DEFINING OPERATIONAL DOMAIN AND SPECIFYING OPERATIONAL DESIGN DOMAINS:
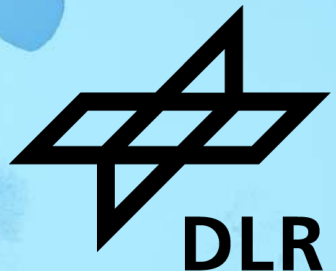## CURRENT PRACTICES, STANDARDS, AND A SYSTEMATIC APPROACH

Ali Shakeri
German Aerospace Center (DLR)
November 2024

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

- A methodology for creating ODD specification

- Summary

ODD example in SAE Level 3
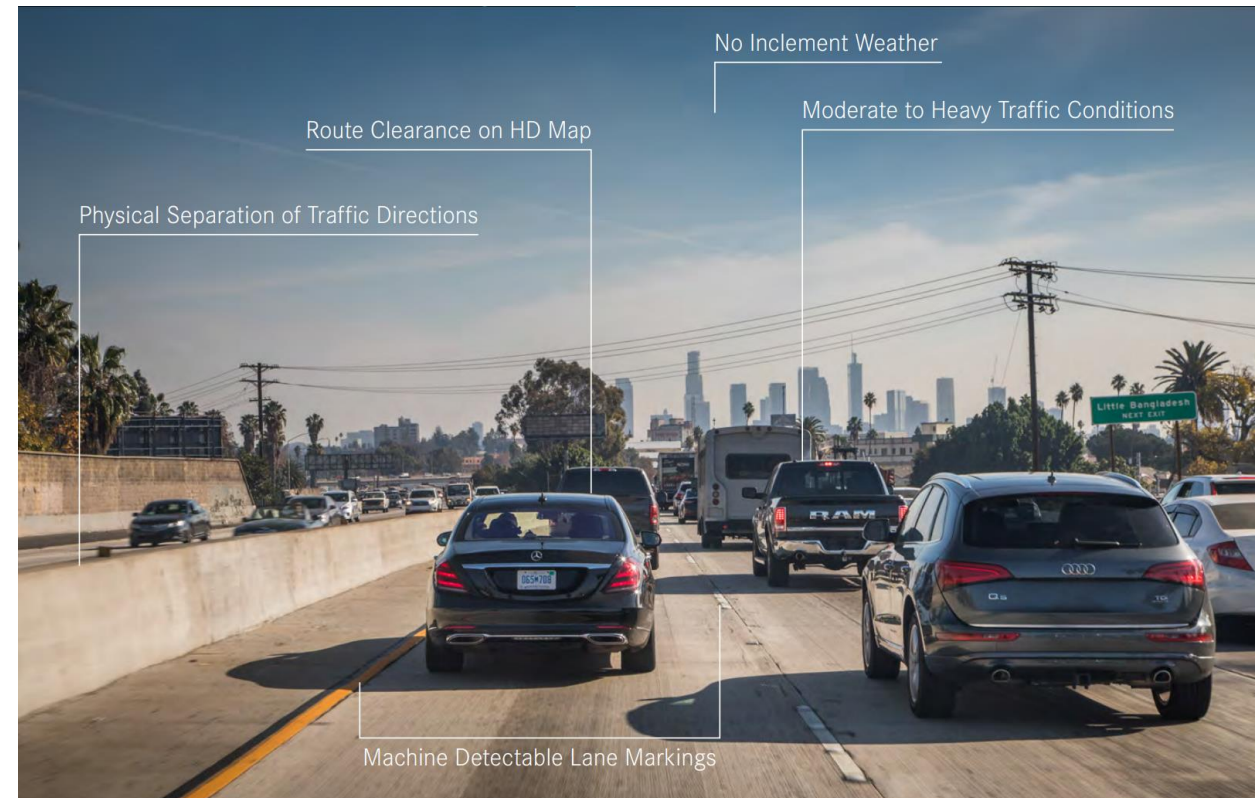## Mercedes-Benz DRIVE PILOT

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

No Inclement Weather

Route Clearance on HD Map

Moderate to Heavy Traffic Conditions

Physical Separation of Traffic Directions

Machine Detectable Lane Markings

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

Operational Domain is complicated

- Scenery elements
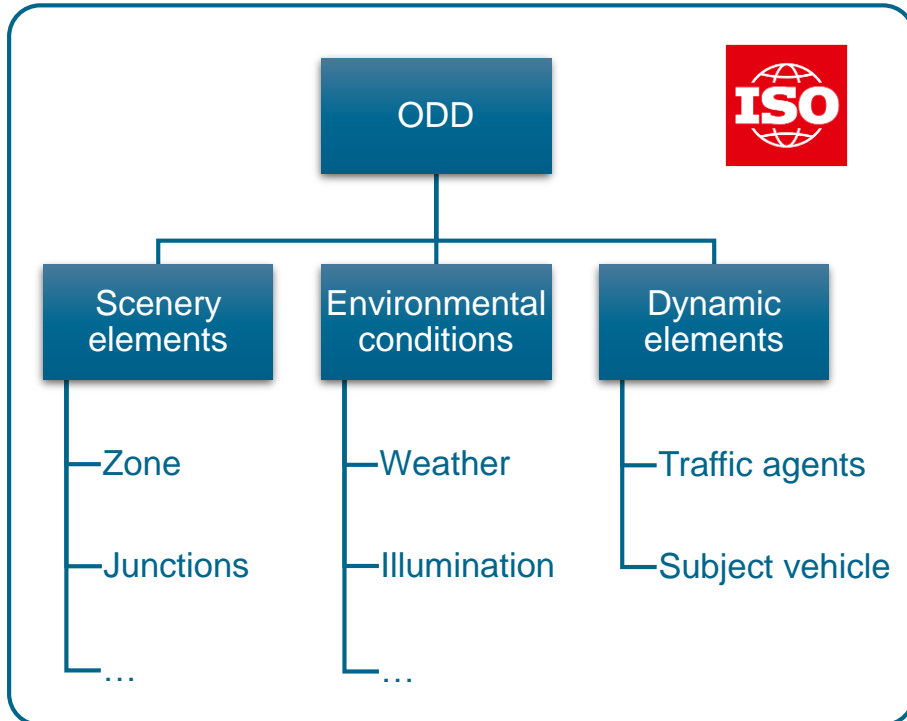- Weather conditions
- Dynamic traffic

Taxonomy Standards
Characterization of operational domain

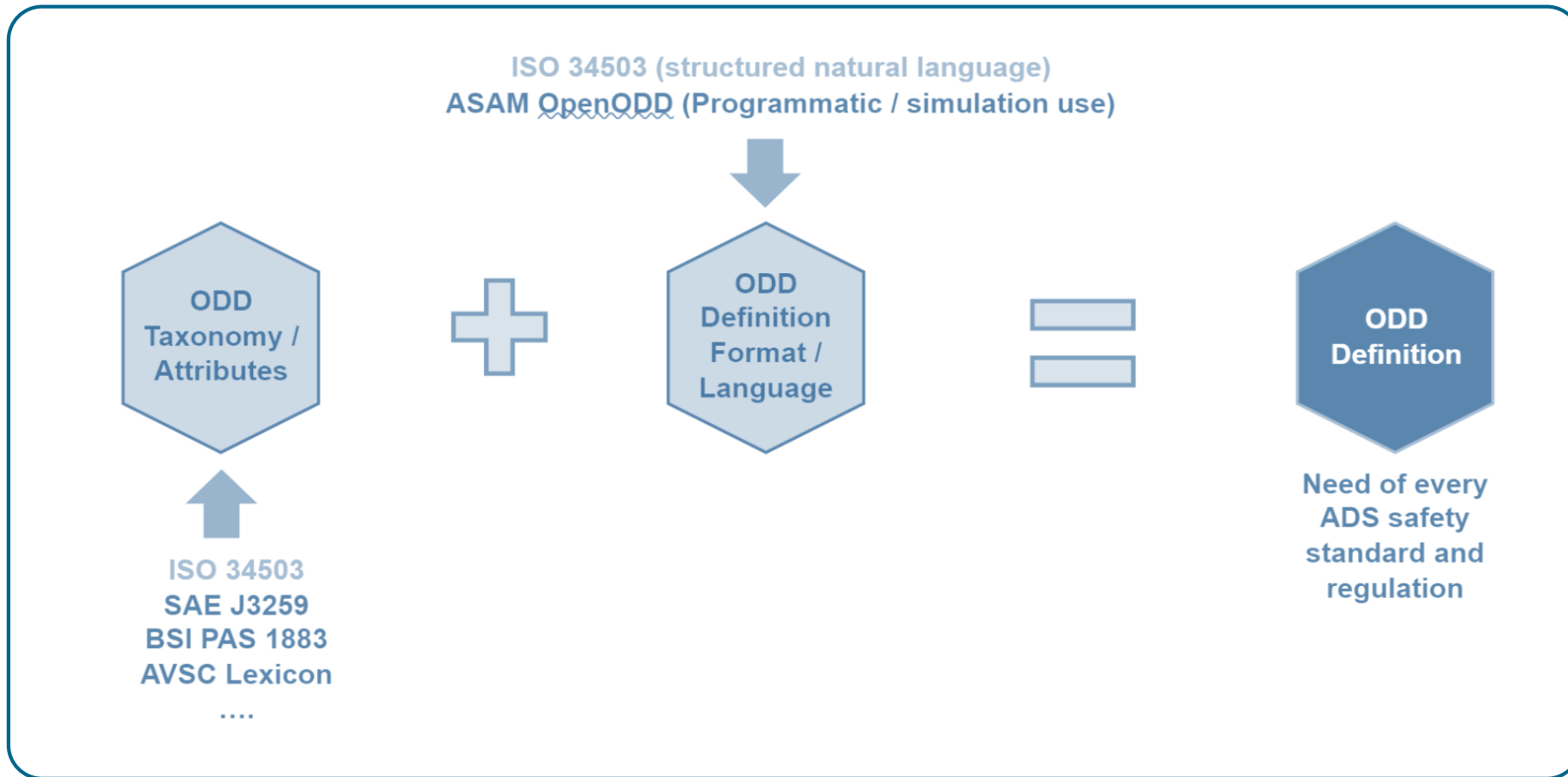Top level taxonomy with ODD attributes. Derived from ISO34503:2023.

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

ISO 34503:2023
Road Vehicles – Test scenarios for automated driving systems – Specification for operational design domain

ISO 34503 (structured natural language)
ASAM OpenODD (Programmatic / simulation use)

ODD Taxonomy / Attributes + ODD Definition Format / Language = ODD Definition

ISO 34503
SAE J3259
BSI PAS 1883
AVSC Lexicon
....

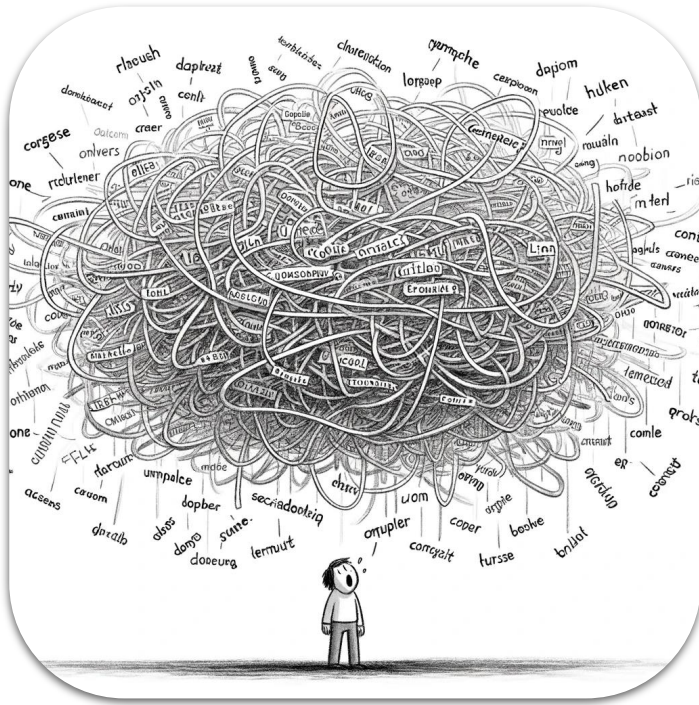Need of every ADS safety standard and regulation

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

Challenges can delay standardization and research

Ali Shakeri, German Aerospace Center (DLR), April 2024

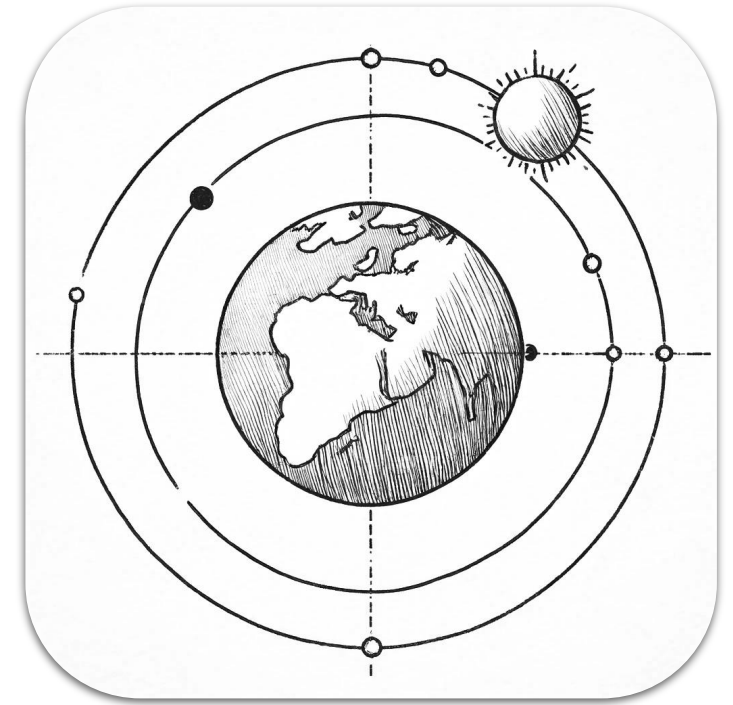**Misinterpretation, Misconception, Proliferation of Terms**

Proliferation of terms

- Increased complexity

Misinterpretation

- Misunderstanding and miscommunication

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 […]
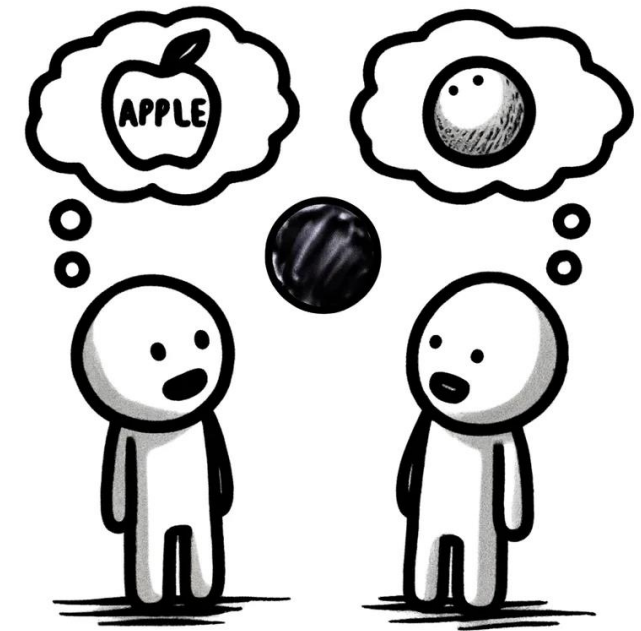
Misconception

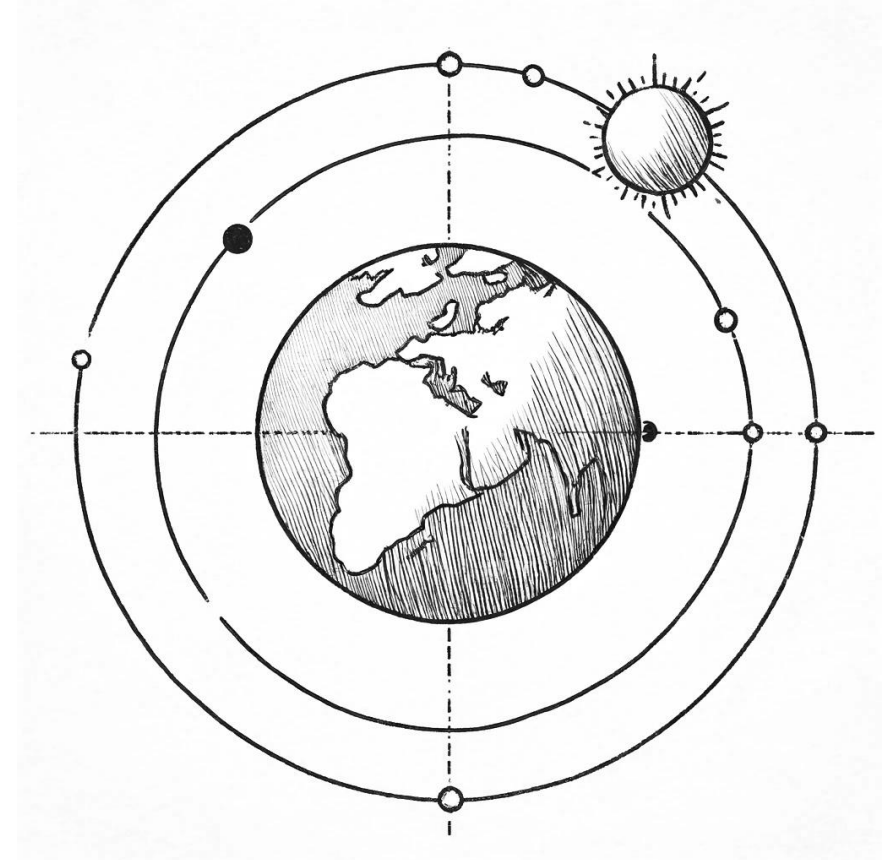## Defining OD as an aggregate of CODs

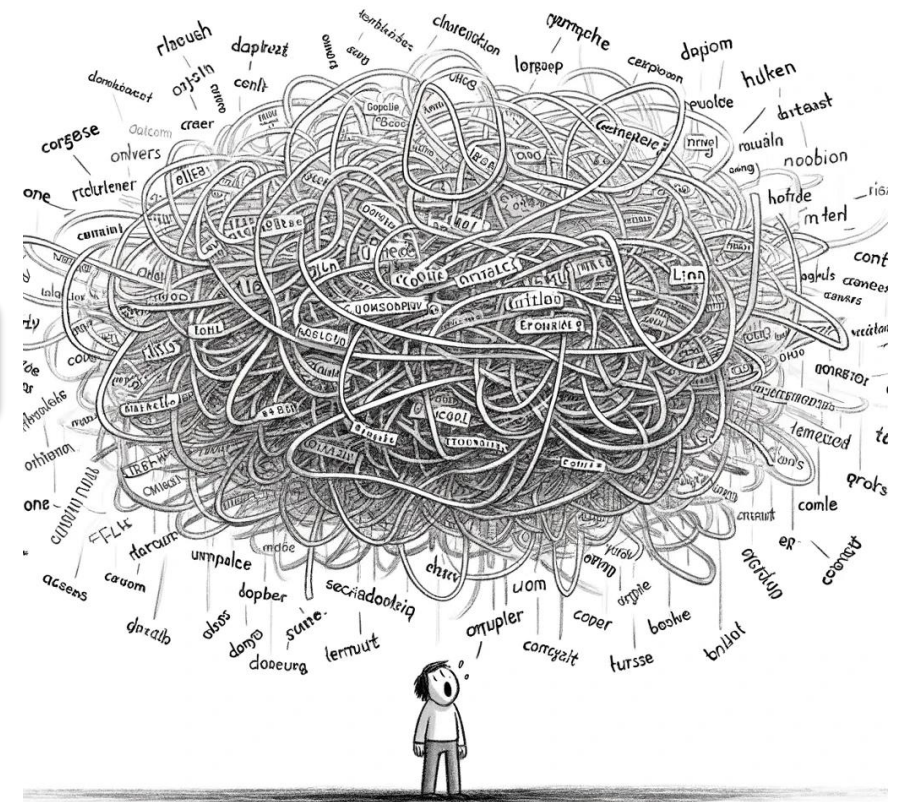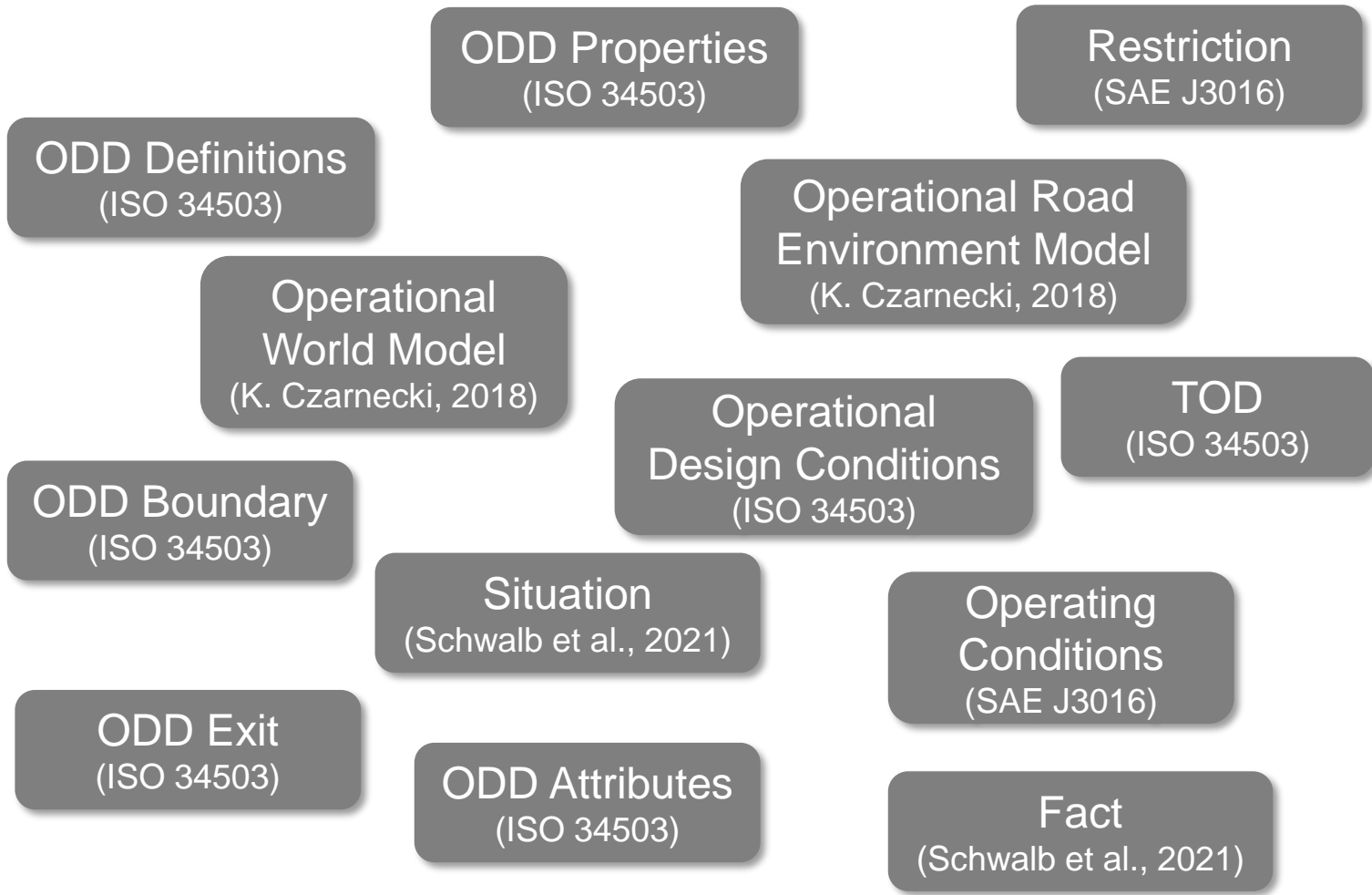This way only knowns are included in OD. What about unknowns?

ODD Taxonomy

ODD is a specific property of a vehicle system

Standards, in fact, provide a taxonomy for characterizing the operational domain attributes
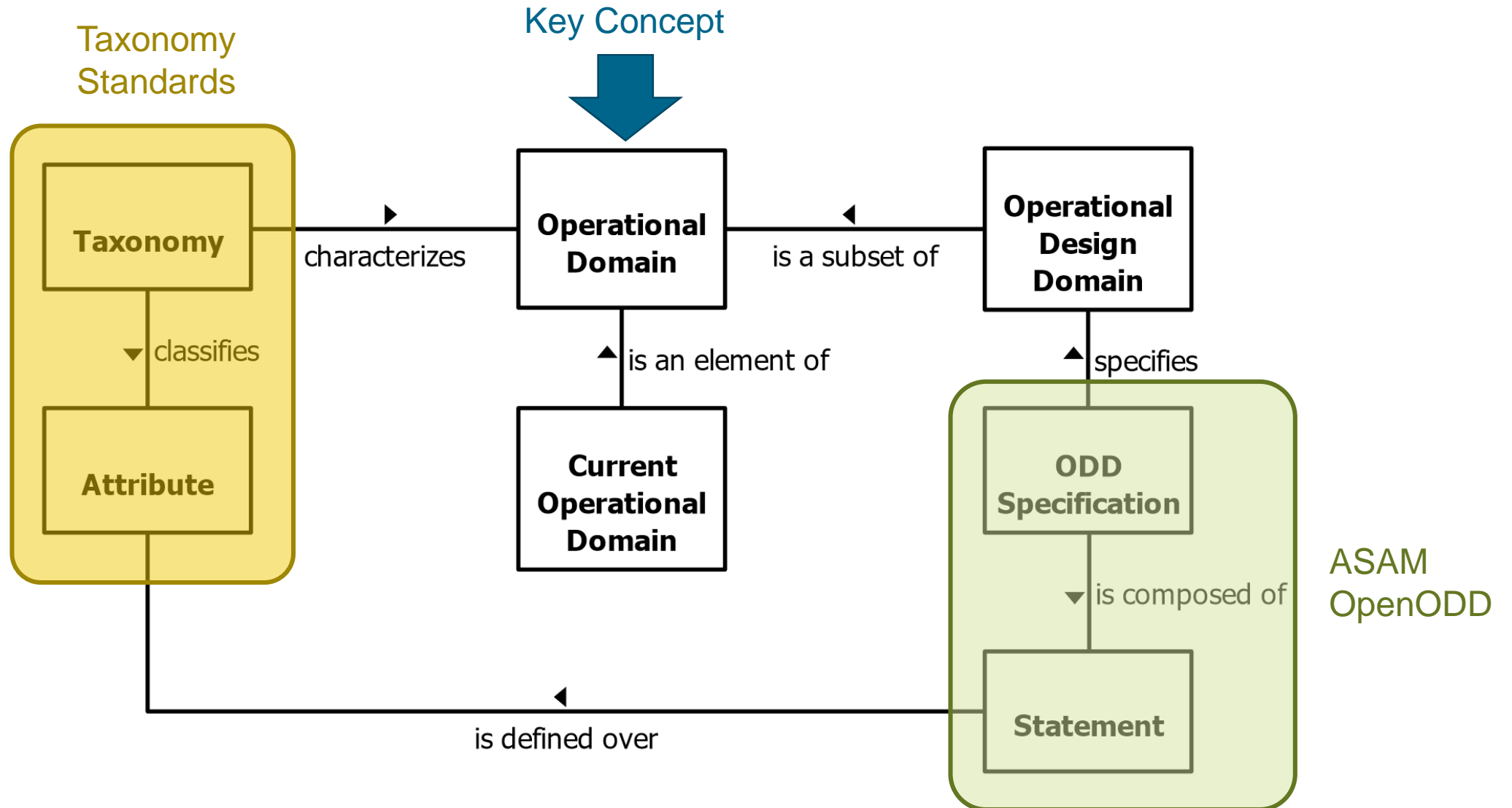
ODD Monitoring

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)

TOD
(ISO 34503)

ODD Boundary
(ISO 34503)

Operational
Design Conditions
(ISO 34503)

Situation
(Schwalb et al., 2021)

Operating
Conditions
(SAE J3016)

ODD Exit
(ISO 34503)

ODD Attributes
(ISO 34503)

Fact
(Schwalb et al., 2021)

Ali Shakeri, DLR, 10th Symposium Driving Simulation

Proposed solution

Taxonomy Standards

Key Concept

Taxonomy → characterizes → Operational Domain

Operational Domain → is a subset of ← Operational Design Domain

Taxonomy → classifies → Attribute

Operational Domain → is an element of ← Current Operational Domain

Operational Design Domain → specifies ← ODD Specification

ODD Specification → is composed of → Statement

Statement → is defined over → Attribute

ASAM OpenODD

Operational Domain
Example

The attribute **road_type**, denoted as R

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

Formalization of Operational Domain and Operational Design Domain for Automated Vehicles

Publisher: IEEE   Cite This   PDF

Ali Shakeri   **All Authors**

The attribute **time_of_day**, denoted as T

$$\mathcal{D}(T) = \{\text{day, night}\}$$

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

$$\text{OD} = \{(\text{motorway, day}), (\text{motorway, night}), (\text{regional, day}),$$
$$(\text{regional, night}), (\text{rural, day}), (\text{rural, night})\}$$

Current Operational Domain in a regional road during day is

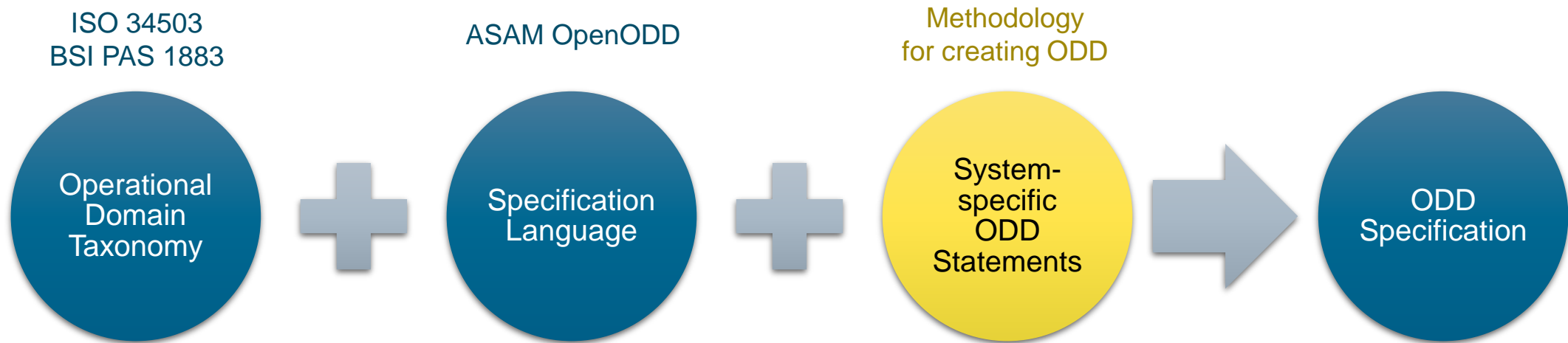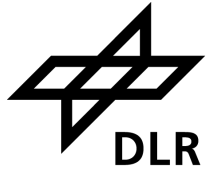$$\text{COD} = (\text{regional, day}) \in \text{OD}$$

Are we done?

Need for a Systematic Methodology

ISO 34503
BSI PAS 1883

ASAM OpenODD

Methodology
for creating ODD

Operational Domain Taxonomy

+

Specification Language

+

System-specific ODD Statements

→

ODD Specification

Problem Statement

- Wide range of parameters affecting functionality of Automated Vehicles
  - Sensor setup affects sensing
  - Operational domain attributes (rain, construction sites, etc.)
  - Regulations need to be considered

- Vast range of operational domain attributes
  - Scenery elements
  - Environmental conditions
  - Traffic conditions

Creating an **ODD specification** through trial and error requires lots of time and effort.

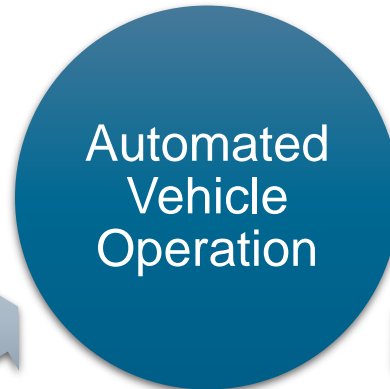There is a need to have a **systematic methodology**.

Our Methodology

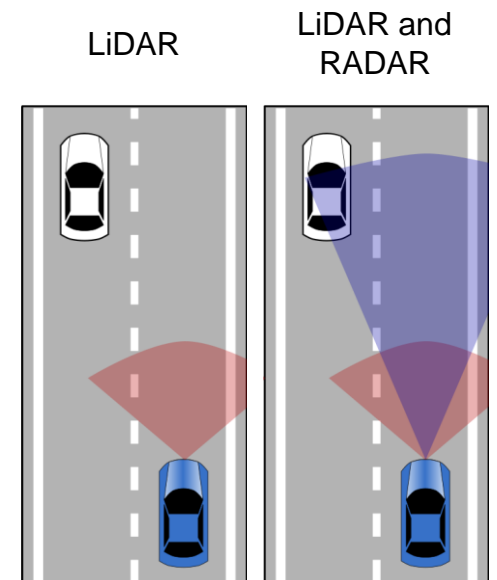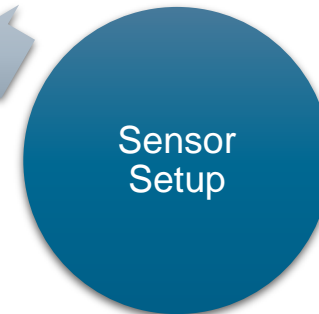# Safe Operation of Automated Vehicles
Important factors

By Ian W. Fieggen - Own work, CC BY-SA 3.0,
https://commons.wikimedia.org/w/index.php?curid=3736092

Operational Domain
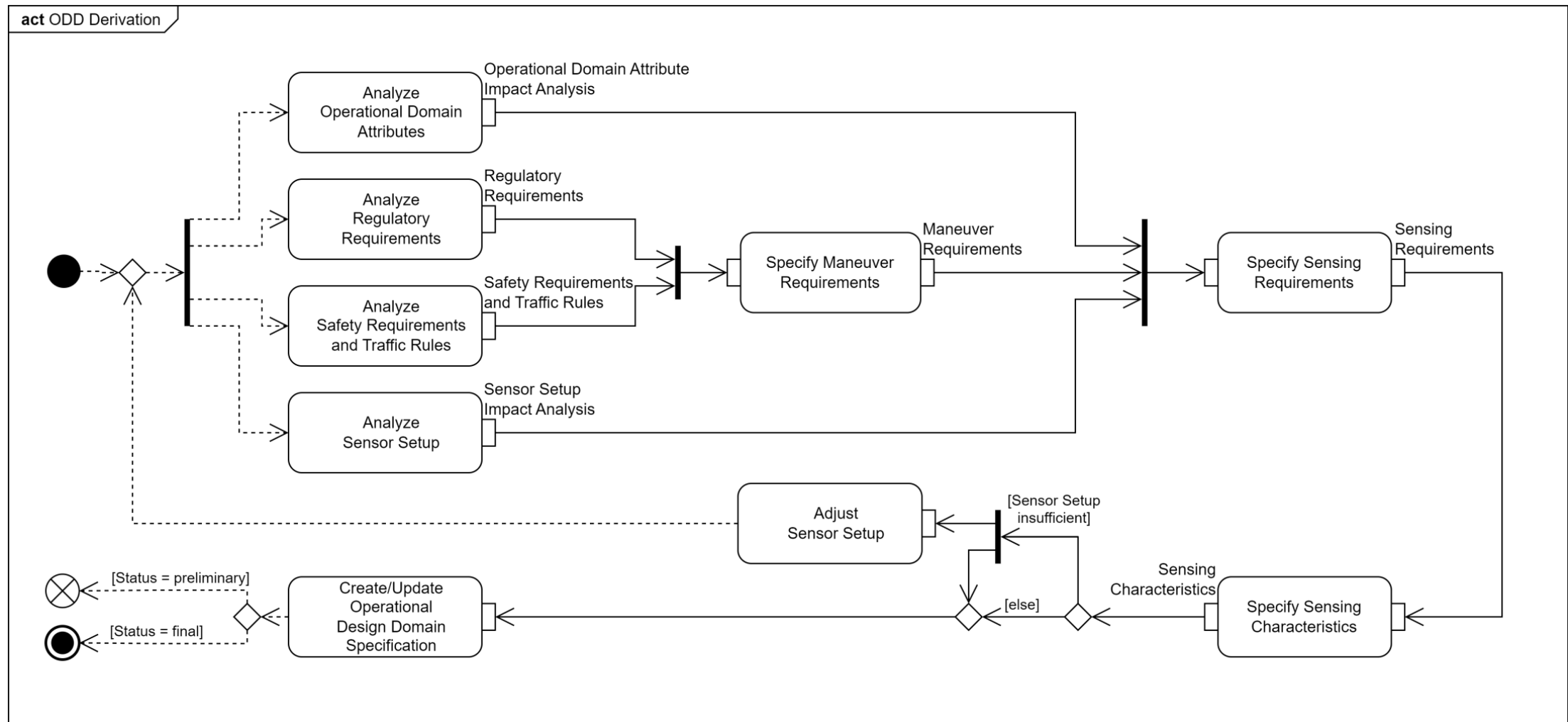
Automated Vehicle Operation

Regulations

Sensor Setup

UNECE No 157
"ALKS can be activated under certain conditions on roads where pedestrians and cyclists are prohibited and …"

LiDAR

LiDAR and RADAR

Systematic creation of an ODD specification

Paragraph 5.2.3.1
"The maximum speed up to which the system is permitted to operate is 130 km/h."

Paragraph 7.1.1
Forward detection range for different speeds is according to a table.

Specified maximum speed / km/h	Minimum forward detection range / m
0…60	46
70	50
80	60
90	75
100	90
110	110
120	130
130	150

Maneuver Requirement
"The forward detection range (FDR) for speed of 130 km/h shall be at least 150 meters."

Sensing Requirement
FDR > 150 m

Analyze OD and Sensor Setup

## We need to analyze how various factors affecting Sensing Characteristics

How operational domain attributes affects sensing characteristics?

Environmental Conditions	Sensing Characteristics			
	Range	Accuracy	Sensitivity	Response Time
Fog	[14], [15]	[16]	-	-
Rain	[14], [15], [17]	[17]	[18], [19]	-
Temperature	-	-	-	-
Lighting	[17], [20]	[17], [20]	[21]	[21]

For references, see: F. Eichenseer et.al. „*A Systematic Methodology for Specifying the Operational Design Domain of Automated Vehicles*"
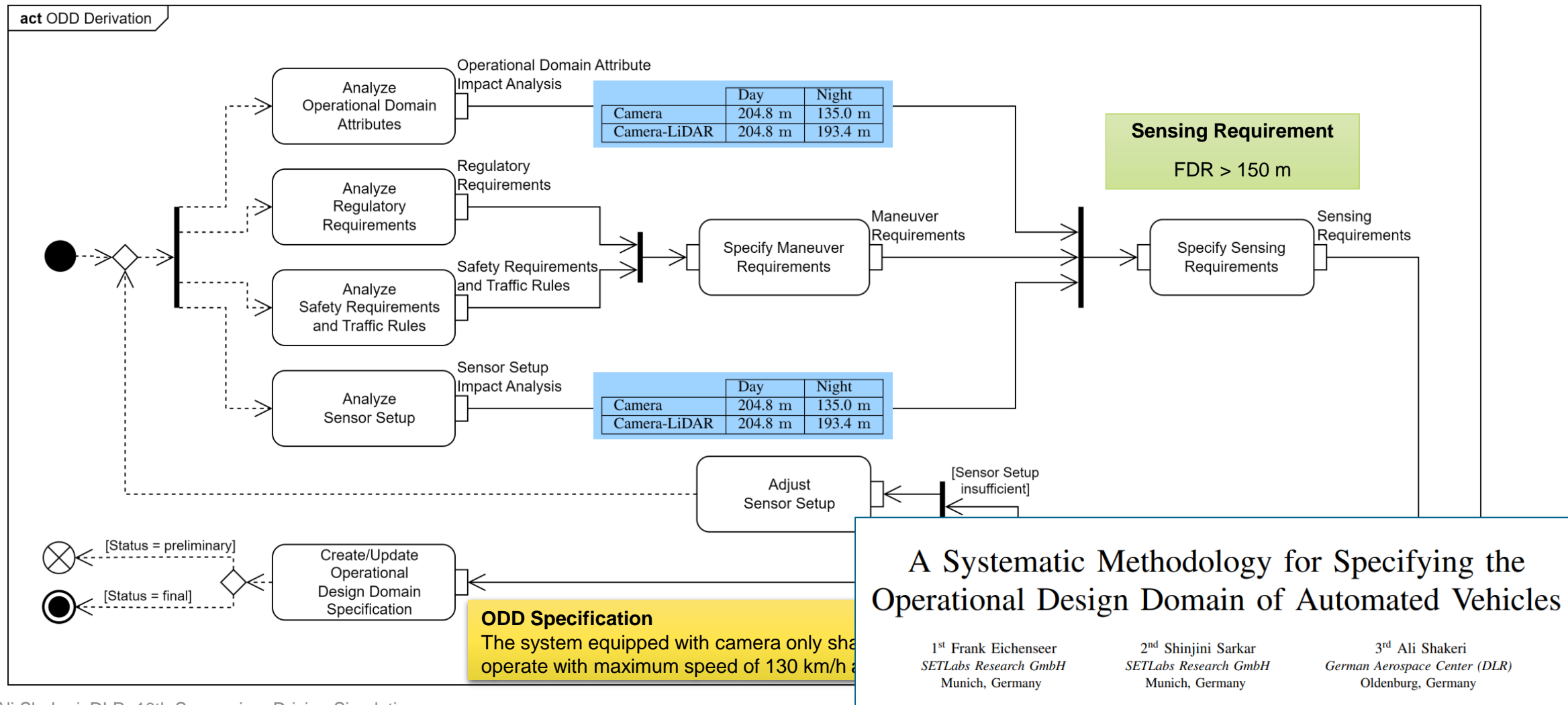
How sensor setup affects sensing characteristic range?

	Day	Night
Camera	204.8 m	135.0 m
Camera-LiDAR	204.8 m	193.4 m
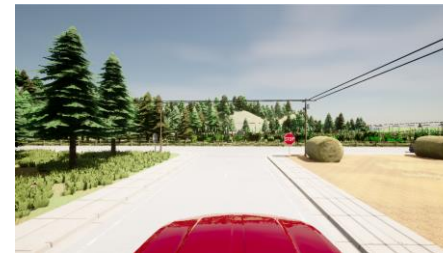
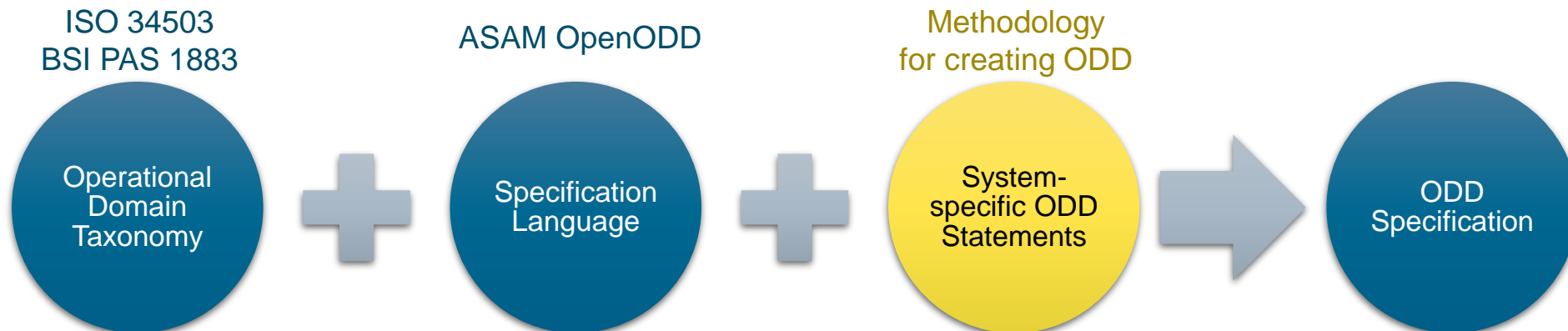## Systematic creation of an ODD specification

Summary

- Brief review of ODD standards and state of the art

- Problems slow down the development

  - Formalization as a foundation for development of ODD-related concepts and methodologies

- Methodology for creating ODD specifications

  - Narrows the focus to a relevant subspace of the operational domain

  - Reduces cost and effort in the development cycle

ISO 34503
BSI PAS 1883

Operational Domain Taxonomy

ASAM OpenODD

Specification Language

Methodology
for creating ODD

System-specific ODD Statements

ODD Specification

Imprint

Topic: Defining Operational Domain and Specifying Operational Design Domains: Current Practices, Standards, and a Systematic Approach

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