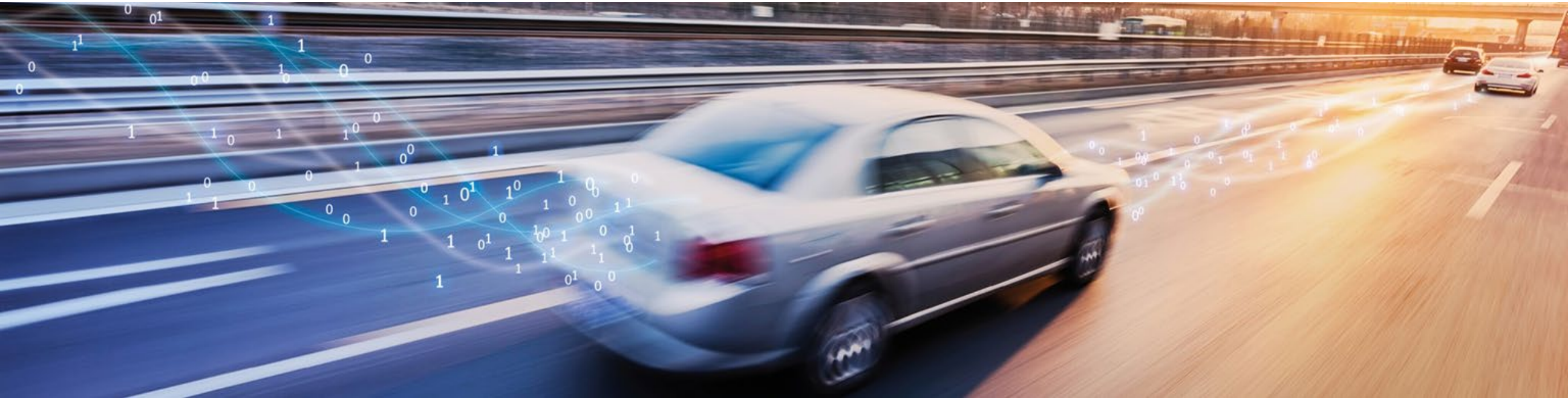
ASAM OpenODD Project:
The world of OD, COD, ODD and more

Dr Edward Schwalb
ASAM US Regional Meeting
26 October 2022



ASAM Association for Standardization of Automation and Measuring Systems

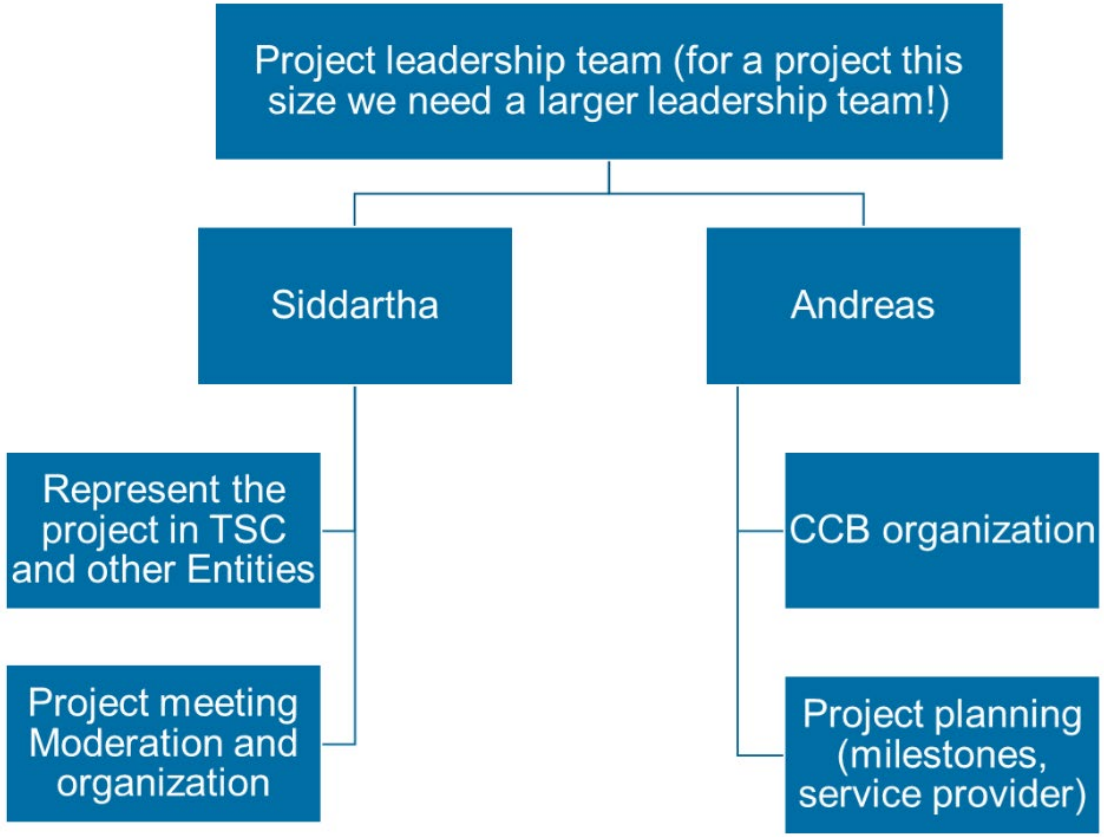
Project Organization

- Concept Paper developed during 2020-2021
- Project Kickoff during summer 2022

- Project Co-Leads
  - Siddartha Khastgir (WMG, University of Warwick, UK
  - Andreas Richter (Volkswagen)

- **33 active organisations**

  (eligible to vote – ASAM members)



Project Status

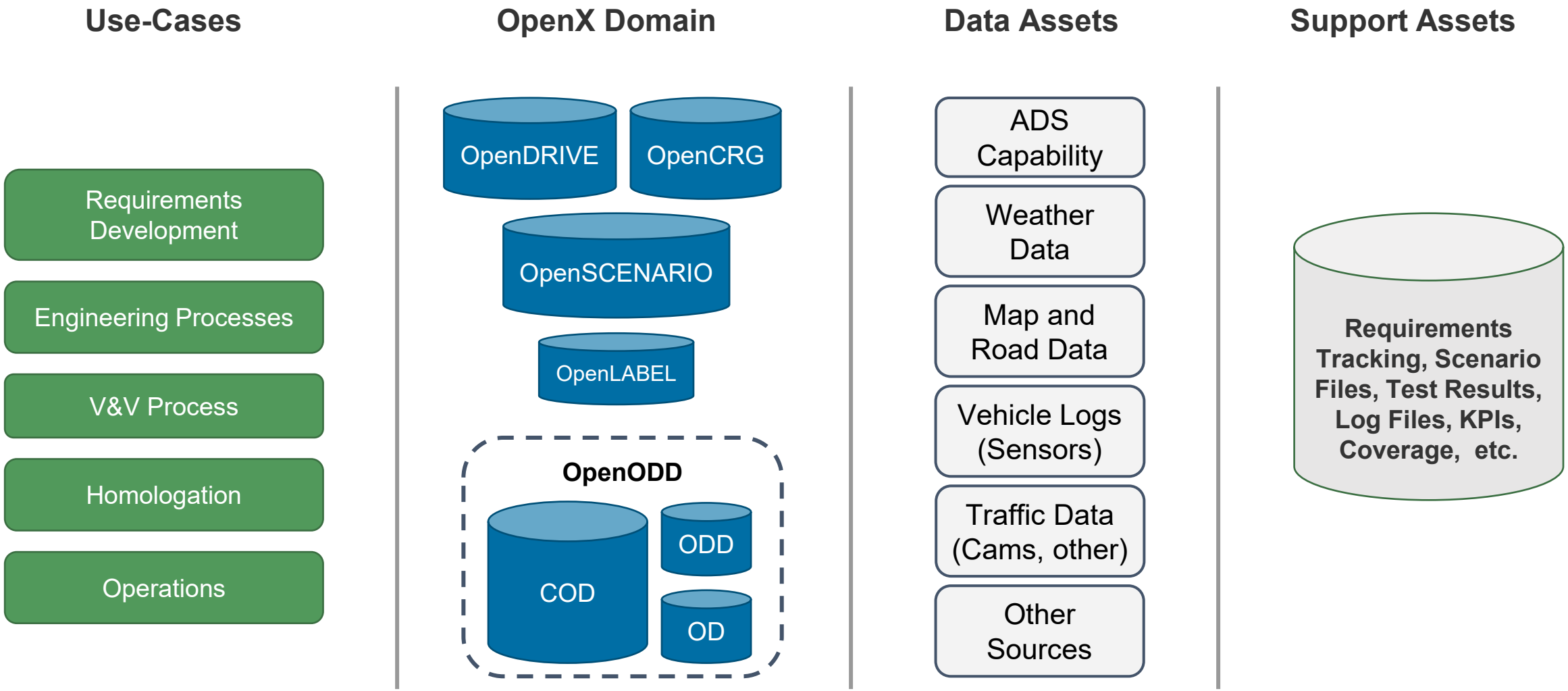
- **Concept Paper completed last year**
- **Project officially kicked off**
  - Conducted 4 Knowledge sharing virtual sessions
  - Conducted 6 QnA virtual sessions
  - Conducted one face to face meeting
  - **Upcoming 2-4 Nov Face 2 Face meeting: WMG @ Coventry, UK**
- TBD: Scope, Syntax, Data, Format
- **33 active organisations (eligible to vote ASAM members)**

Face 2 Face meeting 17-18 Oct: Bosch @ Stuttgart

OpenODD Family …

Note: Some important decision took place in the “Wichtel House”.

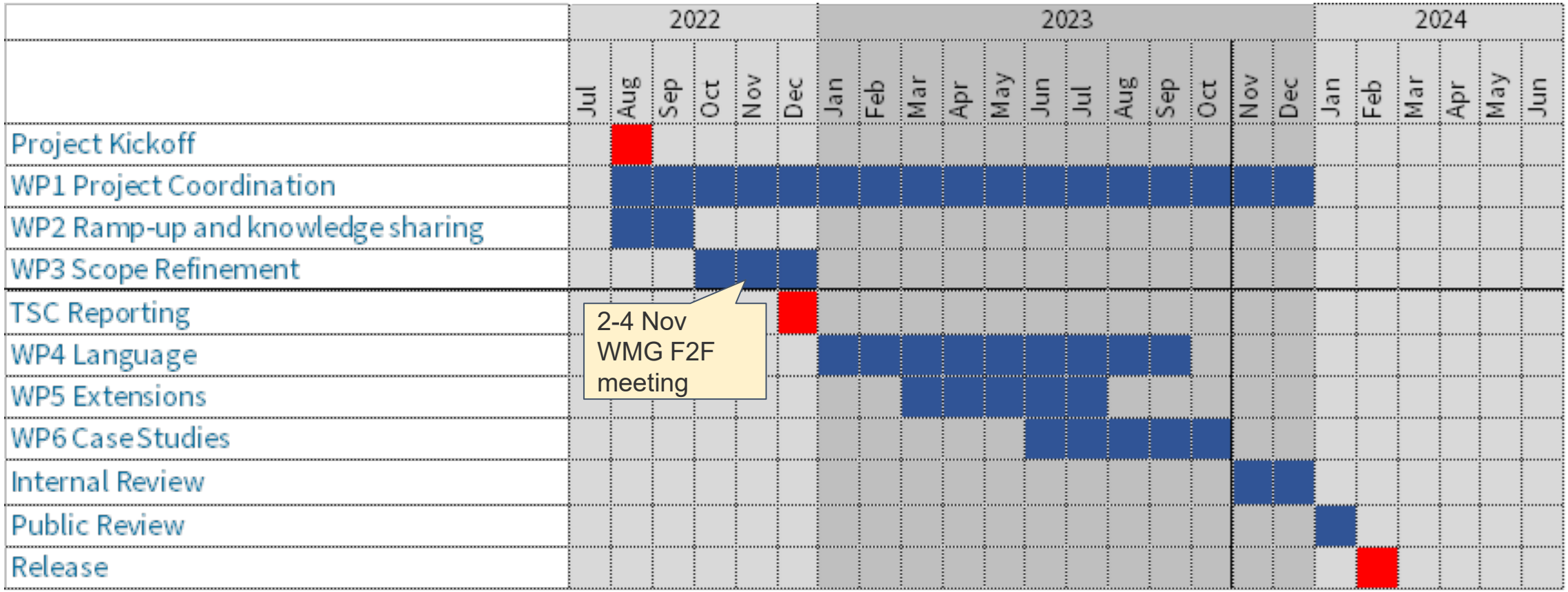
OpenODD in context of OpenX domain



Note: The scope for OpenODD is still to be decided.

Planned Timeline

Progress depends on active contribution of participants accompanied continuous consensus alignment



What is the Operational Domain (OD)?

What is an ODD?

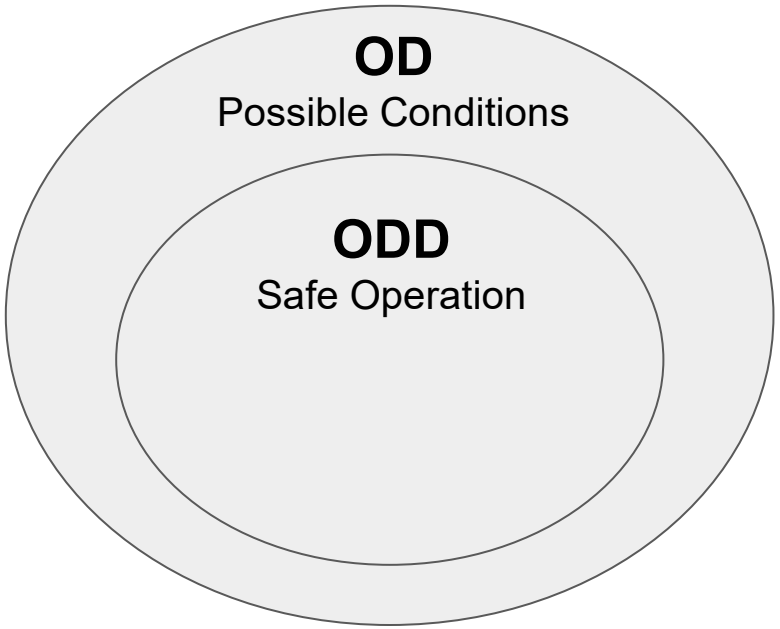
"Operating conditions under which a given driving automation system or feature thereof is specifically designed to function, including, but not limited to, environmental, geographical, and time-of-day restrictions, and/or the requisite presence or absence of certain traffic or roadway characteristics."

- SAE J3016 (2021)

Operational Domain (OD)
What is it?

What are conditions that the ADS is expected to experience?

Which subset admits safe ADS operation?

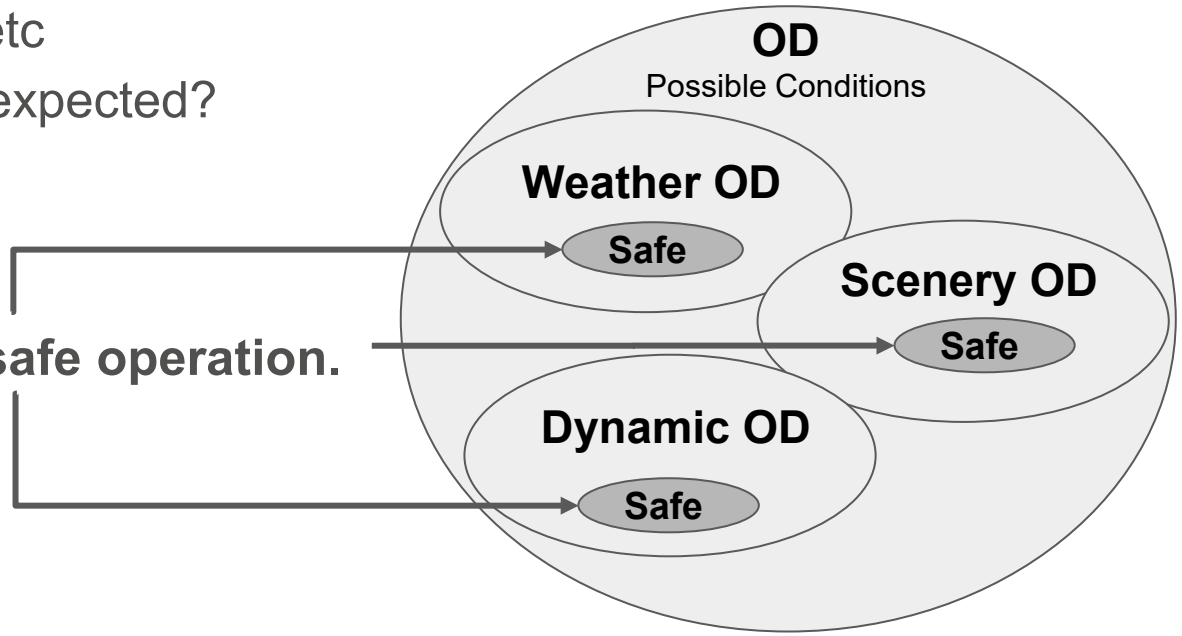


Operational Domain (OD)
What is it?

What circumstances is the ADS expected to experience?

- Weather: Temperature, Rain, Snow, Visibility, etc.
- Scenery: Roads, Intersections, Infrastructure
- Traffic: Vehicles, VRUs, etc
- Which combinations are expected?

ODD is subset which admits **safe operation.**



How to build the ODD?

From Knowledge Transfer Discussion
What do we need to specify?

Specify the **OD subset** in which the ADS can **operate safely**.

- Classify the **Current OD as "in" or "out"**

Formal rules:

- Specify either Inclusion or Exclusion rules
  - A form of "if-then" rules.
  - When do we **include** / **suitable** or **exclude / unsuitable**?

- Pending discussion on the need and how to support
  - complex combination of rules
  - modularity of rules

Note: The language syntax for OpenODD is still to be decided.

From 2022 Knowledge Transfer Discussion
Summary of Proposals

What do we need?

- **Simple** rules
- **Combine** them
- **Interpret** them

Need to discuss

- Uniform **interpretation**
- Possible **solutions**

EXAMPLE

2020 - 2021 Concept

```
permissive_odd: ODD:
    keep(road_topology.lane_dimensions in [3..5]m)
    keep(road_topology.number_of_lanes in [1..2])
    keep(speed < 50 kph)

myODD(
  MODE: 'permissive';
  SUITABLE laneDimensions WHEN {min: 3.0, max: 5.0};
  SUITABLE numberOfLanes WHEN {min: 1.0, max: 2.0};
);
```

2022 Proposals

INCLUDE:

```
road_type:
    - town_local
    - town_expressway
    - motorway
lane_dimensions: [3..5]m
number_of_lanes: [1..2]
speed: < 50 kph
```

EXCLUDE:

```
wind_speed > 100kph
dynamic_zone:
  - street_market
  - mobile_work_zone
  - flooded_street
```

Further simplification was proposed by VW **accommodates all 3!**

Note: The language syntax for OpenODD is still to be decided.

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Proposal by VW for Simplified Approach
Example for **Module Specification**

- **Modularity is required to support engineering organizations**
- A simple format that everyone can understand
- **Can export all proposed tool formats**, generate natural language, and more …

	A	B	C	D	E	F	G	H	I
1	effective_time	export_file	Module_name	Operator	Attribute_affiliation	Attribute_name	Attribute_value	Attribute_valuetype	Attribute_unit
2		highway.yml	HW-g	include	VWG_v10	Road_type	Motorway	string	N/A
3		highway.yml	HW-g	include	VWG_v10	Lane_width	wide_lane	string	N/A
4		highway.yml	HW-g	include	VWG_v10	Lane_width	extra_wide_lane	string	N/A
5		highway.yml	HW-g	include	VWG_v10	is_mixed_use_with_vehicles	true	boolean	N/A
6		highway.yml	HW-g	include	VWG_v10	is_mixed_use_with_vunerab	false	boolean	N/A
7				…					
8		highway.yml	HW-g	exclude	VWG_v10	Road_type	Trunk	string	N/A
9		highway.yml	HW-g	exclude	VWG_v10	Lane_width	narrow_lane	string	N/A
10				…					
11		highway.yml	HW-g	label			true		
12		highway.yml	HW-g	reference			this is dreas' fam		
13			…						
14		highway_germa	HW-DE	include		general highways	true		
15		highway_germa	HW-DE	include	VWG_v10	total_road_width	<= 43.5		
16		highway_germa	HW-DE	include	VWG_v10	crossfall_max_roll_angle	<= 4.57		
17				…					
18		highway_germa	HW-DE	exclude	VWG_v10	min_radius			
19				…					
20		highway_germa	HW-DE	label		general highwa			
21		highway_germa	HW-DE	reference		country	Germany		
22			…						
23		driving.yml	LHD	include	VWG_v10	lane_direction_of_travel	left_hand_travel		
24		driving.yml	LHD	exclude	VWG_v10	lane_direction_of_travel	right_hand_travel		
25			…						
26		driving.yml	RHD	include	VWG_v10	lane_direction_of_travel	right_hand_travel		
27		driving.yml	RHD	exclude	VWG_v10	lane_direction_of_travel	left_hand_travel		
28			…						

Everyone can understand

export

Accommodates all these formats

2020 - 2021 Concept

```
permissive_odd: ODD:
    keep(road_topology.lane_dimensions in [3..5]m)
    keep(road_topology.number_of_lanes in [1..2])
    keep(speed < 50 kph)

myODD(
  MODE: 'permissive';
  SUITABLE laneDimensions WHEN {min: 3.0, max: 5.0};
  SUITABLE numberOfLanes WHEN {min: 1.0, max: 2.0};
);
```

2022 Proposals

```
INCLUDE:                    EXCLUDE:
  road_type:                  wind_speed > 100kph
    - town_local              dynamic_zone:
    - town_expressway           - street_market
    - motorway                  - mobile_work_zone
  lane_dimensions: [3..5]m      - flooded_street
  number_of_lanes: [1..2]
  speed: < 50 kph
```

Note: The syntax and data requirements for OpenODD are still to be decided.

From 2022 Knowledge Transfer Discussion
Example Simplified Interpretation

Proposed simplified interpretation
(with one language candidate):

```
INCLUDE:
   road_type = ”town”

EXCLUDE:
   wind_speed > 100kph
```

COD data

```
- id: CurrentOD1
  road_type: town

- id: CurrentOD2
  road_type: town expressway

- id: CurrentOD3
  wind_speed: 20kph

- id: CurrentOD4
  wind_speed: 120kph
```

In ODD

Not in ODD

In ODD

Not in ODD

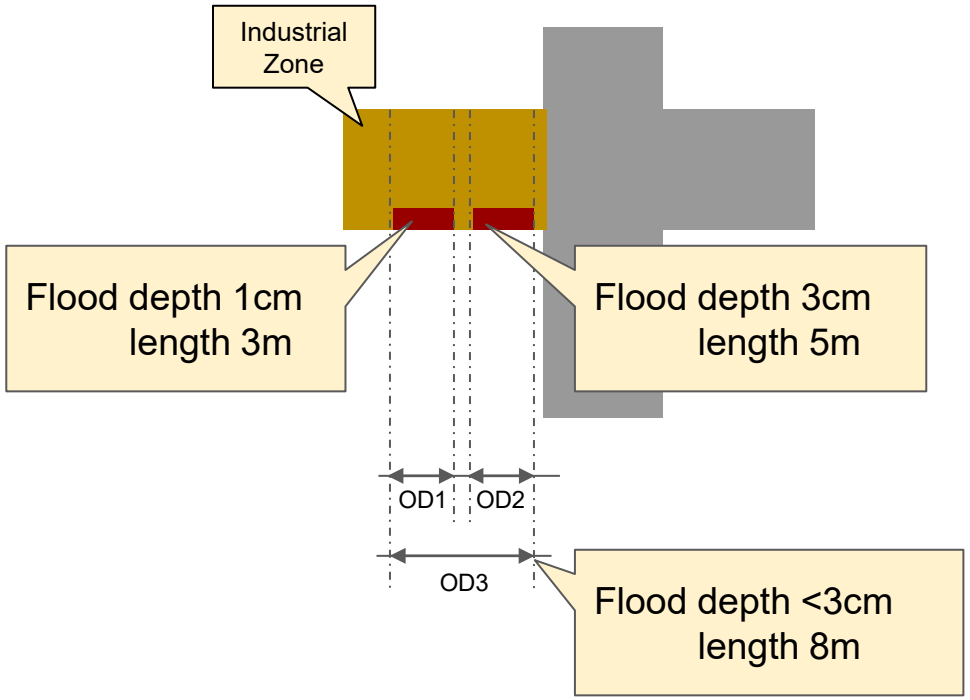
Note: The language syntax for OpenODD is still to be decided.

What about Measures?

From 2022 Knowledge Transfer Discussion
Specification of Measures

Proposal: ***Integrate Measures into Taxonomy***

```
INCLUDE floodings.depth: < 3cm
INCLUDE floodings.length: < 10m
```



Note: The language syntax for OpenODD is still to be decided.

From 2022 Knowledge Transfer Discussion
Specification of Measures

Proposal: ***Integrate Measures into Taxonomy***

```
INCLUDE floodings.depth: < 3cm
INCLUDE floodings.length: < 10m
INCLUDE slippery_frost.length: < 30cm
INCLUDE oil_contamination.length: < 30cm
```

OD data

In ODD

```
- id: OD001
  floodings: true
  floodings.depth: [1cm .. 2cm]
  floodings.length: [1m .. 3m]
  slippery_frost: false
  oil_contamination: false
```

Not In ODD

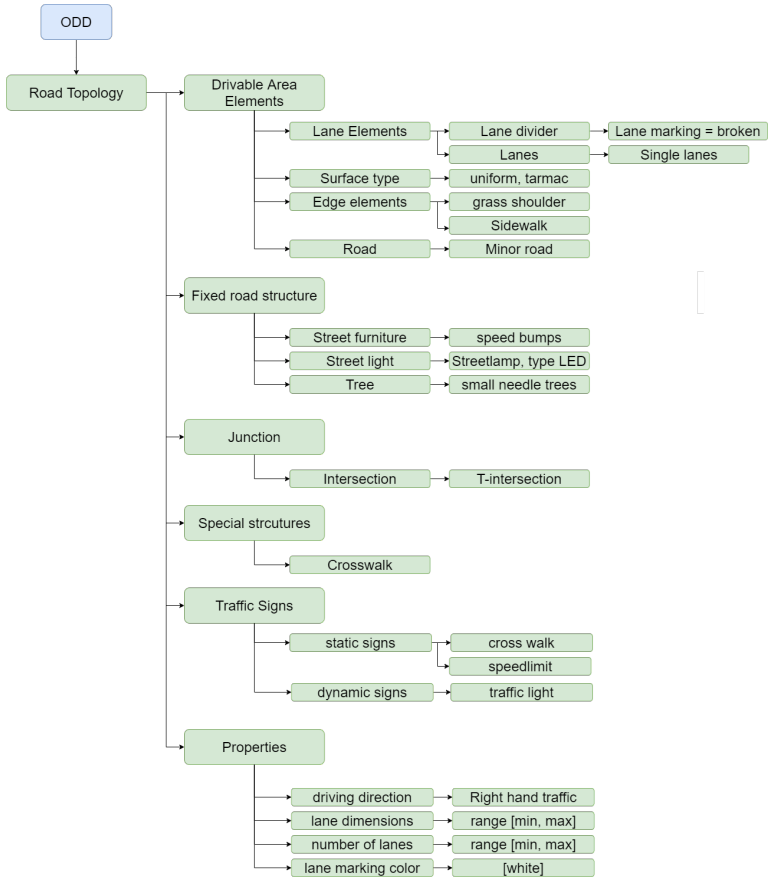
```
- id: OD007
  floodings: true
  floodings.depth: [1cm .. 2cm]
  slippery_frost.length: [20cm .. 40cm]
  oil_contamination: false
```

Note: The language syntax for OpenODD is still to be decided.

Standard Terminology Taxonomy Specifications

ASAM

From 2020-2021 Concept Paper
Taxonomy Hierarchy Example



… but ODD spec format is taxonomy agnostic

Note: The taxonomy format for OpenODD is still to be decided.

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From 2022 Knowledge Transfer Discussion
Refinement contributed by VW

- Each term can be associated with human readable description
- Taxonomies can be combined,
  - either when terms are unique
  - or using name spaces

```
road_type:
  town_road:
    - expressway
    - collector_road
    - arterial_road
```

+

```
road_type:
  town_road:
    - local_road
    - play_street
    - private_road
```

=

```
road_type:
  town_road:
    - expressway
    - collector
    - arterial_road
    - local_road
    - play_street_road
    - private_road
```

- Agreed to support extension of taxonomies via references
- **Taxonomy content specification is not in scope**
  - need to reference, e.g. BSI PAS 1883, in the ODD
  - agreed to require value types and units as applicable

Note: The taxonomy format for OpenODD is still to be decided.

Representing Uncertainty

Need for Modeling Uncertainty
EU Regulation Draft

Rules for the application of Regulation (EU) 2019/2144 of the European Parliament and of the Council as regards uniform procedures and technical specification for the type-approval of the automated driving system (ADS) of fully automated vehicles

7. Functional and operational safety

7.1.1. The manufacturer shall define the acceptance criteria from which the validation targets of the ADS are derived to evaluate the residual risk for the ODD taking into account, where available, existing accident data[1], data on performances from competently and carefully driven manual vehicles and technology state-of-the-art.

[1] For instance based on current accident data on buses, coaches, trucks and cars in the EU, an indicative **aggregated acceptance criteria of 10^{-7} fatalities per hour of operation** could be considered for market introduction of ADSs for comparable transport services and situations. The manufacturer may use other metrics and method provided it can demonstrate that it leads to an absence of unreasonable safety risk when compared with comparable transport services and situations within the operational domain.

Modeling Uncertainty
Introduce Clarify into “fuzzy” Situations

- Multiple Possible Categorical Values

```
rain_intensity_level:
  - light_rain
  - moderate_rain
```

- Multiple Possible Numeric Values

```
floodings.depth: [2..20]cm
```

- Uncertain rate of occurrence

```
pedestrian.occurrence: <10^-7 Hr^-1
```

Note: The language syntax for OpenODD is still to be decided.

Concept Paper Uncertainty Level of Detail
Occurrence Levels Abbreviation using Qualifiers

Concept paper proposes two options for representing pedestrians' uncertainty:

- Pure True/False approach: Definitions should not contain any uncertainty qualifiers, e.g.:
  INCLUDE: Freeway
  EXCLUDE: Pedestrian
  In ODD when: **Pedestrian=false**

- Qualified True/False: Increasing LOD using qualifiers, similar to refined road types, e.g.
  INCLUDE: Freeway
  EXCLUDE: Pedestrian**@P7** **(i.e. exclude Pedestrian.occurrence > 10^{-7} Hr^{-1})**
  In ODD when: **Pedestrian=false <u>OR P7=true</u>**

Note: The language syntax for OpenODD is still to be decided.

Uncertainty Level of Detail
Stakeholder Dependent

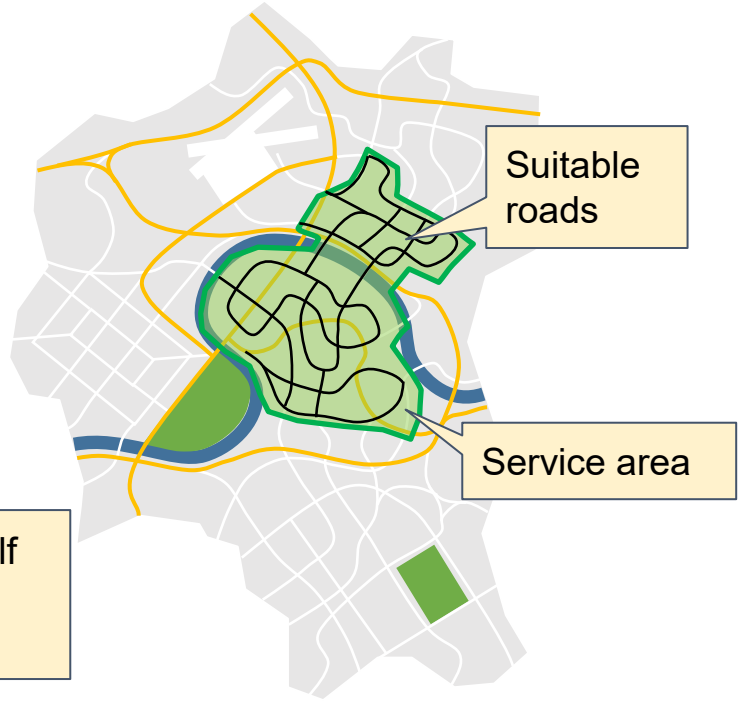
Stakeholders such as engineering, development, safety, testing need detailed descriptions whereas other stakeholders such as public authorities need very coarse level of detail (explaining the service area)

```
INCLUDE:
        road_type:
          - motorway
          - town_expressway
  EXCLUDE:
        restricted_lane:
          - tidal_lane
        lane_width:
          - narrow_lane
          - extra_wide_lane
        lane_marking_availability:
          - temporary_available
          - temporary_unavailable
    lane_marking_quality:
          - poor
```

pedestrians.occurrence: $<10^{-7}$ Hr^{-1}
slippery_frost.occurrence: $<10^{-1}$ m^{-1}

Query

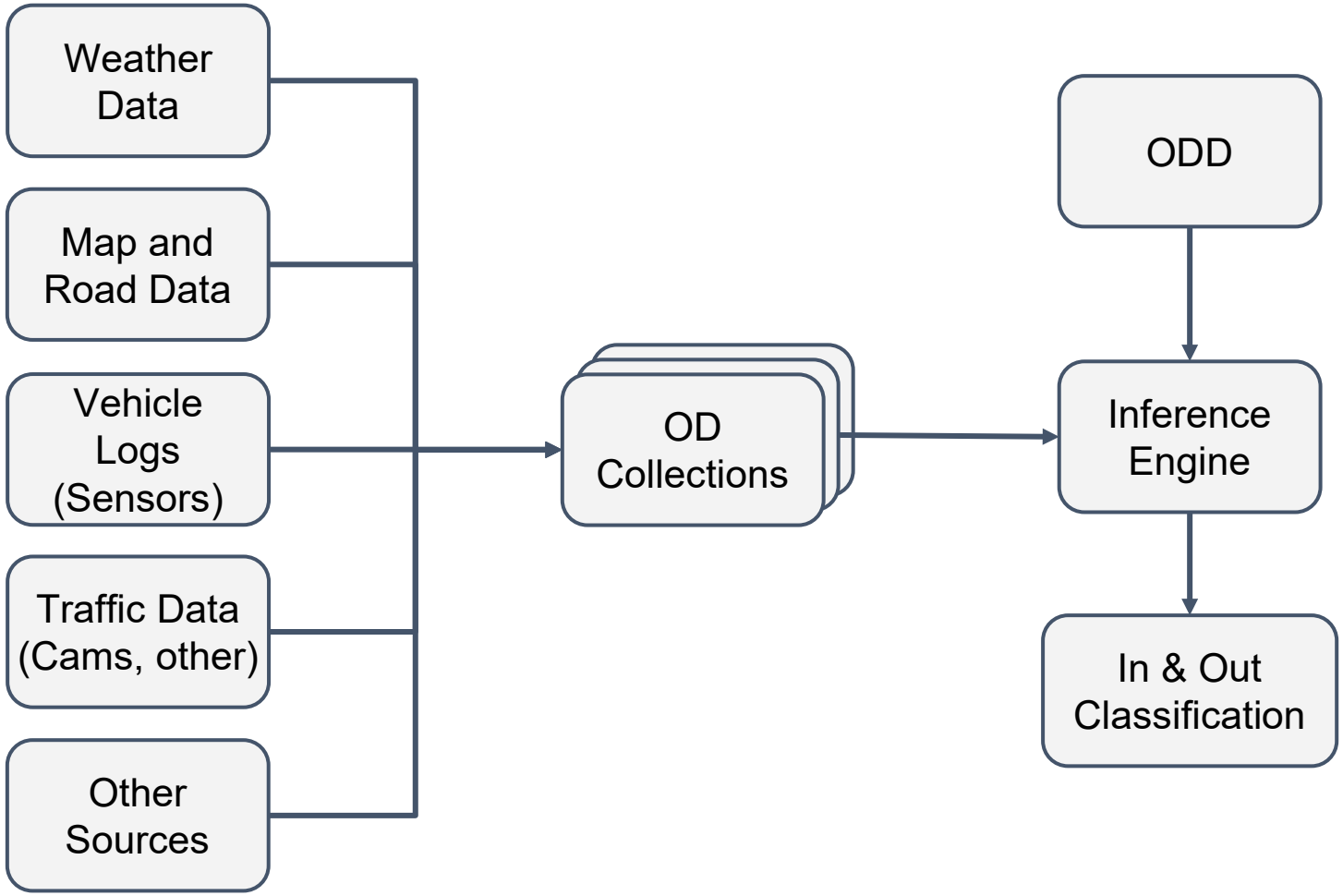
This must not be half of the truth of the detailed definition.



Note: The language syntax for OpenODD is still to be decided.

Data Providers
Which data do we need?

From Knowledge Transfer Session
Information Architecture

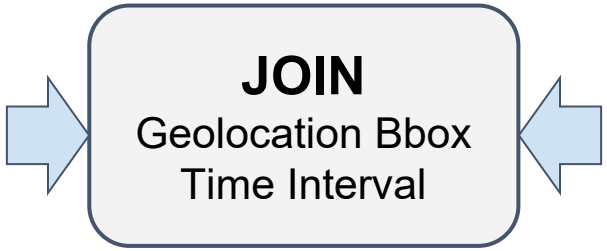


Note: The data requirements and language syntax for OpenODD are still to be decided.

From Knowledge Transfer Session
Combine Data Sources

Map Data

```
- id: OD1_maps
  road_type:
    - town_arterial.length: 504km
    - town_collector.length: 565km
    - town_local.length: 3450km
    - private.length: 44km
    - other.length: 22km
  transverse_plane_type:
    - divided.length: 558km
    - undivided.length: 4027km
  longitudinal_plane:
    - up_slope.max: 4%
    - up_slope.avg: 2%
    - down_slope.max: 4%
    - down_slope.avg: 2%
  lane_width:
    - narrow_lane      # < 2.75 m
    - normal_lane      # 2.75 - 3.25 m
    - wide_lane        # 3.25 - 3.75 m
    - extra_wide_lane # > 3.75 m
```



Weather Data

```
- id: OD1_weather
  fog_severity:
    - severity1 # > 1609 m
    - severity2 # 805 - 1609 m
    - severity3 # 244 - 805 m
  severity1.occurrence: < 10^-1 day^-1
  severity2.occurrence: < 10^-2 day^-1
  severity3.occurrence: < 10^-3 day^-1
  max_humidity: <= 100.0%
  min_humidity: >= 52.0%
  max_operational_ambient_temperature: <= 35.5°C
  min_operational_ambient_temperature: >= -13.1°C
  particulates_intensity: <= 779.44grainspm3
  particulates_size: <= 100.0µm
  rain_quantity: <= 38.7mmph
  rain_quantity_level:
      - light_rain    # < 2.5 mmph
      - moderate_rain # 2.5 - 7.6 mmph
      - heavy_rain    # 7.7 - 50 mmph
  snowfall_intensity:
      - light_snow    # > 1 km
      - moderate_snow # 0.5 - 1 km
      - heavy_snow    # < 0.5 km
  sun_intensity: <= 885.9Wpm2
  wind_force_level:
      - force00 # < 1 kph
      - force01 # 1 - 5 kph
      - force02 # 2 - 11 kph
      - force03 # 12 - 19 kph
      - force04 # 28 - 28 kph
      - force05 # 29 - 38 kph
  wind_speed: <= 35.12kph
```

Note: The data requirements and language syntax for OpenODD are still to be decided.

From Knowledge Transfer Session
Example Data Contributed by VW

```
- id: CurrentOD1
  fixed_zone:
    - work_zone
    - industrial_zone
  road_type: town_expressway
  dynamic_zone: flooded_street
  rain_quantity_level:
    - light_rain
    - moderate_rain
  freezing_rain: true
  wind_speed: 80kph
  ambient_temperature: 24.2degC
  motorway.length: 170m
  work_zone.length: 60m
  industrial_zone.length: 170m
  mixed_use_zone.length: 90m
  tourist_zone.length: 90m
  spatial_start: 53.579254,10.0246383
  spatial_end:   53.579255,10.0246384
  start_time: 20220410T153012
  end_time:   20220410T203107
```

Categorical Data

Data requirements are specified in terms of a list of fields

Note: The data requirements and language syntax for OpenODD are still to be decided.

From Knowledge Transfer Session
Example Data Contributed by VW

```
- id: CurrentOD1
  fixed_zone:
    - work_zone
    - industrial_zone
  road_type: town_expressway
  dynamic_zone: flooded_street
  rain_quantity_level:
    - light_rain
    - moderate_rain
  freezing_rain: true
  wind_speed: 80kph
  ambient_temperature: 24.2degC
  motorway.length: 170m
  work_zone.length: 60m
  industrial_zone.length: 170m
  mixed_use_zone.length: 90m
  tourist_zone.length: 90m
  spatial_start: 53.579254,10.0246383
  spatial_end:   53.579255,10.0246384
  start_time: 20220410T153012
  end_time:   20220410T203107
```

Numerical Data

Data requirements are specified in terms of a list of fields

Note: The data requirements and language syntax for OpenODD are still to be decided.

From Knowledge Transfer Session
Example Data Contributed by VW

```
- id: CurrentOD1
  fixed_zone:
    - work_zone
    - industrial_zone
  road_type: town_expressway
  dynamic_zone: flooded_street
  rain_quantity_level:
    - light_rain
    - moderate_rain
  freezing_rain: true
  wind_speed: 80kph
  ambient_temperature: 24.2degC
  motorway.length: 170m
  work_zone.length: 60m
  industrial_zone.length: 170m
  mixed_use_zone.length: 90m
  tourist_zone.length: 90m
  spatial_start: 53.579254,10.0246383
  spatial_end:   53.579255,10.0246384
  start_time: 20220410T153012
  end_time:   20220410T203107
```

Aggregate Data

Data requirements are specified in terms of a list of fields

Note: The data requirements and language syntax for OpenODD are still to be decided.

From Knowledge Transfer Session
Example Data Contributed by VW

```
- id: CurrentOD1
  fixed_zone:
    - work_zone
    - industrial_zone
  road_type: town_expressway
  dynamic_zone: flooded_street
  rain_quantity_level:
    - light_rain
    - moderate_rain
  freezing_rain: true
  wind_speed: 80kph
  ambient_temperature: 24.2degC
  motorway.length: 170m
  work_zone.length: 60m
  industrial_zone.length: 170m
  mixed_use_zone.length: 90m
  tourist_zone.length: 90m
  spatial_start: 53.579254,10.0246383
  spatial_end:   53.579255,10.0246384
  start_time: 20220410T153012
  end_time:   20220410T203107
```

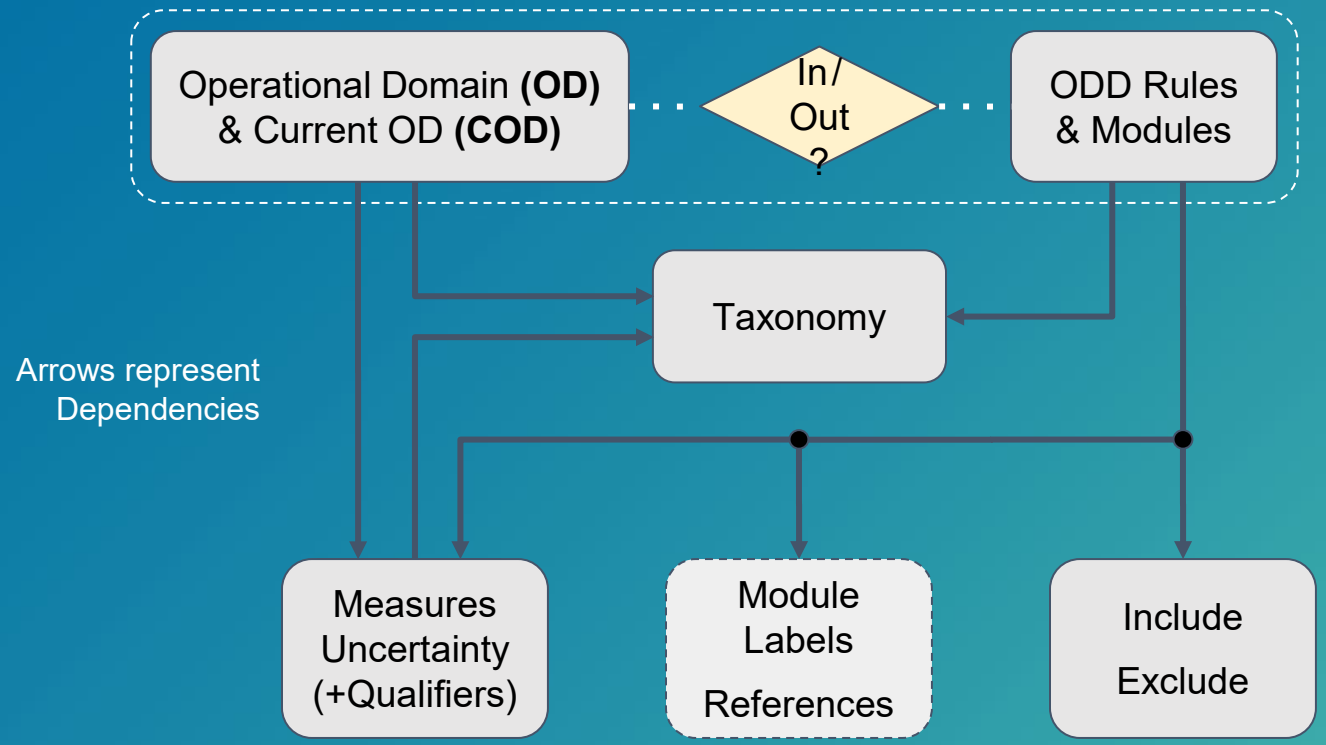
Extent Data

Data requirements are specified in terms of a list of fields

Note: The data requirements and language syntax for OpenODD are still to be decided.

Implied Relevant Components

Source: Edward Schwalb, Ph.D; not officially approved



Note: The scope for OpenODD is still to be decided.

ASAM

Questions…

Discussion.