OPERATIONAL DESIGN DOMAINS IN AUTOMATED VEHICLES:
A REVIEW OF STATE-OF-THE-ART STANDARDS, CHALLENGES, AND PROPOSED SOLUTION

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German Aerospace Center (DLR)

Content of the talk

- Review of ODD and standards
  - ODD recap using SAE level 3 example
  - Taxonomy standards
  - OpenODD standard
- Existing challenges
  - Misinterpretation, Misconception, Proliferation of Terminology
- Proposal to improve current situation

ODD example in SAE Level 3
Mercedes-Benz DRIVE PILOT

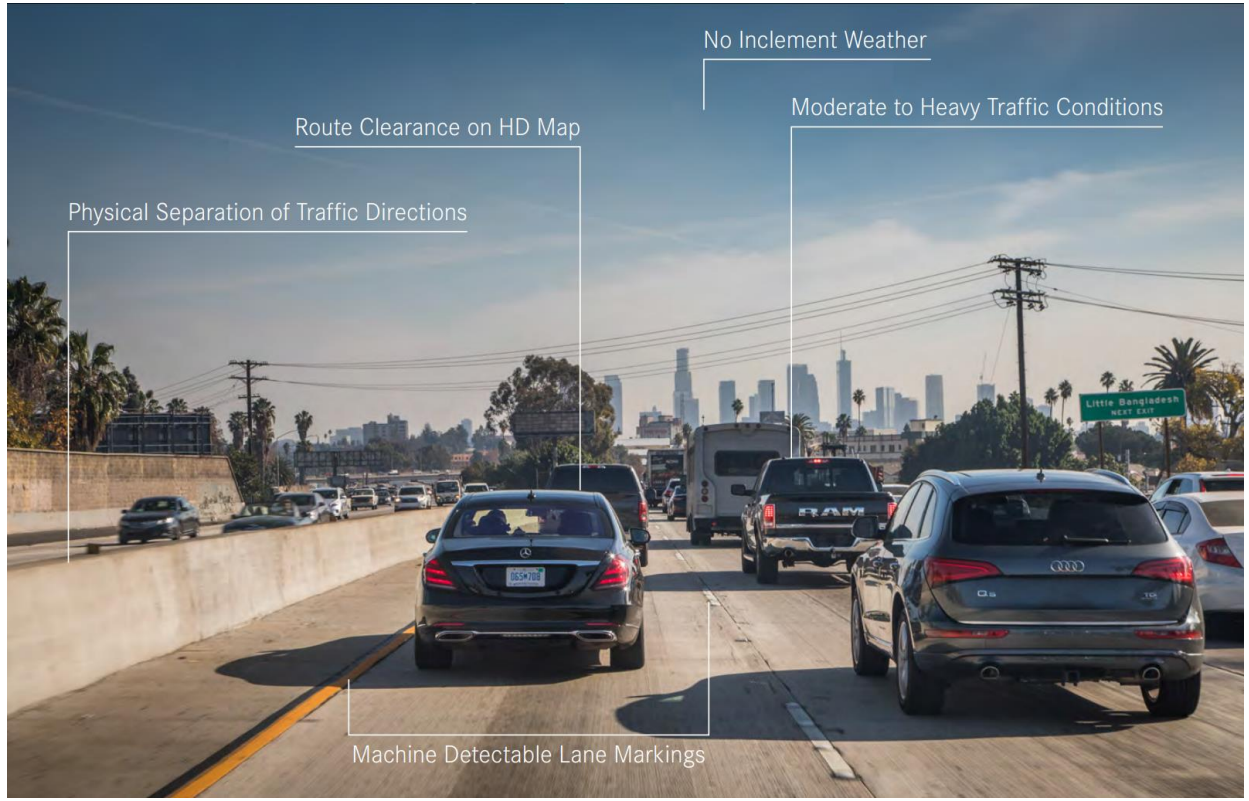
ODD Specification

Activation condition

- Only in Autobahn, heavy traffic
- At least two lanes,
- Absence of tunnels,
- Speed up to 60 km/h,
- Visible lane markings

Transition demand

- heavy rain, snowstorms, heavy fog,
- adverse traffic conditions,
- construction site



Source: Introducing DRIVE PILOT: An Automated Driving System for the Highway (mercedes-benz.com)

Motivation
Environment is more complicated

- Scenery elements
- Weather conditions
- Dynamic traffic

Taxonomy Standards
Characterization of operational domain

PAS 1883:2020
Operational Design Domain (ODD) taxonomy for an automated driving system (ADS) - Specification

SAE AVSC00002202004:2020
AVSC Best Practices for Describing an Operational Design Domain: Conceptual Framework and Lexicon

ISO/SAE PAS 22736:2021
Taxonomy and definitions for terms related to driving automation systems for on-road motor vehicles

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

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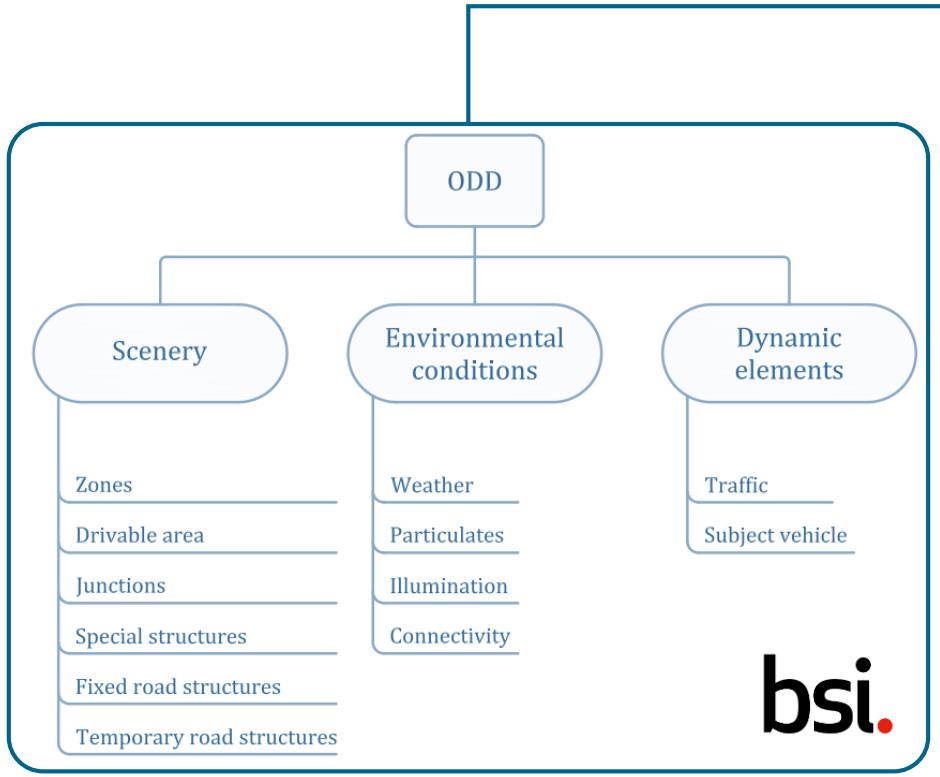
5. Lexicon
- 5.1 Weather-Related Environmental Conditions
- 5.2 Road Surface Conditions
- 5.3 Roadway Infrastructure
- 5.4 Operational Constraints
- 5.5 Road Users
- 5.6 Non-Static Roadside Objects
- 5.7 Connectivity

Automated Vehicle Safety Consortium™
A Program of SAE ITC

AVSC establishes a lexicon. But it “is not intended to be comprehensive”

Taxonomy Standards
Characterization of operational domain



Top level taxonomy with ODD attributes
Source: PAS1883, The British Standards Institution

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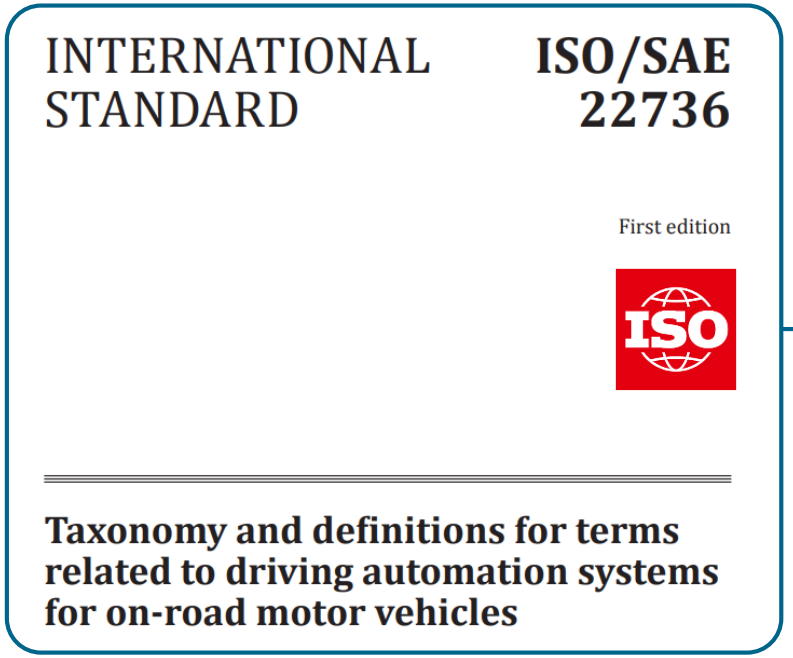
INTERNATIONAL STANDARD

ISO/SAE 22736

First edition

ISO

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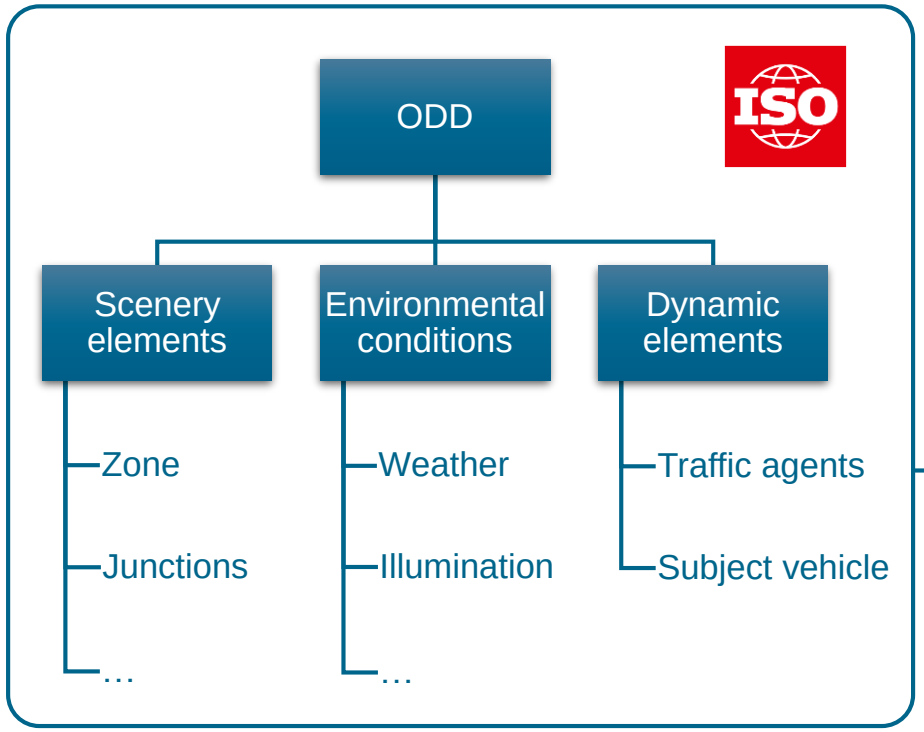
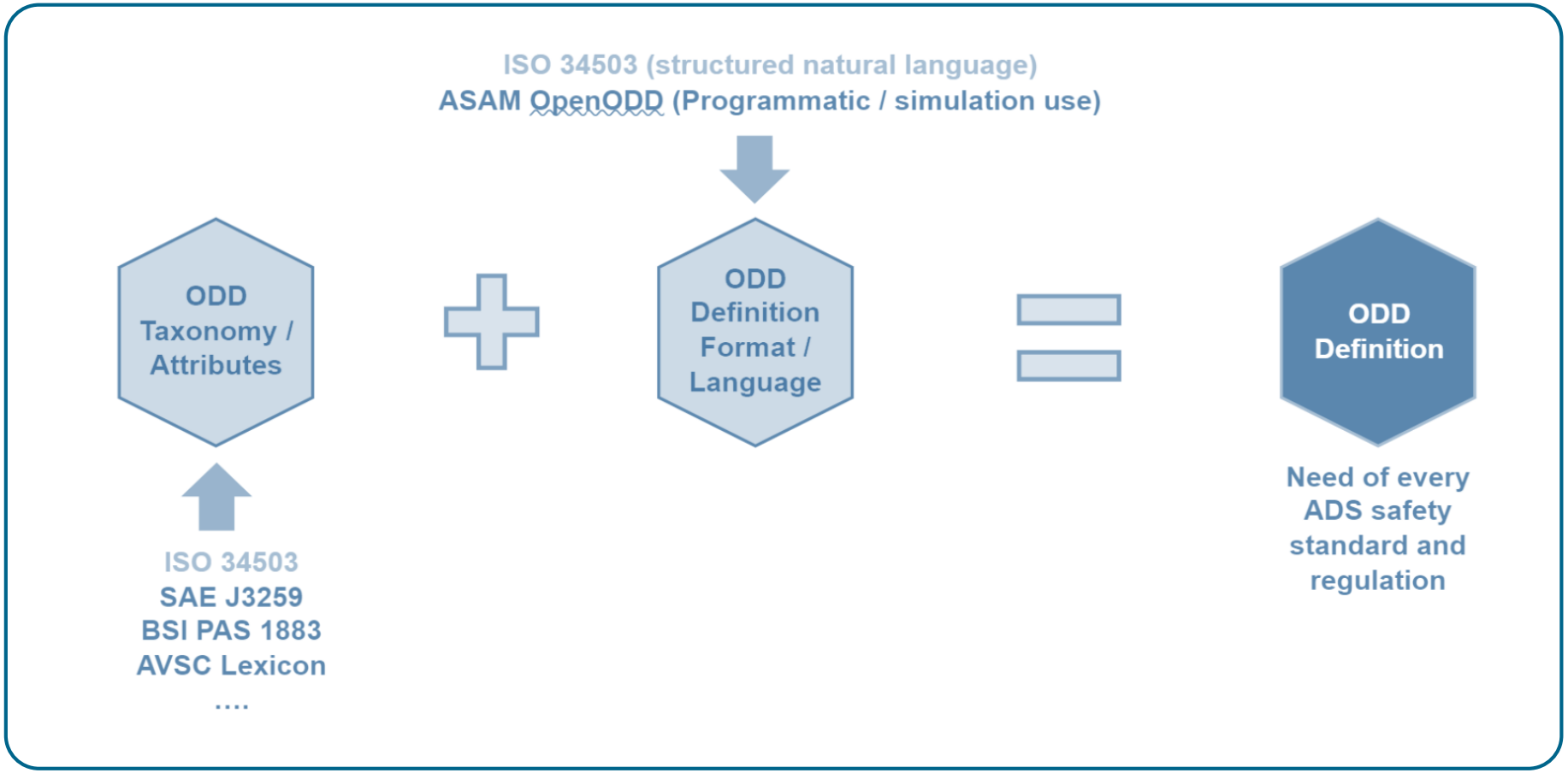
Top level taxonomy with ODD attributes. Derived from ISO34503:2023.



ASAM OpenODD does not intend to develop another taxonomy

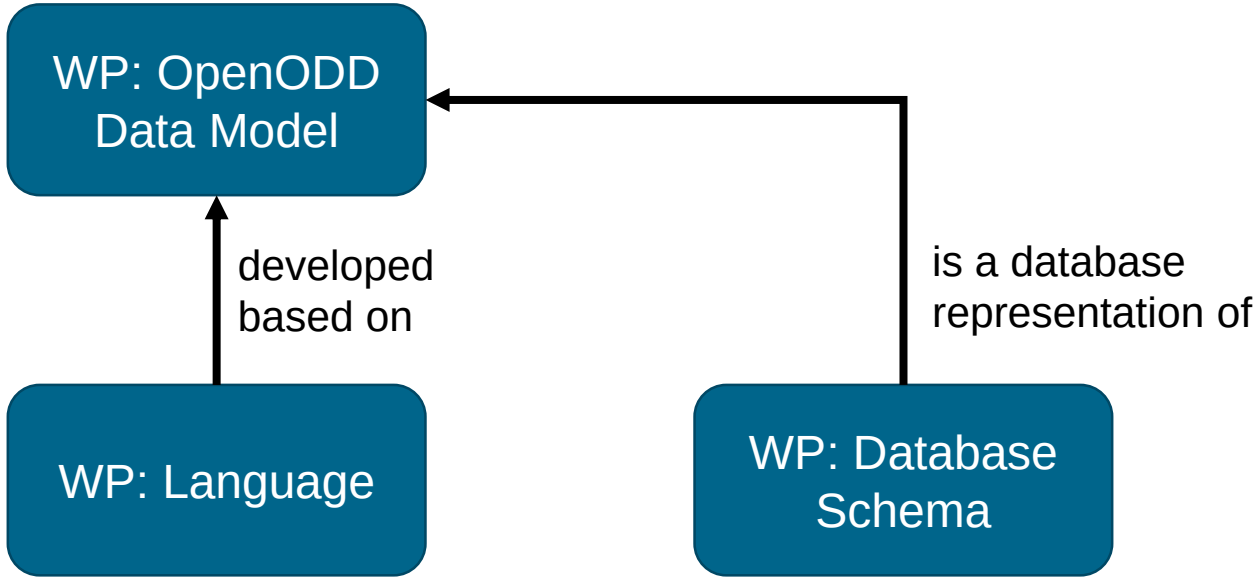
ASAM OpenODD
Scope



ASAM OpenODD Scope is to provide a language/format for specifying ODD. Source: Dr. Siddartha Khastgir, Oct 2022.

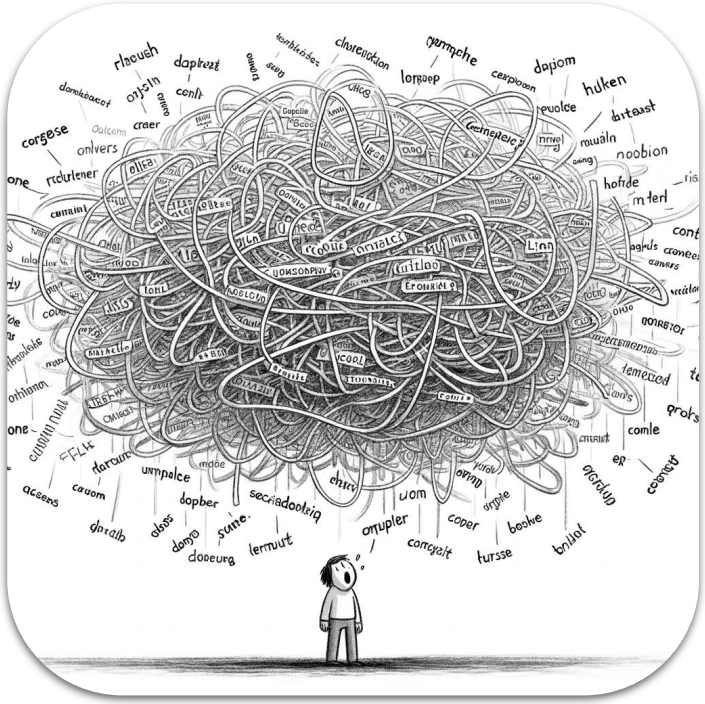
ASAM OpenODD
Status

ODD-related terms and their relationship



Challenges can delay standardization and research

Challenges
Misinterpretation, Misconception, Proliferation of Terms



Proliferation of terms

- Increased complexity

Misinterpretation

- Misunderstanding and communication

Misconception

- Incorrect and incomplete information

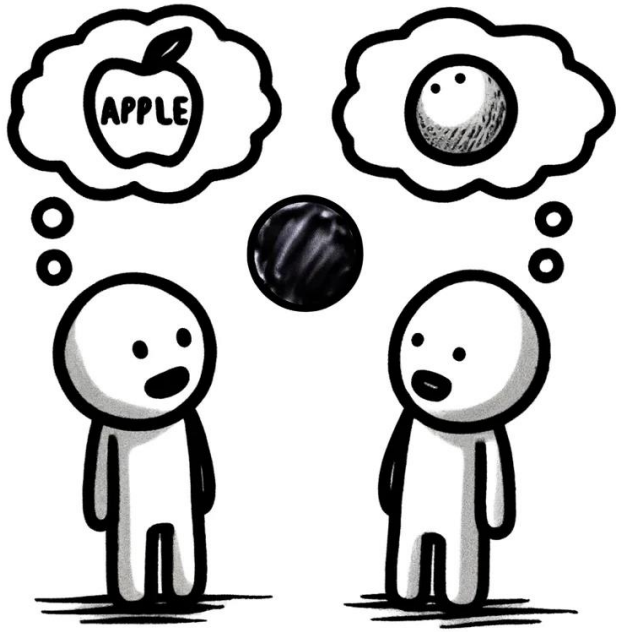
Misinterpretation of terminology

SAE J3016, ODD: **operating conditions** under which a given driving automation system or feature thereof is specifically designed to function, 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.]

ISO 34503, TOD: **set of operating conditions** in which and ADS will be **expected to operate**, including but not limited to […]

ISO 34503, COD: **specific set of operating conditions**, which **exists presently** in the immediate vicinity of an ADS, including but not limited to […]

ISO 34503, OD: **set of operating conditions**, including but not limited to […]



Misconception

Defining OD as an aggregate of CODs

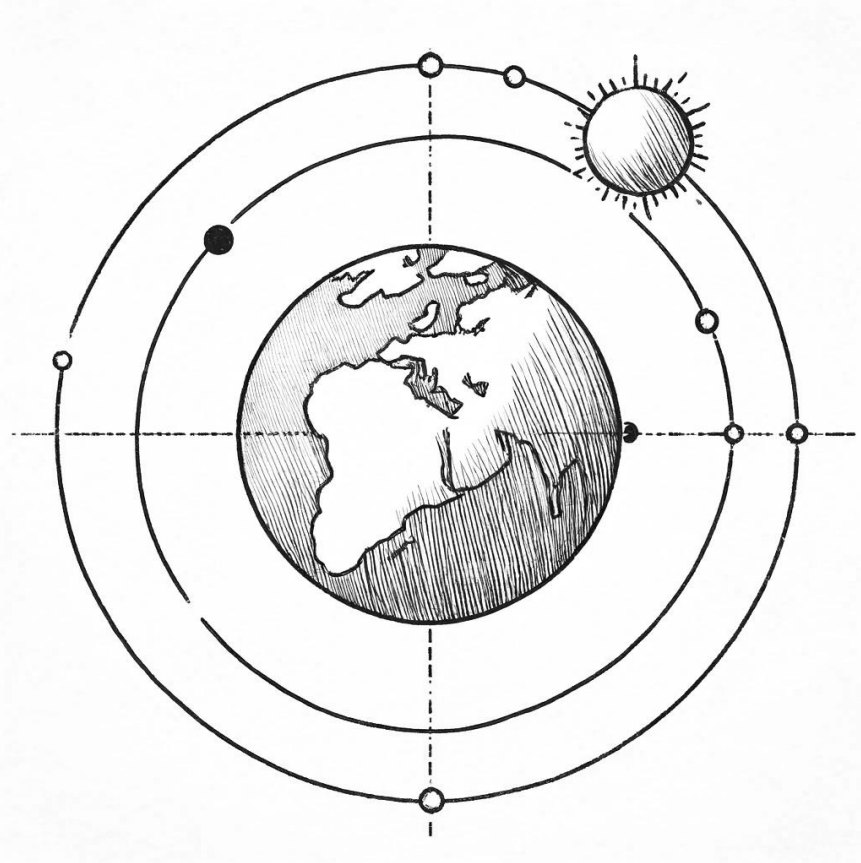
- This way only knowns are included in OD. What about unknowns?

ODD Taxonomy

- ODD is a specific property of a vehicle system
- Standards, in fact, provide a taxonomy for characterizing the operational domain attributes

ODD Monitoring

- What is the thing that we monitor? ODD? COD? Or something else?



Proliferation of terminology

ODD Properties
(ISO 34503)

Restriction
(SAE J3016)

ODD Definitions
(ISO 34503)

Operational Road Environment Model
(K. Czarnecki, 2018)

Operational World Model
(K. Czarnecki, 2018)

Operational Design Conditions
(ISO 34503)

TOD
(ISO 34503)

ODD Boundary
(ISO 34503)

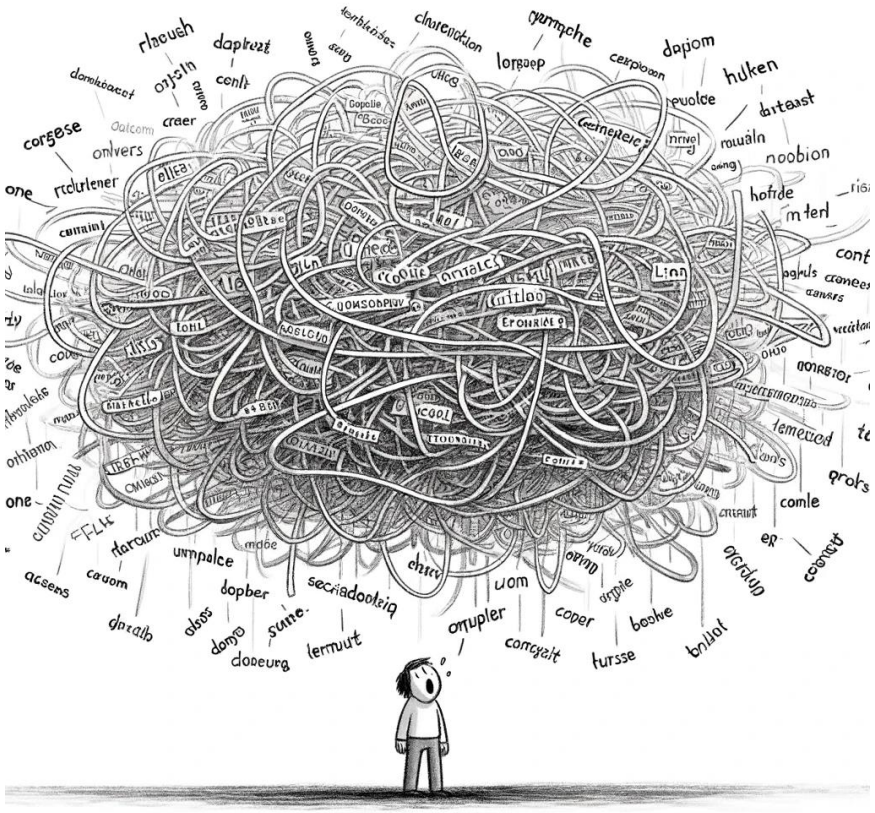
Situation
(Schwalb et al., 2021)

Operating Conditions
(SAE J3016)

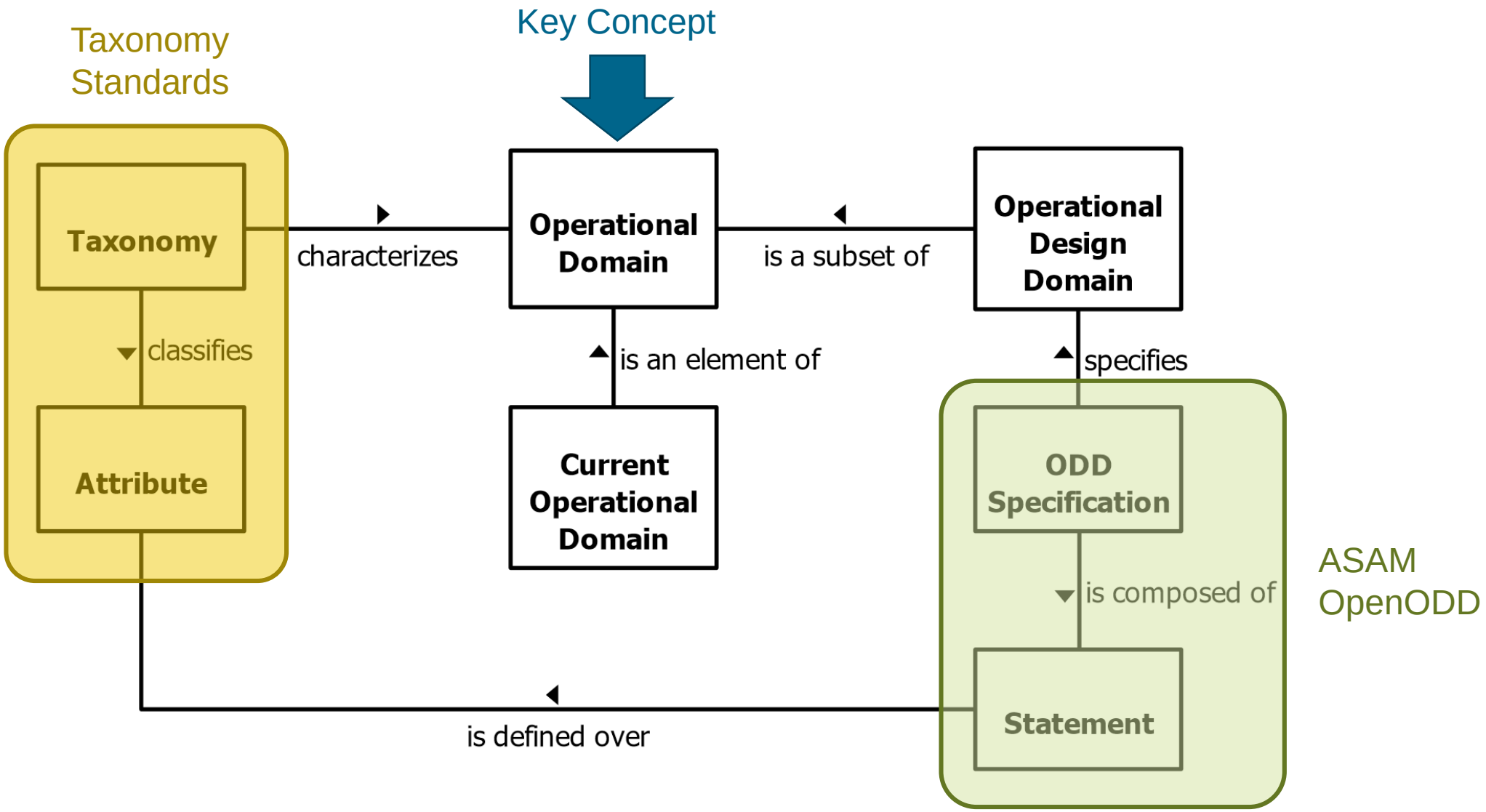
ODD Exit
(ISO 34503)

ODD Attributes
(ISO 34503)

Fact
(Schwalb et al., 2021)



Proposed solution



Operational Domain
Formal Representation

OD is characterized by a set of attributes, $\mathbb{A}$, and their data types, $\mathcal{D}$

$$\mathbb{A} = \{A_1, A_2, \dots, A_n\}, \qquad \mathcal{D}(A)$$

OD can be represented mathematically over data types

$$\mathrm{OD} = \mathcal{D}(A_1) \times \mathcal{D}(A_2) \times \cdots \times \mathcal{D}(A_n)$$

Operational Domain
Example

The attribute **road_type**, denoted as R

$$\mathcal{D}(R) = \{\text{motorway}, \text{regional}, \text{rural}\}$$

The attribute **pedestrian**, denoted as P

$$\mathcal{D}(P) = \{\text{true}, \text{false}\}$$

Then OD of such a space is a set over tuple $\mathcal{D}(R) \times \mathcal{D}(P)$

$$\begin{aligned}\text{OD} = \{&(\text{motorway}, \text{true}), (\text{motorway}, \text{false}), (\text{regional}, \text{true}),\\ &(\text{regional}, \text{false}), (\text{rural}, \text{true}), (\text{rural}, \text{false})\}\end{aligned}$$

Current Operational Domain in a regional road where pedestrian exists is

$$\text{COD} = (\text{regional}, \text{true}) \in \text{OD}$$

ODD Specification
Formal Representation

Example: Consider natural language ODD Specification

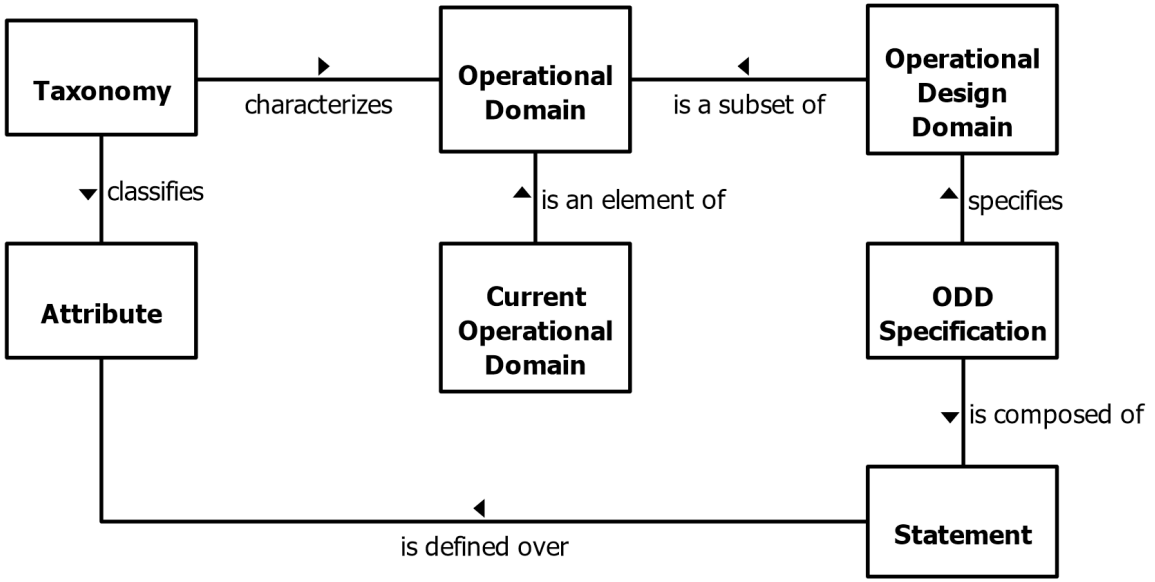
The system is designed and only allowed to operate
on motorways, *(1)*
where pedestrians are prohibited *(2)*

$$S_R \coloneqq (R = \text{motorway})$$
$$S_P \coloneqq (P = \text{false})$$
$$\text{ODD Spec.} \coloneqq S_R \ \wedge \ S_P$$

$$\text{ODD Spec.} \quad \dashrightarrow \quad \text{ODD} = \{(\text{motorway}, \text{true})\} \subseteq \text{OD}$$

Summary

- Brief review of ODD standards
- Problems slow down the development
- Proposal: revisiting terms and their relations
- Formal methods can help



What do you think?

Imprint

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