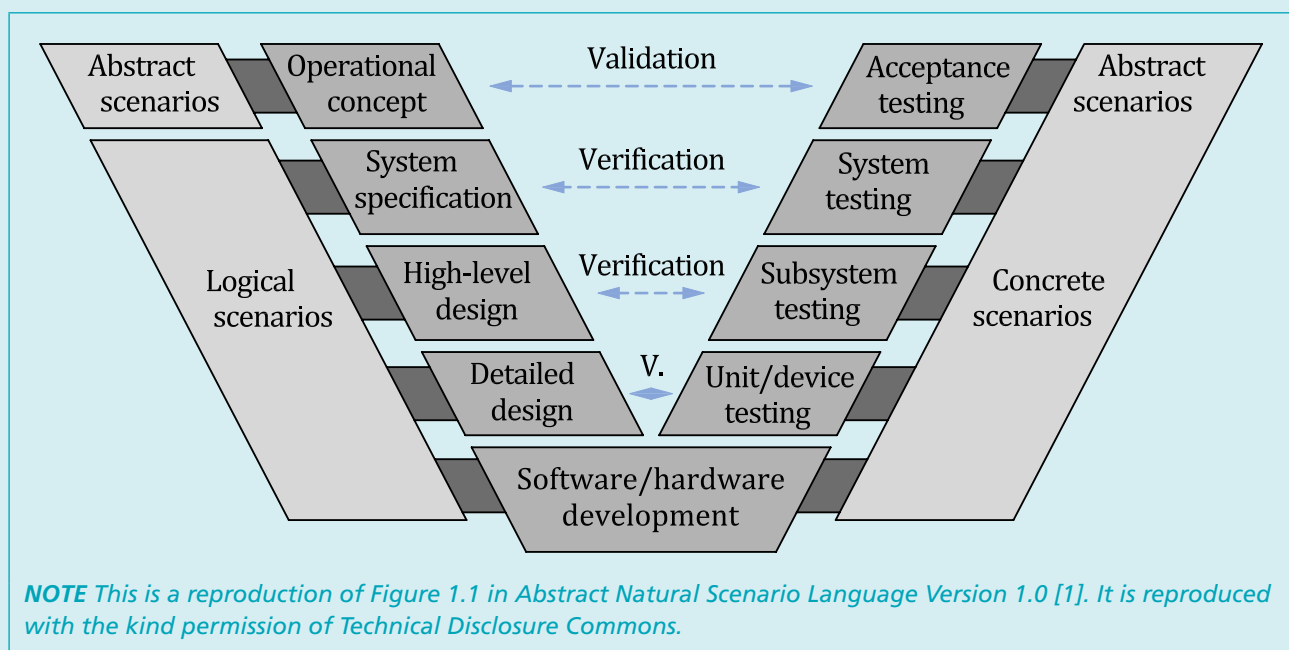
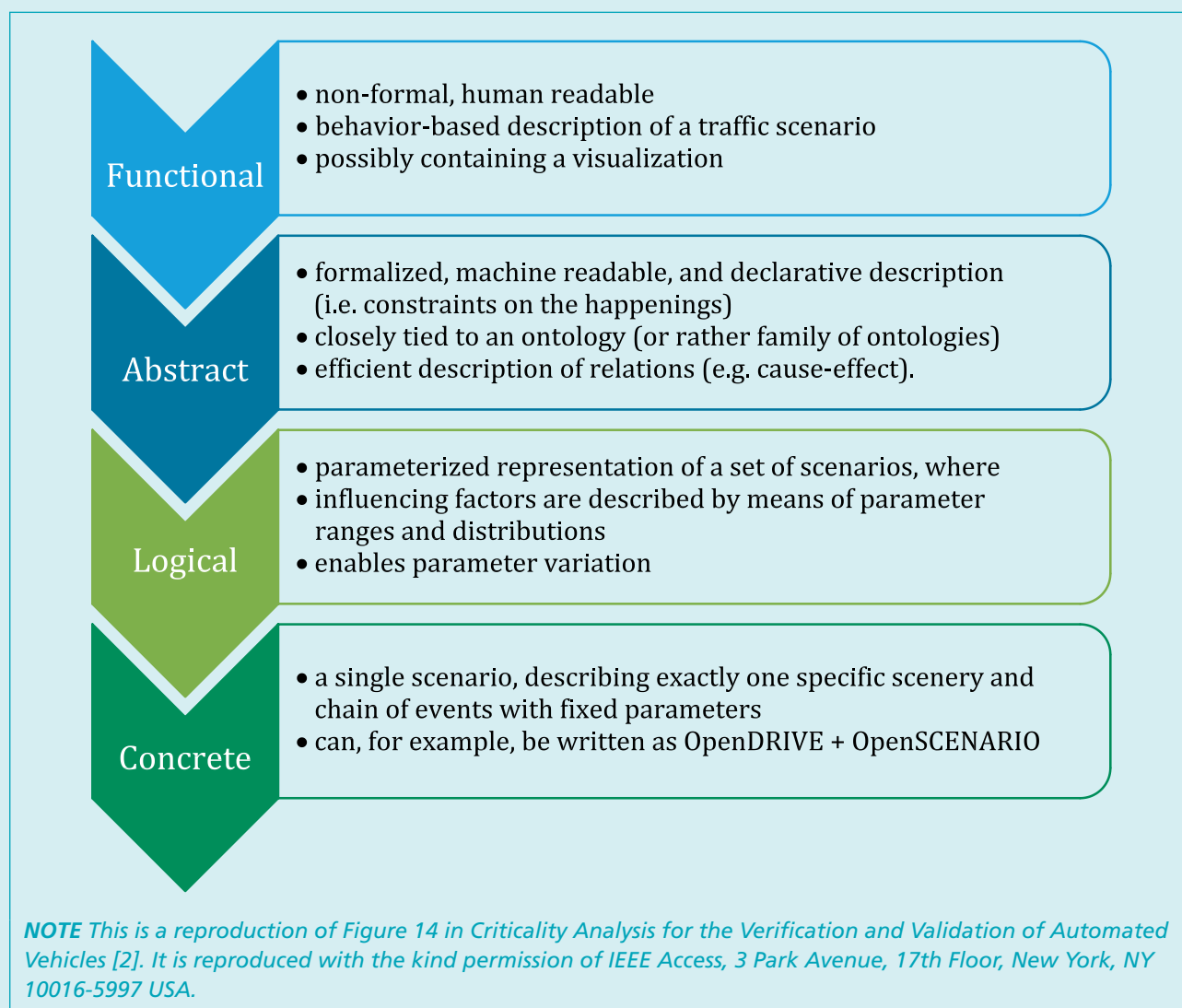


Figure 2 – Scenario abstraction levels

0.3 Functional scenarios are textual descriptions in free text (without any templates or regulations regarding grammar and vocabulary) and are therefore out of scope of this standard. Abstract scenarios are formalized versions of those scenarios. Logical and concrete scenarios are low-level abstraction, parameterized and machine interpretable scenarios. While considerable industry effort has been made to tackle the scenarios description at these abstraction levels, there lacks a standard and unified description format for the natural language-based format at the abstract scenario level, which this standard seeks to address.

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1 Scope

This BSI Flex sets out requirements for a structured natural language format for test scenario definition of an automated driving system (ADS) Level 3 and higher. BSI Flex 1889 v2.0 supports users of scenarios by providing a natural language for the description of scenarios used in scenario-based testing of ADS. This BSI Flex, however, does not cover the processes required to assess or approve that an ADS is safe. This BSI Flex is intended to be used by organizations providing test/audit services of the systems and processes related to the assurance of an ADS and automated vehicle (AV). It might also be of interest to manufacturers, developers of Level 3 and higher ADS, suppliers of components and subcomponents, simulators and anyone involved in scenario-based testing.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes provisions of this document¹⁾.

PAS 1883, *Operational Design Domain (ODD) taxonomy for an automated driving system (ADS) – Specification*

¹⁾ Documents that are referred to solely in an informative manner are listed in the Bibliography.

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

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

3.1.1 dynamic elements

movable objects and actors with which the automated vehicle (AV) interacts in the operational design domain (ODD) within the dynamic driving task (DDT) timeframe

3.1.2 environmental conditions

weather and other atmospheric conditions

NOTE *Environmental conditions do not contain scenery elements.*

3.1.3 formalised (natural language)

using grammar and vocabulary to restrict natural language expression

3.1.4 GLONASS

Russian satellite navigation system, providing an alternative to Global Positioning System, with a position accuracy of 5 m to 10 m

NOTE *Also known as Global'naya Navigatsionnaya Sputnikovaya Sistema.*

3.1.5 minimal risk condition (MRC)

stable, stopped condition to which a human driver or ADS brings a vehicle after performing the DDT fallback in order to reduce the risk of a collision or other loss when a given trip cannot be continued

[SOURCE: BSI Flex 1890 v5.0:2023-04, 3.1.53 – modified, minimal risk manoeuvre changed to DDT]

3.1.6 minimal risk manoeuvre (MRM)

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

[SOURCE: BSI Flex 1890 v5.0:2023-04, 3.1.54 – modified, driving automation system changed to ADS]

3.1.7 operational driving task

dynamic driving task that involves split-second reactions that can be considered precognitive 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.*

3.1.8 scenario

description of a driving situation that includes the pertinent actors, environment, objectives and sequences of events

[SOURCE: BSI Flex 1890 v5.0:2023-04, 3.1.72]

3.1.9 scenery elements

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

NOTE *This definition is in the context of an ODD.*

3.1.10 tactical driving task

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

NOTE *This definition is a modified version of the one taken from Michon, 1985 [5].*

3.1.11 traffic actor

anyone who uses a road, including sidewalk or pavements and other adjacent spaces

3.1.12 vulnerable road users

person at higher risk of being injured or killed in a collision by having less crash protection than occupants of motor vehicles with protective bodywork

NOTE *Examples include pedestrians, cyclists, horse riders, motor-cyclists, users of mobility scooters or e-scooters and persons with disabilities or reduced mobility and orientation.*

[SOURCE: BSI Flex 1890 v5.0:2023-04, 3.1.103]

3.2 Abbreviated terms

ADS	automated driving system
DDT	dynamic driving task
GPS	global positioning system
ODD	operational design domain
MRC	minimal risk condition
MRM	minimal risk manoeuvre

4 Understanding scenarios, ODD and scenario-based testing

COMMENTARY ON CLAUSE 4

Being able to differentiate between ODDs and scenarios and understanding the scenario-based testing concept are key factors for the correct usages of the scenario format.

An ODD is a specification of the ADS that defines the operating conditions within which the system is designed to operate safely; such conditions consist of scenery elements, environmental elements and dynamic elements, as detailed in PAS 1883.

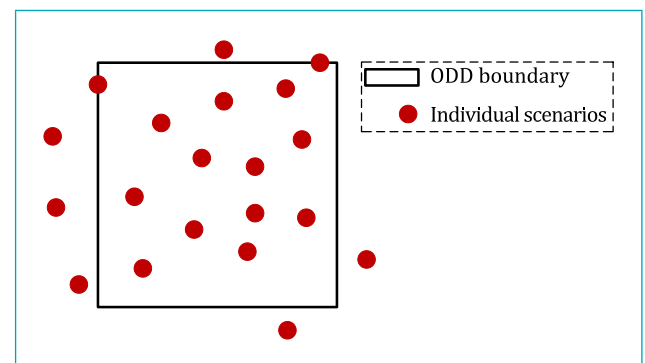
A scenario defines a unique combination of the ODD attributes and the additional behaviour characteristics of the dynamic agents, furthermore the temporal development of all the conditions is also described within a scenario. Incorporating the ODD-based model into the scenario definition enables a coherent and effective approach for the safety assurance of the ADS.

As illustrated in Figure 3, the solid square is a simple representation of an ODD “boundary”, and the red dots are the individual scenarios. The ODD only defines a boundary rather than the unique combination of the attributes’ values. For example, “a suitable rainfall condition of up to heavy rain” (i.e. applicable range includes no rain to heavy rain) is a valid ODD statement, whereas a rainfall condition of (exactly) mild rain is a valid scenario parameter at the natural language level. When comparing the scenario parameters (excluding the behaviour aspect as it is not part of the ODD) against an ODD specification, a scenario can fall within the ODD boundary, at the boundary, or outside the boundary.

Scenario-based testing shall utilize such unique relations between ODDs and scenarios to effectively gather safety evidence of the performance of the ADS in relation to its claimed ODD boundary.

NOTE 1 For example, the ADS needs to be able to handle those scenarios that fall at or within the ODD boundary, but not necessarily for the scenarios outside the boundary. The scenarios at the boundary, as well as the scenarios near the boundary are highly effective “edge cases” for the ADS’ safety assurance. The ODD boundary and the scenario parameter space are of multi-dimensional level, rather than a 2-D and 1-D representation, respectively.

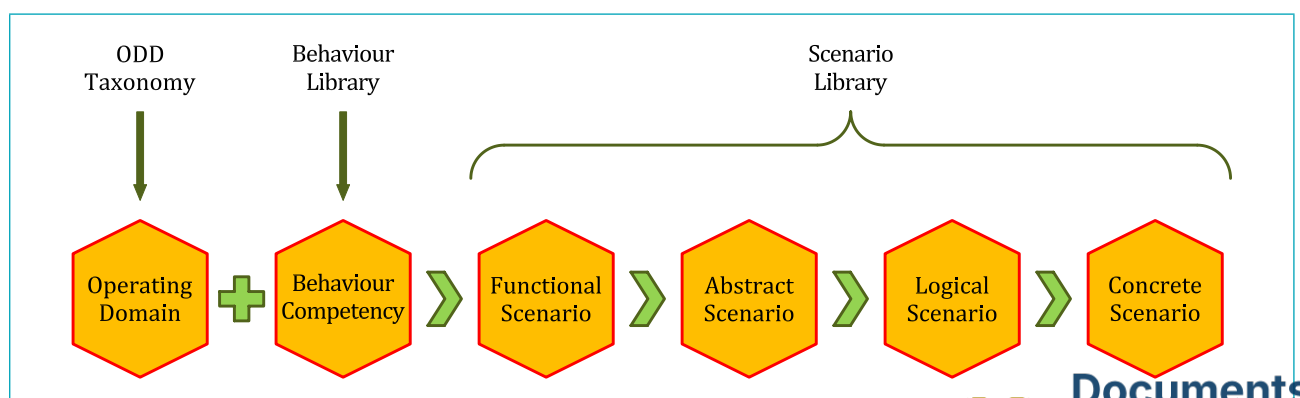
Figure 3 – Relations between ODD and scenarios



The ODD definition shall be used as one of the inputs for scenario-based safety evaluation for the ADS.

NOTE 2 As a result, one of the first steps in the safety evaluation process involves the definition of the ODD for the ADS. A subsequent step involves testing the desired behaviour of the ADS by choosing a set of behaviours from a behaviour competency library. An instantiation of the ODD together with a desired behaviour and the description of the traffic participant behaviour according to events and triggers provides a scenario definition for the ADS. Such scenarios can then be defined at either the functional, abstract, logical, or concrete scenario level (see Figure 4).

Figure 4 – Relationship between ODD, behaviour and scenarios



5 Natural Language Abstract Scenario Description Language (NL SDL)

5.1 Human readability

The natural language scenario description shall be developed for use by a wide range of end users, with an emphasis on non-technical audiences. The language shall be human readable, structured and understandable by non-technical audiences, as well as non-programmers.

5.2 Expression of mandatory and optional attributes

The language shall target a wide range of use cases and be flexible in terms of complexity, levels of detail, and attributes used to define a scenario. Therefore, a set of mandatory attributes shall be stated to be defined.

In addition, an extensive set of optional attributes shall be introduced to allow users to add detail level and complexity to the scenarios.

5.3 Structured grammar

To enable an accurate and unambiguous expression of the intended scenarios, and to facilitate the transition towards logical and concrete scenarios for testing and development, the language shall have a structured and well-defined grammar.

NOTE Such structure can facilitate the manual interactions with the scenarios (i.e. writing and reading), as well as the machine interactions (i.e. parsing, auto-generation).

5.4 Includes scenario overview

To facilitate the sorting and administrative organization of scenarios, the language shall enable the end user to specify additional information that is not part of the scenario storyboard.

NOTE For example, versioning, authorship and scenario maturity state are all relevant and necessary information from such an administrative perspective.

5.5 Extensibility

The scenario attributes and the language format shall serve as a foundation for defining natural language scenarios. End users shall be able to extend and add customized attributes (aligned with the language ontology) within the language for their unique use cases.

5.6 Ability to define qualitative and quantitative parameters

The natural language format shall define parameters in a qualitative manner as the default option, due to the natural language nature and its position within the established levels of scenario format. However, when the precision of the parameter needs to be further defined, a quantitative measure shall also be made available.

5.7 Alignment with ODD taxonomy and other standards

COMMENTARY ON 5.7

The language format is intended to facilitate the development, testing and operational activities of ADS across a wide variety of end users.

The language format shall align with relevant best practices and standards. Due to the unique roles of the ODD and scenario with the scenario-based testing workflow, the language shall align with ODD standards to form a common and coherent approach.

5.8 Spatial and temporal behaviour description

Due to the nature of scenarios, the natural language scenario description shall be able to express both the spatial description and the temporal description.

NOTE For example, the locations of the scenario objects and the road network form part of the spatial description; the manoeuvre sequence of the dynamic agents forms part of the temporal description.

5.9 Convertibility to logical and concrete level scenarios

The formalized natural language scenario format is positioned at the abstract scenario level and to facilitate the scenario-based testing process, it shall be convertible into the logical and concrete scenarios for machine execution and other testing activities.

6 Scenario composition

COMMENTARY ON CLAUSE 6

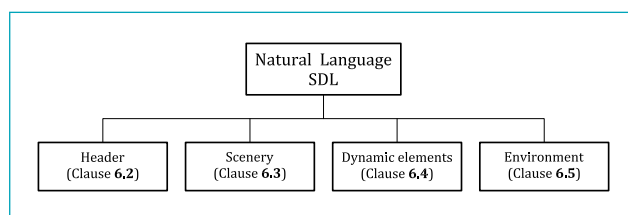
For all the quantitative descriptions of scenario parameters, their corresponding units also need to be specified.

6.1 Scenario attributes

At the top level, the natural language scenario description shall comprise the following high-level scenario elements (see Figure 5):

- header (see 6.2), which includes administrative information;
- scenery, such as road network, traffic infrastructures and other road structure;
- dynamic, such as dynamic actors in the scenarios, together with their behaviours; and
- environment, which also includes the connectivity based on the ODD taxonomy in PAS 1883.

Figure 5 – High-level scenario elements



6.2 Header

COMMENTARY ON 6.2

The header information is intended to provide a standardized reference for scenarios and information related to the scenario which is not directly contributing towards the context of the scenario.

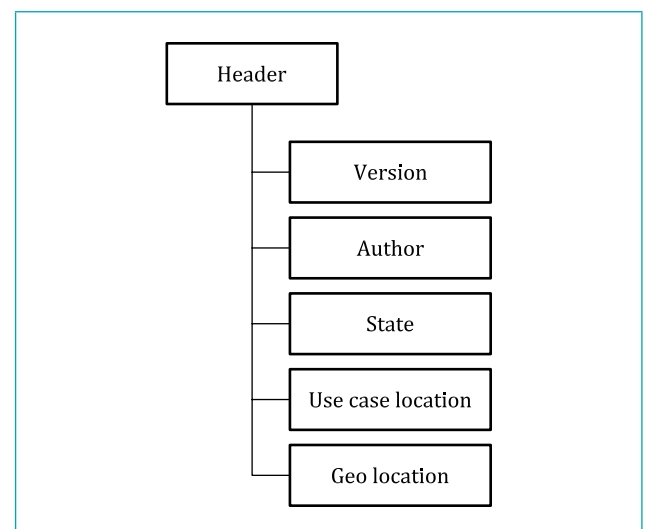
The header shall comprise the following attributes (see Figure 6):

- version information, defined using a numerical number, such as "1.0.0";
- author name, defined using a string format, such as "John Doe"; and
- state of the scenario, to indicate the maturity of the scenario, such as "Draft" or "Final".

NOTE 1 The choice of keywords for defining the state of the scenario is at the user's discretion.

NOTE 2 In addition, the header could also indicate a "Use" case location related to high-level road layout and not specific to a real-world physical location, such as "Motorway" or "Urban"; or a "Geo-location" related to real-world locations, such as "London" or "Birmingham". Header information can be treated as meta information which could include information such as project name.

Figure 6 – Elements within the Header



6.3 Scenery

6.3.1 Scenery elements

The scenery shall comprise of the following elements, as shown in Figure 7:

- junctions; and
- drivable area.

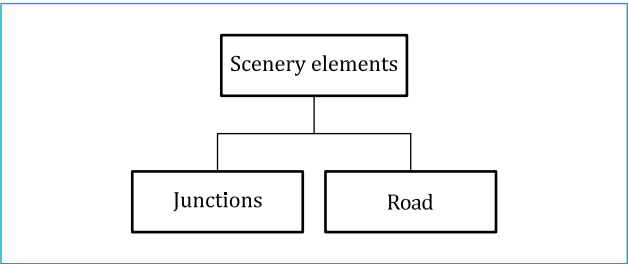
NOTE 1 The scenery describes the logical road network, the road infrastructures and the temporary modifications to the road infrastructures or network.

NOTE 2 As road is the most common example of a drivable area, road has been used in this standard. However, the contents of this standard are relevant for any drivable area.

Using a modularized and scalable approach, the scenery information shall set out the junction and road network where individual junctions and roads shall be described respectively, with their associated road infrastructures and modifications. The road connection information defined in the junction details shall link individual roads (segments) together, consequently achieving the construction of the overall layout.

NOTE 3 *If the attributes do not adequately represent the needs of the specific scenarios, stakeholders may extend them, including the introduction of relevant measurement units (which might reflect temporal or other aspects).*

Figure 7 – High-level elements within Scenery



6.3.2 Junctions

6.3.2.1 General

At the logical road network level, the required junction attributes shall be divided into the following elements, as shown in Figure 8:

- a) junction type; and
- b) road connection.

Figure 8 – High-level elements within Junctions

