Traffic Management for Connected and Automated Driving (TM4CAD)

Vehicle Manufacturers Perspective Workshop

Tom Alkim, Strategic Advisor Connected & Automated Mobility – MAPtm

10 June 2022, Aachen

Agenda

08:30	Walk in coffee	
09:00	Welcome, introduction to TM4CAD and research questions	Jaap Vreeswijk + Tom Alkim
09:15	Basic concepts and terminology associated with ODD definition + Distributed ODD Awareness (DOA) framework	Siddartha Khastgir
09:40	Interactive part 1: *how do OEMs understand the DOA framework?*	Sven Maerivoet
10:40	*30-min coffee break*	
11:10	What kind of roadside or other road operator information do automated driving systems likely need?	Luisa Andreone + Aria Etemad
11:40	Prioritisation of information needs	Risto Kulmala
12:00	Interactive part 2: *what information types and attributes should be prioritized for supporting automated driving and what role can road operators play?*	Risto Kulmala
12:55	Conclusions	Jaap Vreeswijk + Tom Alkim
13:00	Lunch	

Consortium

- MAP traffic management (the Netherlands)
- Traficon (Finland)
- Transport & Mobility Leuven (Belgium)
- WMG, University of Warwick (UK)
- Steve Shladover (US – independent)
- Hironao Kawashima (Japan – Keio University)

Connected, Cooperative & Automated Mobility (CCAM)

CCAM has the potential to make transport:

- Safer: bring down the number of road fatalities and accidents
- Greener: help to reduce harmful emissions from transport by smoothening traffic flow and avoiding unnecessary trips
- More accessible: ensure inclusive mobility access for all

If it's done "right"!

Connected, Cooperative & Automated Mobility (CCAM)

However, a number of challenges have to be addressed:

- Key technologies still being developed (need to be safe, tested, validated)
- The right legal framework has to be set up (adopted at MS and EU-level)
- CAVs will have to be integrated into the broader transport system and interact with other forms of mobility
- Acceptance and trust in CCAM technology and services, by users and society, has to be nurtured every step of the way

About TM4CAD – Expected results

- The project is funded by CEDR Call 2020 Impact of CAD on Safe Smart Roads
- Start: 13 September 2021 | End: 12 March 2023 (18 months)
- 7 workshops and 4 deliverables

- Identify the full range of **ODD attributes** for consideration, based on experience from working on ODD issues in standardization activities and in other related research projects;
- Integrate the very different perspectives of the CAD vehicle system developers and the road authorities and operators to **focus on the areas of intersection** between them;
- Introduce the concept of **ODD attribute awareness** and the role of infrastructure in it;
- Develop recommendations based on understanding the technical constraints on the ODD-relevant **information that can be perceived and exchanged in real time** by the NRAs and the sensing systems on the CAD-equipped vehicles;
- Provide insights on how to support CAD operation and ODD management, and **how ISAD should be refined** for traffic management use, and
- Detail how traffic management systems and CAD vehicles can **best interact** to improve traffic operations.

Traffic Management for CAVs

- To what extent is Traffic Management different for CAVs?
- Sending information to humans driving vehicles or vehicles being driven by software requires a different approach
- How is information being interpreted? What level of context awareness?
- Mixed traffic conditions add complexity
- Define appropriate driving behaviour and response of CAVs
- Related to specific Operational Design Domains (ODD)

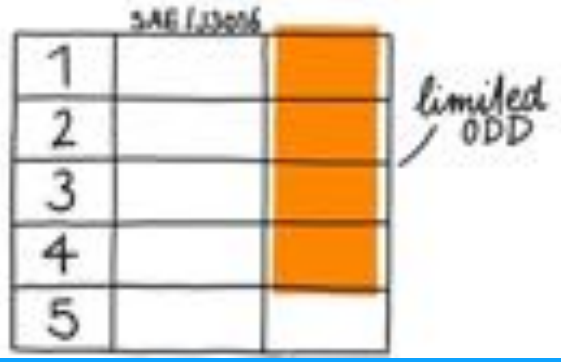
Operational Design Domain (ODD) framework

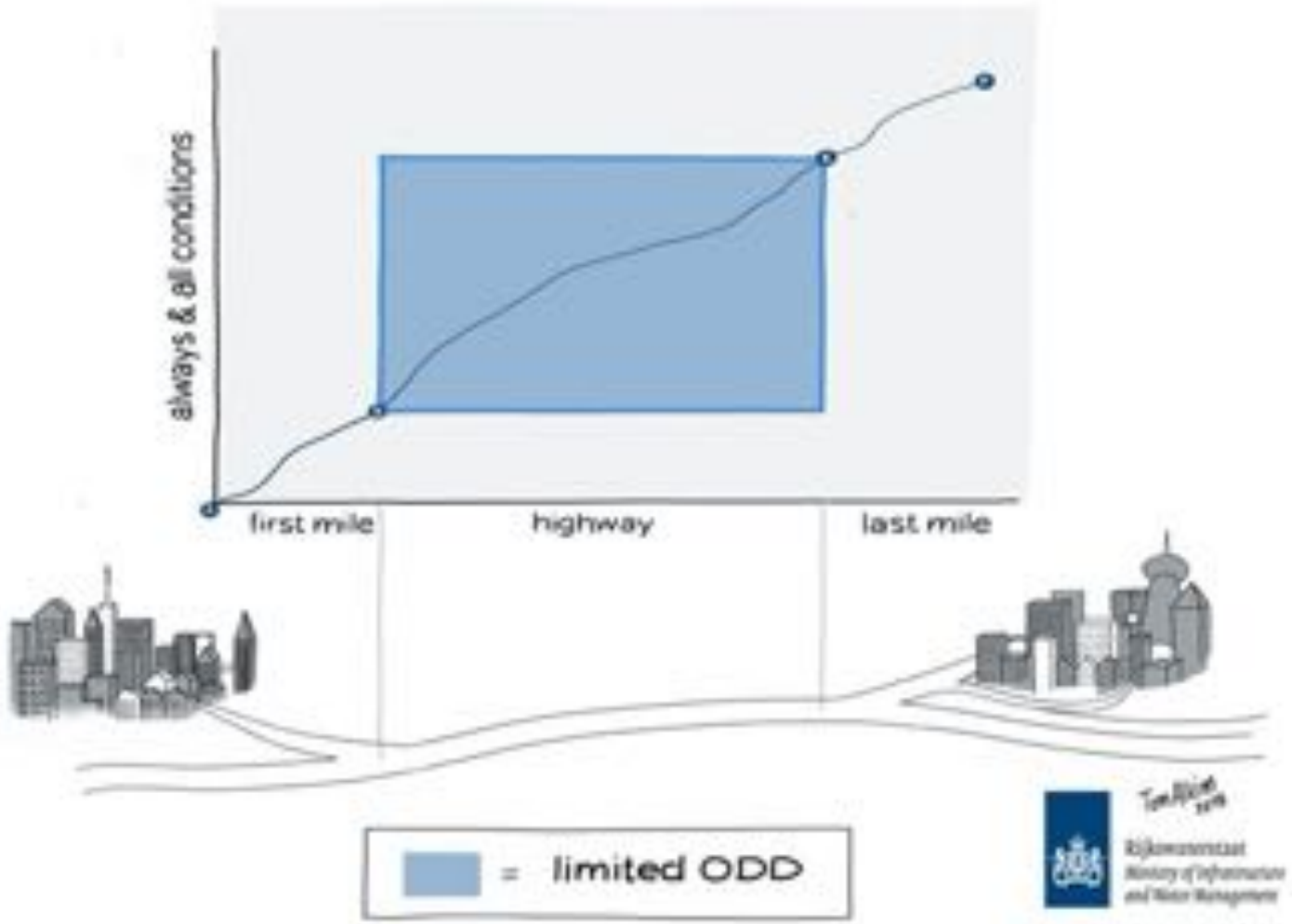
STORYLINE ODD FRAMEWORK

A
Driver leaves home to drive to work. First mile is driven manually.

B
... gives control to vehicle (ToC) and continues the trip in automated mode. Does something else with the freed up time, like reading email, posting on instagram or drinking coffee.

E
Vehicle approaches the exit and driver prepares to take back control (ToC) and drives last mile manually to destination.





ODD framework infrastructure – traffic - weather

STORYLINE ODD FRAMEWORK

A
Driver leaves home to drive to work. First mile is driven manually.

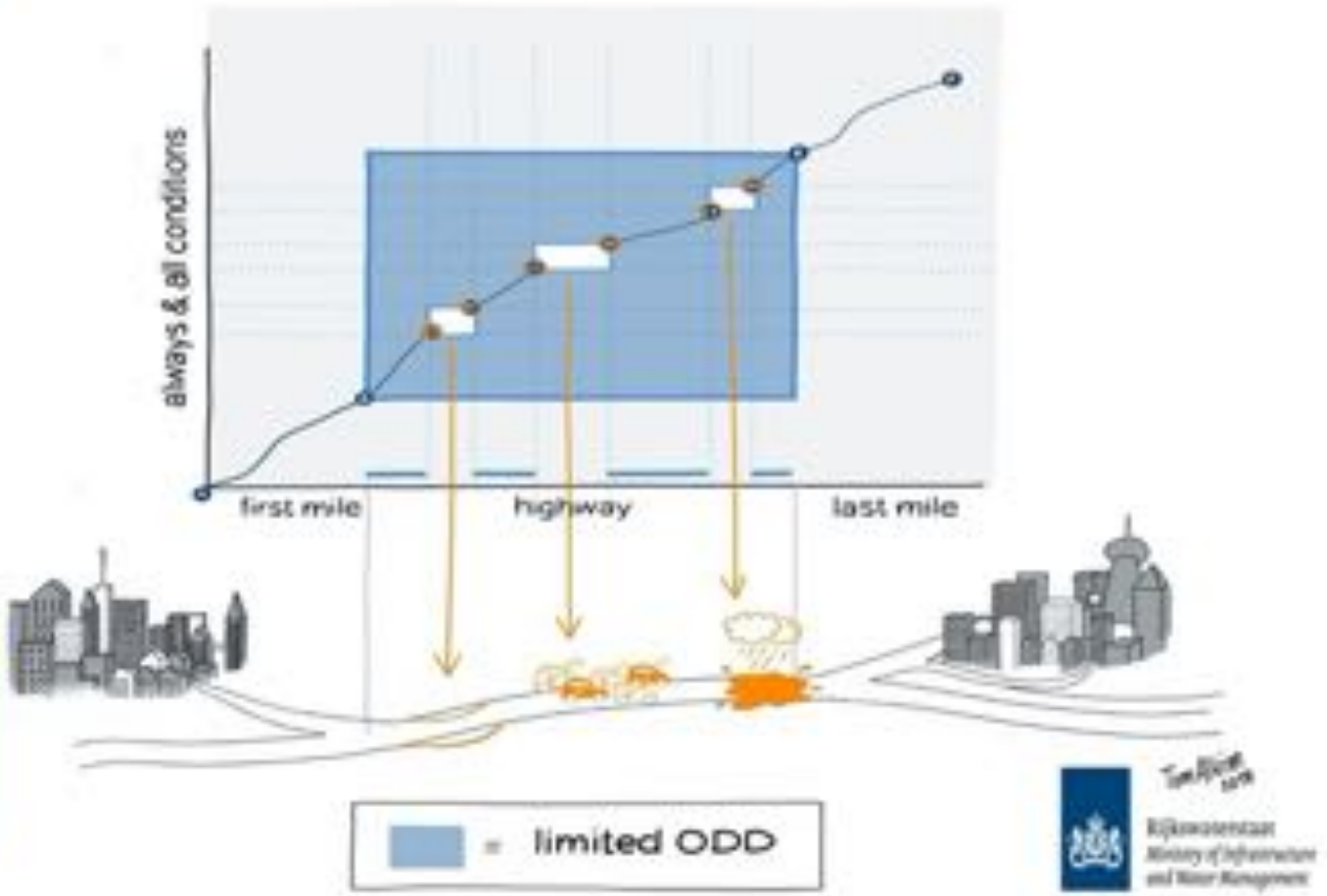
B
... gives control to vehicle (ToC) and continues the trip in automated mode. Does something else with the freed up time, like reading email, posting on Instagram or drinking coffee.

C1
During the trip vehicle encounters temporary lane markings, vehicle is confused and ODD ends. Driver needs to take over control (ToC).
D1
Conditions back to normal, ODD is available again, driver gives back control (ToC).

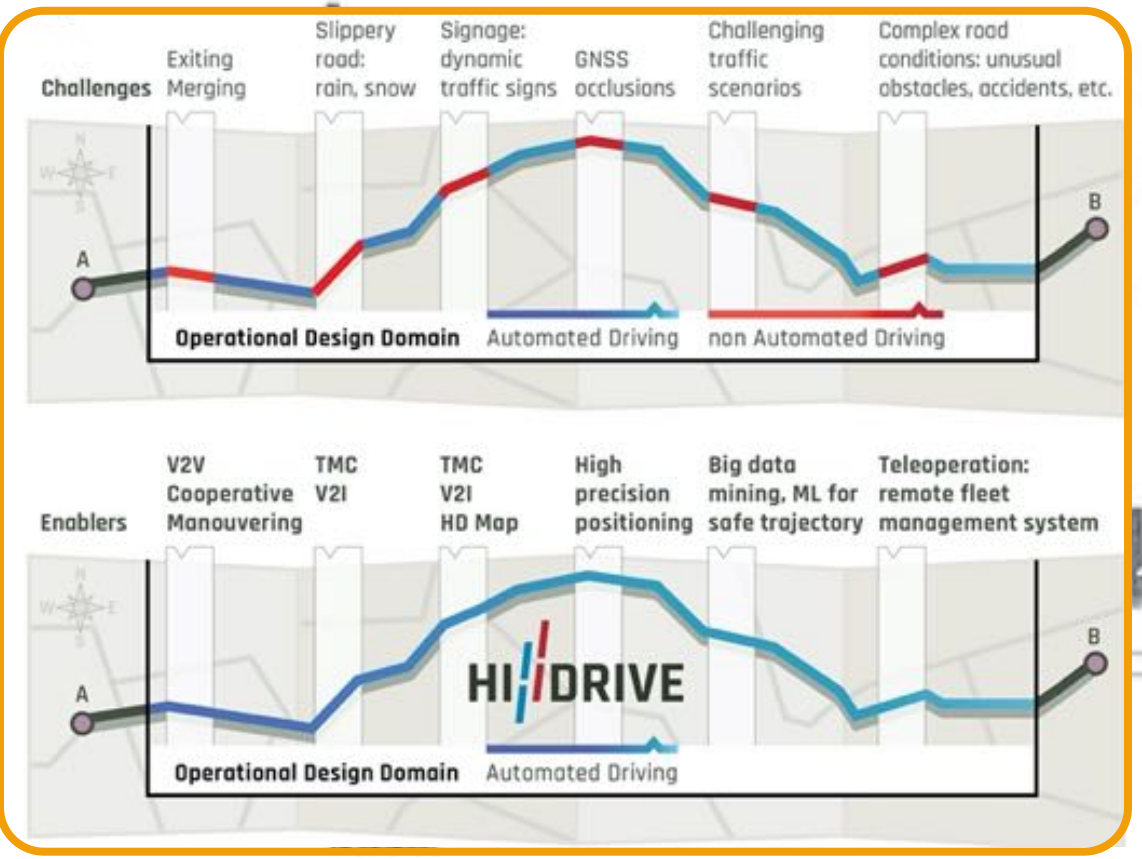
C2
During the trip vehicle has to merge in heavy mixed traffic, vehicle can't handle the situation and ODD ends. Driver needs to take over control (ToC).
D2
Conditions back to normal, ODD is available again, driver gives back control (ToC).

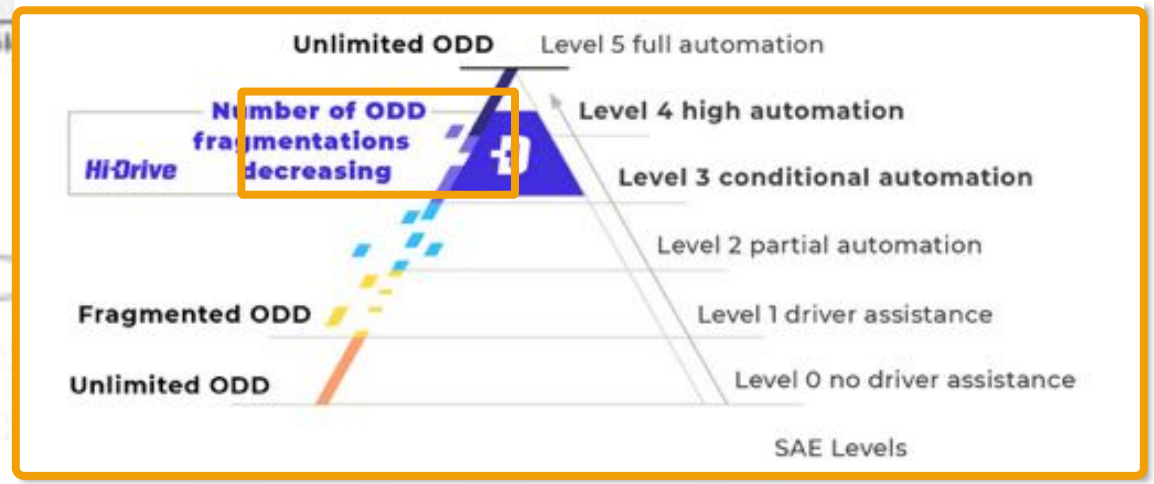
C3
During the trip a heavy rain shower occurs, vehicle can't handle the situation and ODD ends. Driver needs to take over control (ToC).
D3
Conditions back to normal, ODD is available again, driver gives back control (ToC).

E
Vehicle approaches the exit and driver prepares to take back control (ToC) and drives last mile manually to destination.



ODD framework infrastructure – traffic - weather





Workshop objectives

- Understand basic concepts and define common terminology associated with ODD definition and present Distributed ODD Awareness (DOA) concept including the relationship to ISAD
- “Determination of the information needs and who is to provide this information in the bidirectional interaction between TMC and vehicle”
- “Definition of the roles and responsibilities in the interaction between OEMs/Service Providers and NRAs on operational level”.
- Discuss the presented concepts and ask the OEMs what kind of information they would find most useful to help their ADS determine (in real time) whether the roadway segment they are approaching will be suitable for ADS driving

Traffic Management for Connected and Automated Driving (TM4CAD)

Basic Concepts and Distributed ODD Awareness (DOA) framework

Siddartha Khastgir

Traffic Management for Connected and Automated Driving (TM4CAD)

Interactive part: How do OEMs understand the Distributed Operational Design Domain Awareness (DOA) framework?

Basic Concepts and Terminology

- Levels of automation
- Operational Design Domain (ODD)
- Importance of ODD and real-time ODD awareness
- Examples of needed ODD attributes

Levels of Automation – SAE J3016/ISO PAS 22736

Distinguishing roles of human driver and driving automation technology

- **Level 0** – Human performs entire dynamic driving task (DDT)
- Driving assistance systems:
  - **Level 1** – System performs either lateral or longitudinal vehicle motion control (ACC or lane tracking)
  - **Level 2** – System performs both lateral and longitudinal vehicle motion control under continuous driver supervision (many current products)
- Automated Driving Systems (ADS):
  - **Level 3** – System performs entire DDT under specified ODD conditions, but driver must be available to intervene when requested by system
  - **Level 4** – System performs entire DDT under specified ODD conditions, and can achieve minimal risk condition without human intervention
  - **Level 5** – System can drive under all conditions that human can (dream)

Levels of Automation – SAE J3016/ISO PAS 22736

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Operational Design Domain (ODD)

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"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)

Understanding ODD: standardization galore!

- Need for common understanding
- Crowded landscape

Major activities:

- BSI (UK): PAS 1883
- ISO: ISO 34503 – (TC22 SC33 WG9)
- ASAM: OPENODD
- SAE: ORAD, AVSC
- UL: 4600
- IEEE: P2843
- UNECE: WP29

Importance of ODD

- At least as important as level of automation
- **Defined by each CAD system developer** based on their design constraints, not by any other entity
- **Different for every CAD system**, based on limitations of its technology
- To ensure safe operations, each CAD system **must remain within its ODD constraints**:
  - If ODD constraints are violated, cease automated driving
  - (Level 3) – request driver to intervene
  - (Level 4) - automatically transition to minimal risk condition (safe stop)

Need for real-time ODD awareness

- CAD system **continuously monitors ODD attributes** where it is operating to determine whether it can continue to operate
  - Safety cases and regulations should prohibit operations when ODD constraints are violated
- Anticipate **impending ODD constraint violations** to allow time for graceful transition to driver control (Level 3) or to minimal risk condition (Level 4)
- **Infrastructure cooperation** needed for information about attributes that CAD vehicle sensors cannot detect directly, such as:
  - Traffic incidents obstructing lanes beyond line of sight
  - Fog obstructing visibility beyond line of sight
  - Planned road works
  - Freezing pavement causing black ice

ODD Attribute Categories

- Physical attributes of the roadway and its environs
  - Quasi-static physical infrastructure
  - Road surface conditions that vary with weather conditions
- Operational attributes of the roadway (traffic management services available, traffic conditions)
- Digital information support for CAD operations
- Ambient environment attributes (weather, visibility, electromagnetic)

(These will need updates on different time scales)

ODD Awareness

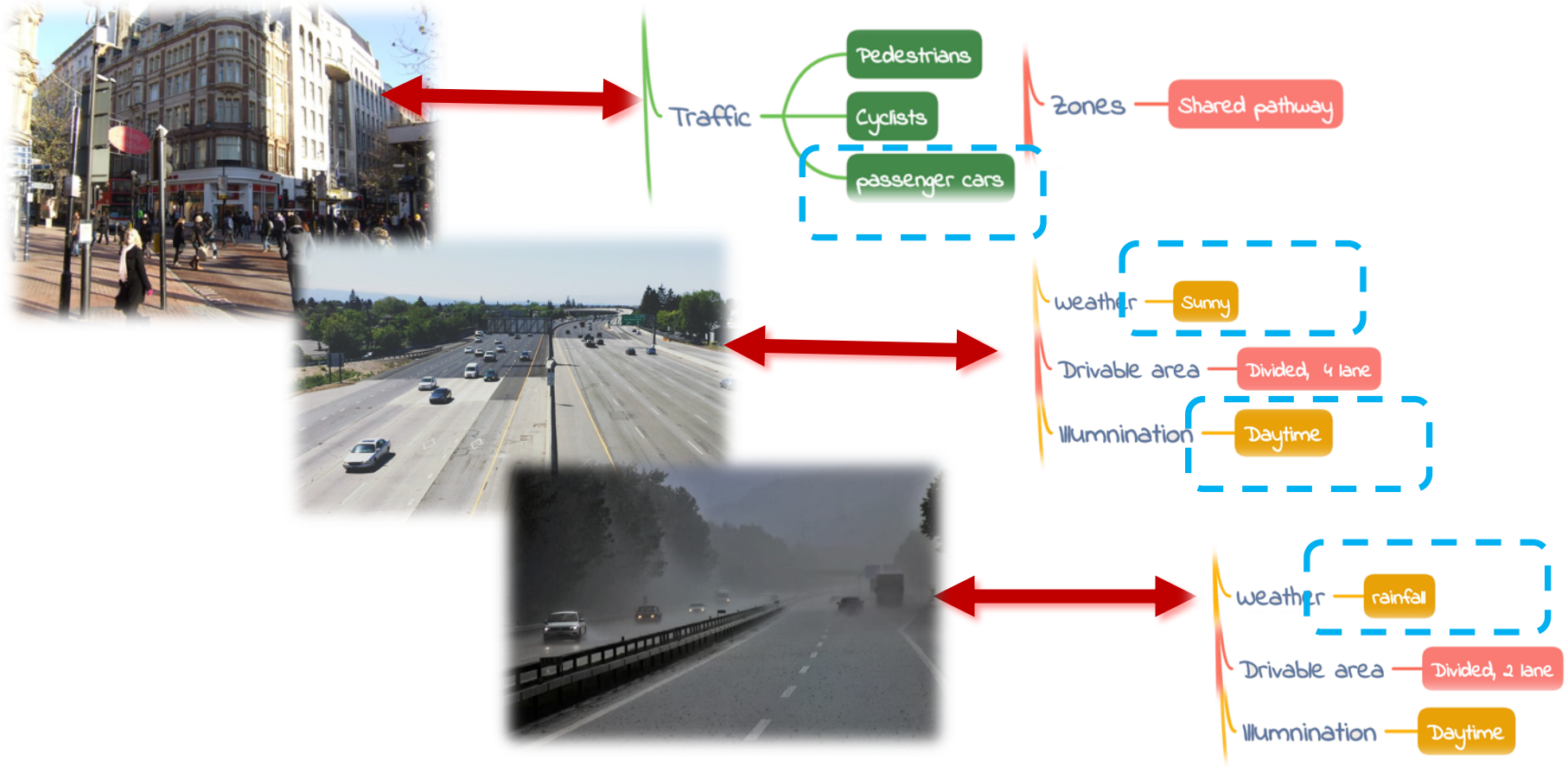
Traffic
- Pedestrians
- Cyclists
- passenger cars

Zones
- Shared pathway

- weather: Sunny
- Drivable area: Divided, 4 lane
- Illumination: Daytime

- weather: rainfall
- Drivable area: Divided, 2 lane
- Illumination: Daytime

ODD Awareness



ODD Awareness - Rainfall

- What does rainfall rate mean?
- How do we measure rainfall rate?
- How do we address local variability issues?
- Can the CAD system measure it **via on-board sensing only?**

Distributed ODD Awareness - Rainfall

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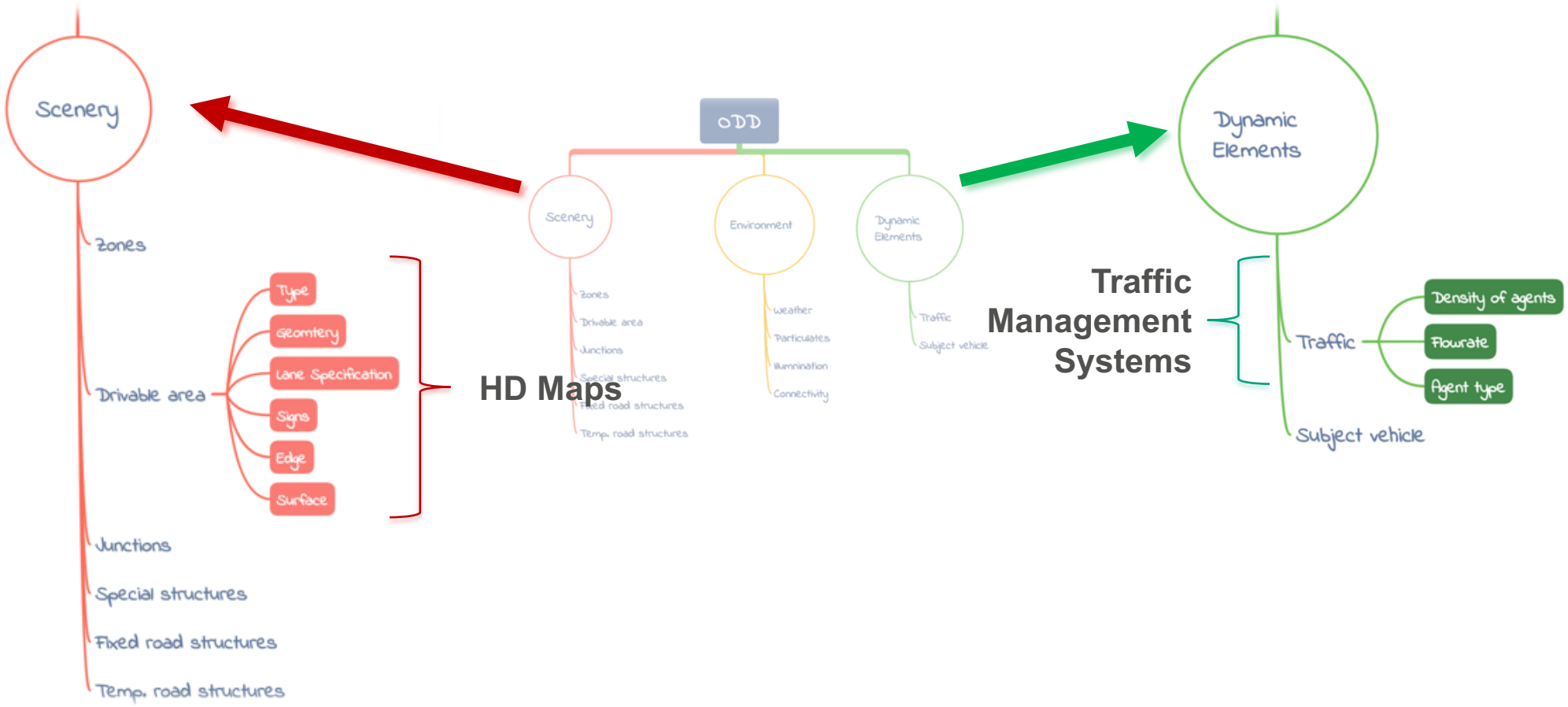
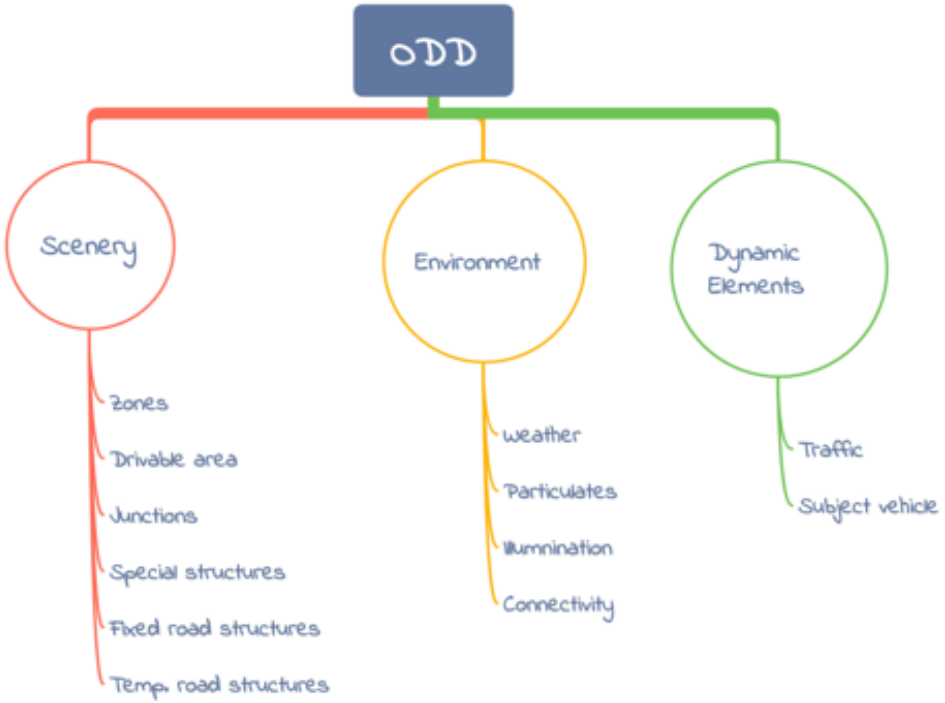
Distributed ODD Awareness



Distributed ODD Awareness

- **Any ODD attribute** can be measured via off-board sensing



Distributed ODD Awareness

- **Any ODD attribute** can be measured via off-board sensing
- Every ODD attribute **doesn't need to be** measured via off-board sensing
- Off-board measurements will require **infrastructure investment**
- **Connectivity** implicitly becomes a requirement

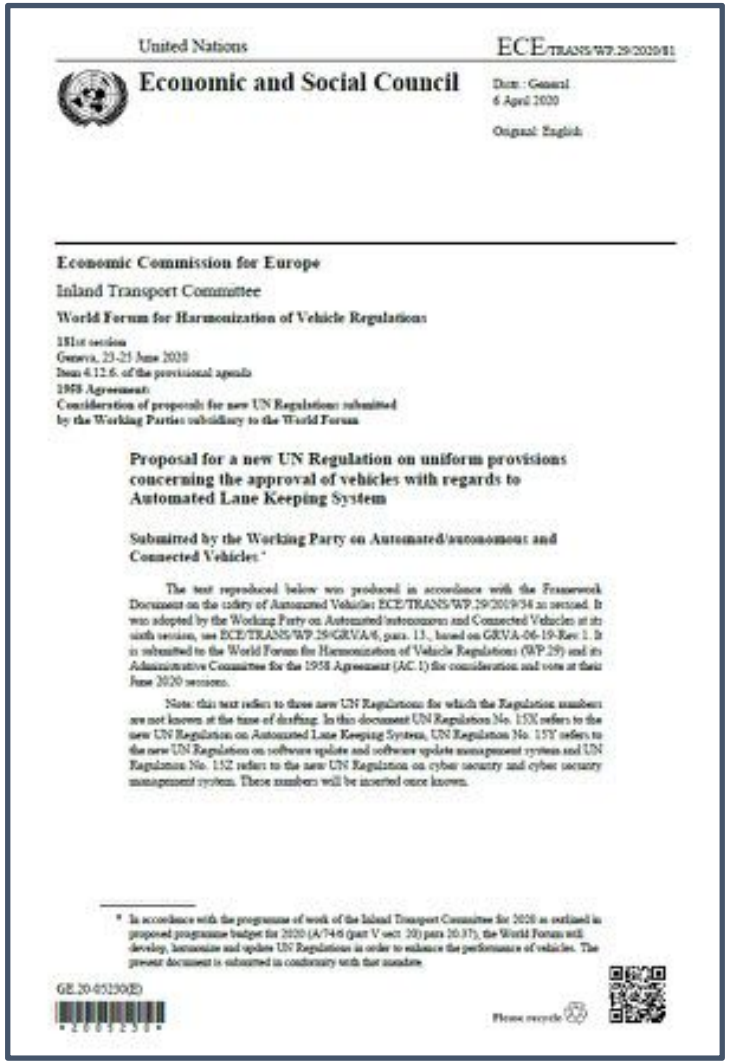
Understanding information criticality

Criticality of information refresh rate will impact infrastructure investment & connectivity requirements:

- **Category 1**: Changes very seldom (e.g. road layout, intersections etc.)
- **Category 2**: Changes every (few) days (e.g. vegetation growth)
- **Category 3**: Changes every (few) hours (e.g. wet road surface)
- **Category 4**: Changes every (few) minutes (e.g. variable message signs)
- **Category 5**: Changes every (few) seconds

What is ALKS?

- Automated Lane Keeping System (ALKS) UN Regulation 157
- ALKS controls the lateral and longitudinal movement of the vehicle for extended periods without further driver command.
- ALKS can be activated **under certain conditions**
- Regulation limits the operational speed to 60 km/h maximum and passenger cars (M1 vehicles).



United Nations ECE/TRANS/WP.29/2020/81

Economic and Social Council

Economic Commission for Europe

Inland Transport Committee

World Forum for Harmonization of Vehicle Regulations

Proposal for a new UN Regulation on uniform provisions concerning the approval of vehicles with regards to Automated Lane Keeping System

Submitted by the Working Party on Automated/autonomous and Connected Vehicles*

Source: ECE/TRANS/WP.29/2020/81

What is ALKS?

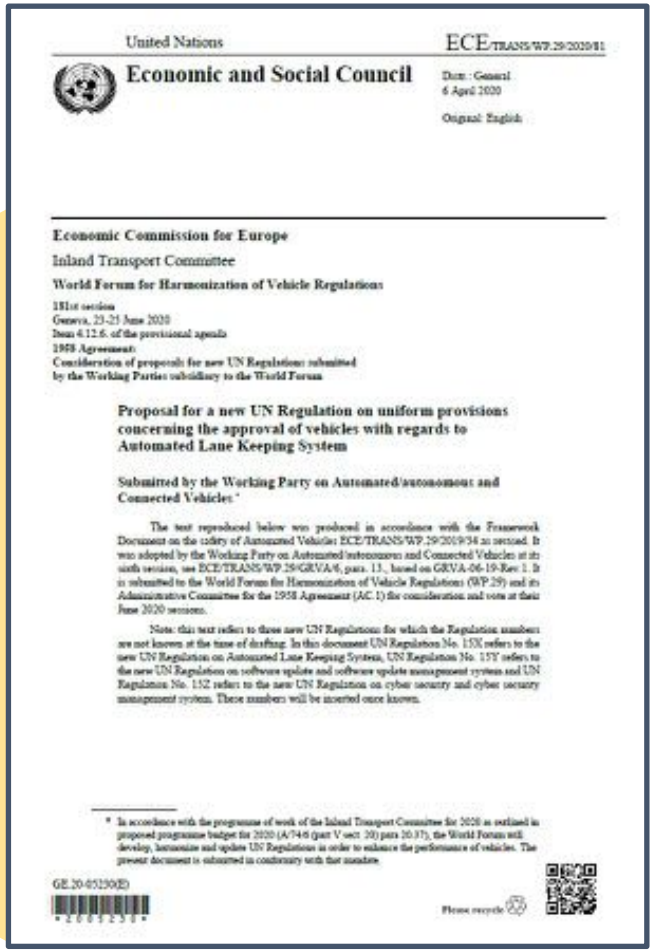
The Type-approval authority shall assess the documentation package to show that "The System":

(a) Is designed and was developed to operate in such a way that it is free from unreasonable risks for the driver, passengers and other road users within the declared ODD and boundaries;

(b) Respects, under the performance requirements specified elsewhere in this UN Regulation;

(c) Was developed according to the development process/method declared by the manufacturer and that this includes at least the steps listed in paragraph 3.4.4.

Source: ECE/TRANS/WP.29/2020/81



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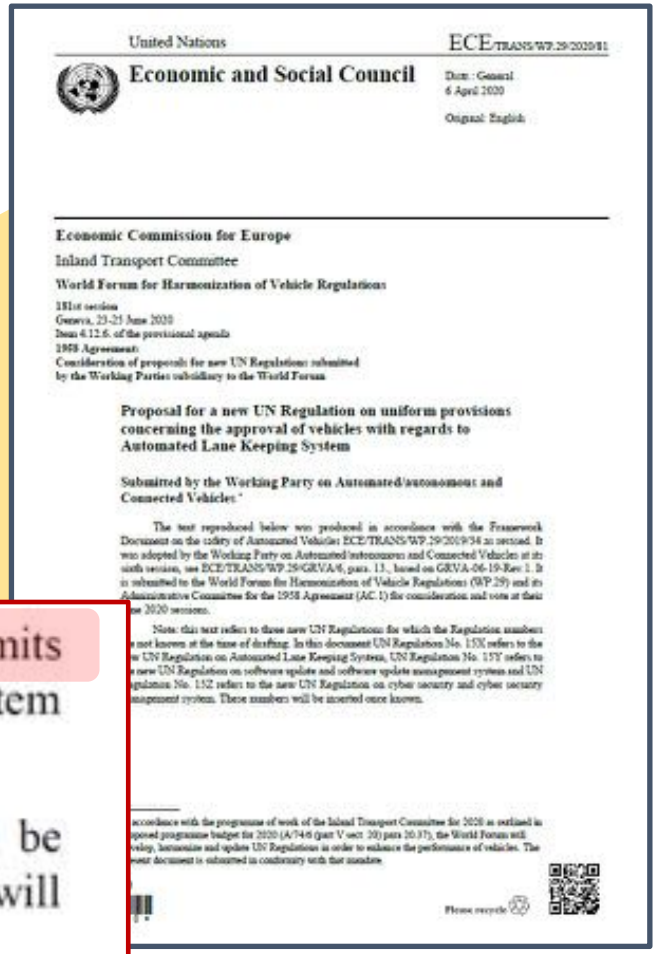
3.2.3. Limits defining the boundaries of functional operation including ODD-limits shall be stated where appropriate to automated lane keeping system

(c) performance.

3.2.4. Interaction concept with the driver when ODD limits are reached shall be explained including the list of types of situations in which the system will generate a transition demand to the driver.



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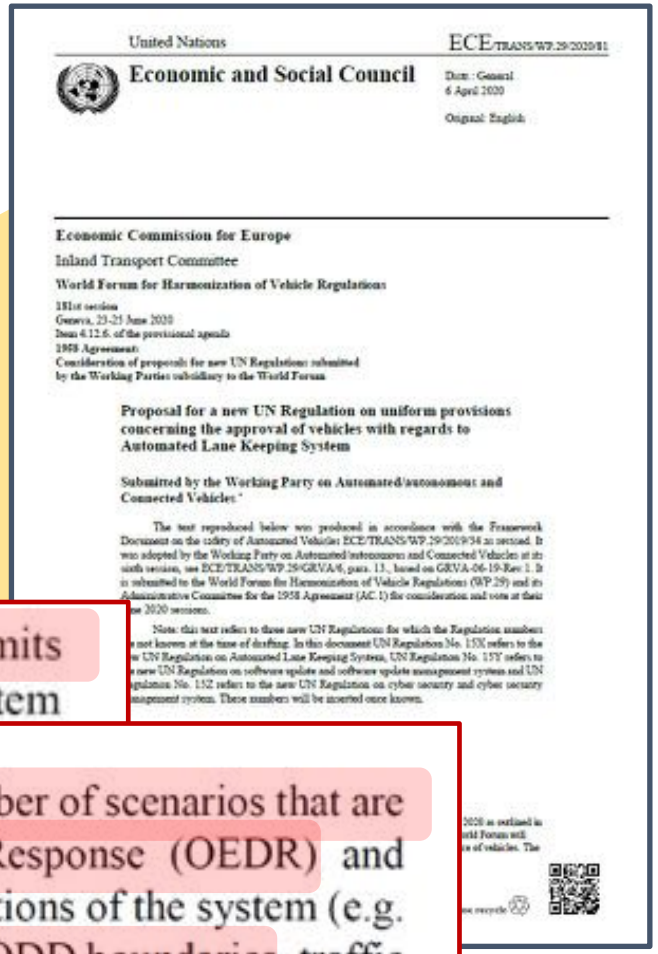
(c) perform

3.2.4. Interact explaine generate

4.1.2.1. The Type Approval Authorities shall also check a number of scenarios that are critical for the Object and Event Detection and Response (OEDR) and characterization of the decision-making and HMI functions of the system (e.g. object difficult to detect, when the system reaches the ODD boundaries, traffic disturbance scenarios) as defined in the regulation.



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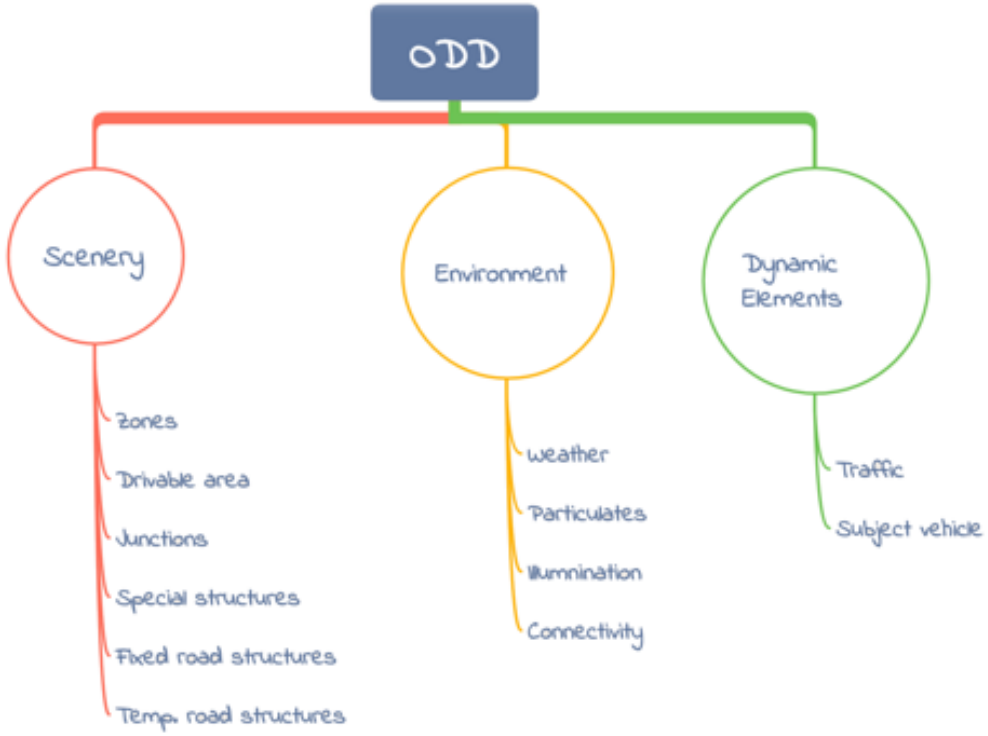
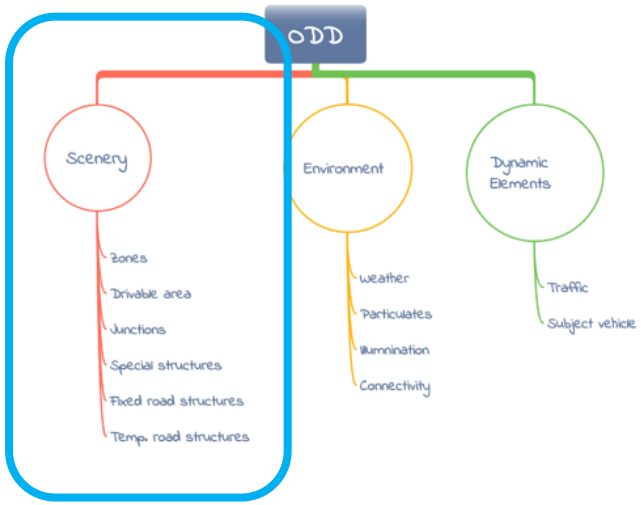
Interplay between ODD and ALKS



ODD Taxonomy as per BSI PAS 1883

Interplay between ODD and ALKS



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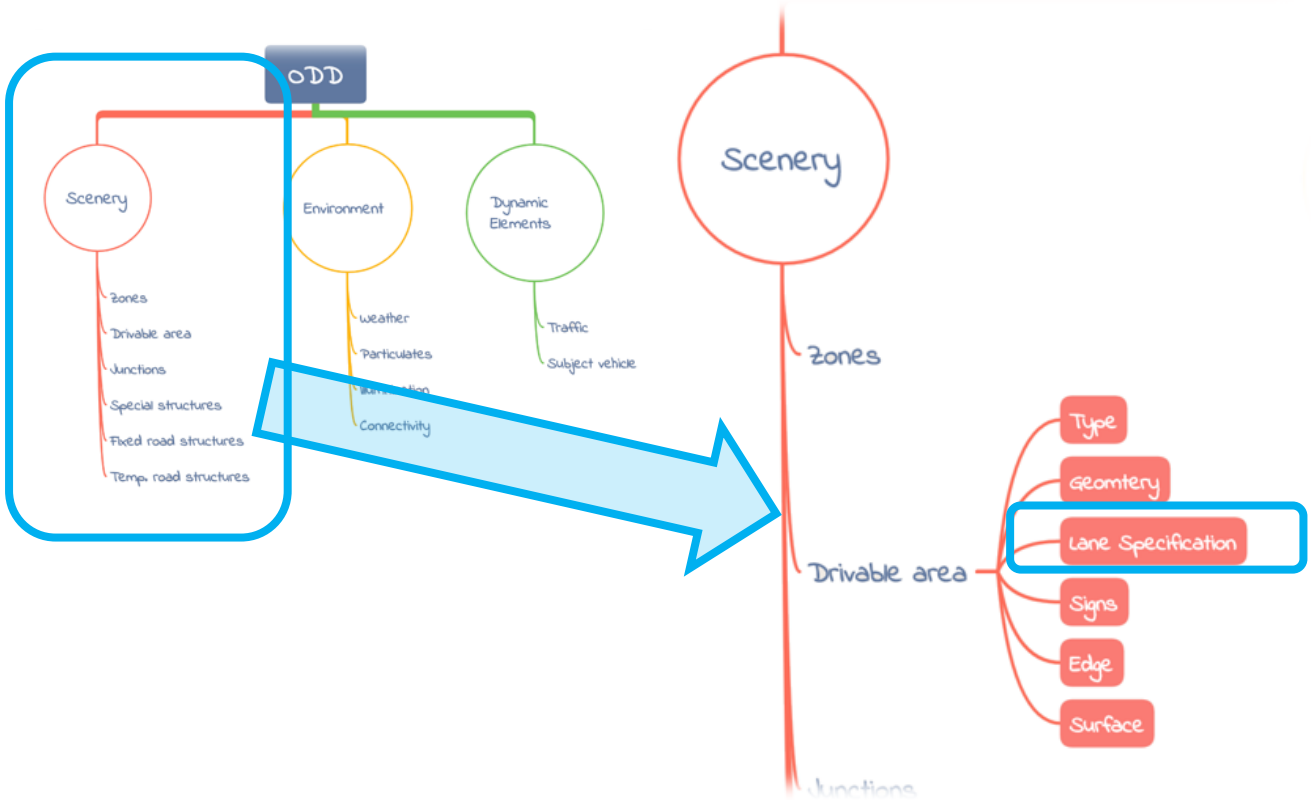

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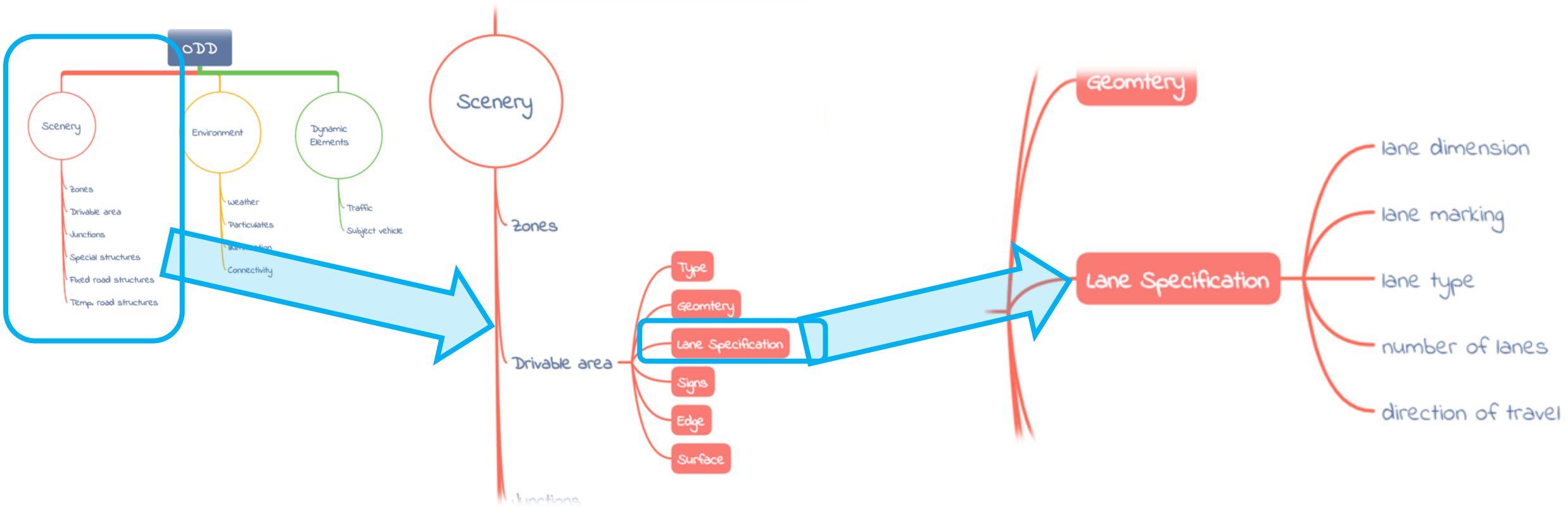

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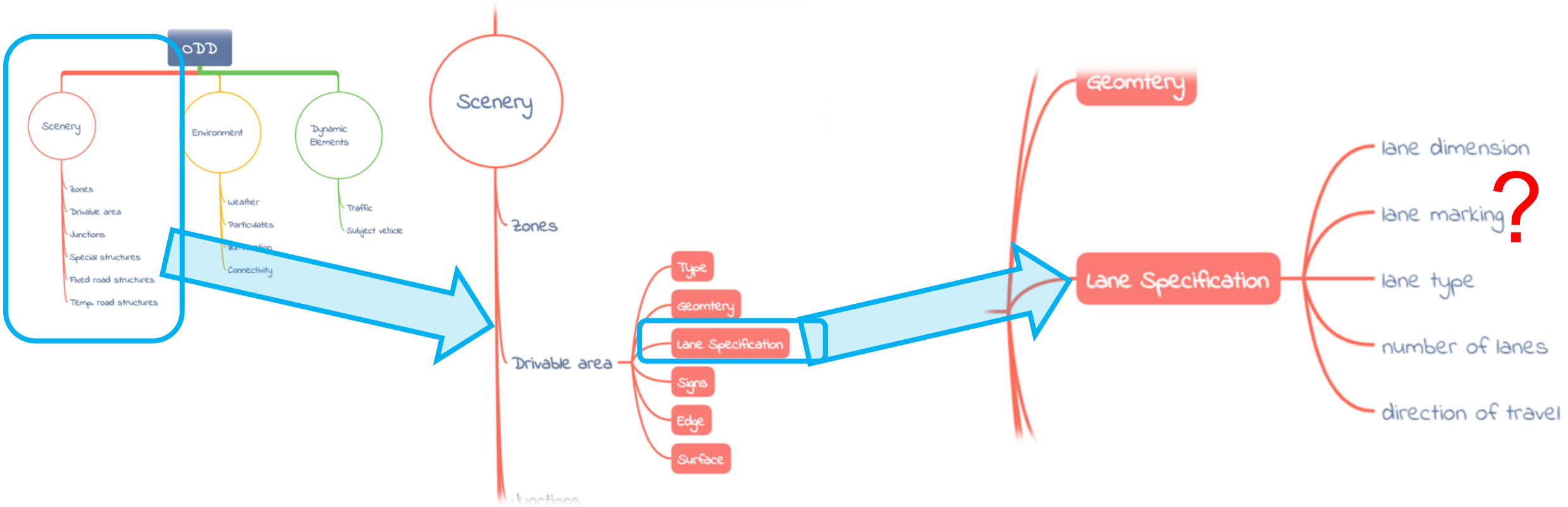
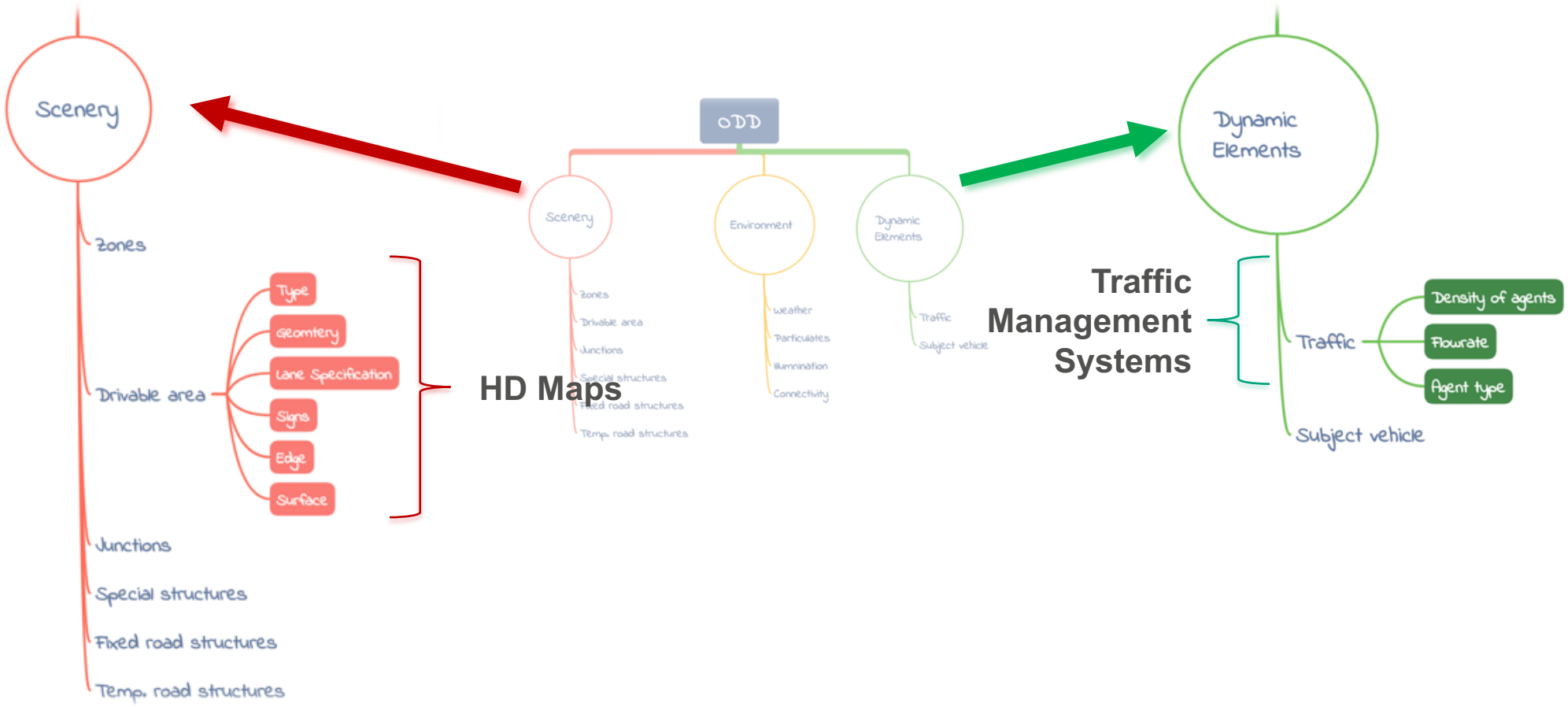


ODD Taxonomy as per BSI PAS 1883

Lane markings

Distributed ODD Awareness



Things we need to consider…

Distributed ODD Awareness: Freedom of Choice

- DOA Framework can be implemented in **multiple ways**
- OEMs need to decide based on stakeholder needs and required **design architectures**
- Trade-off between the best setup and the most beneficial setup
- Potentially, use case driven

General operational design domain (ODD)

- General
  - How do you currently consider the ODD?
  - What role do the ODDs currently have in your developments?
  - Where do you see pitfalls/shortcomings of the ODD definitions?

- ODD fragmentation
  - How would you deal with the fragmentation of an ODD?
  - What role can the exchange of information on local attributes/conditions have here?
  - How do you use technology and AI to help here (e.g., making certain attributes obsolete)?

- Which partners/stakeholders do you see involved

Distributed ODD Awareness (DOA)

- How do you see information criticality?
  - Relevance and urgency of the information sent/received?
  - Timeliness of the information sent/received?

- How do you see interaction with the infrastructure?
  - One-way ⇔ two-way communications?
  - Interfleet/-brand connectivity?

- Exchange of information with:
  - Road operators?
  - Traffic managers?
  - Maintenance contractors?
  - (Weather and traffic information) service providers?
  - Mobile network operators
  - Land survey agencies (e.g., resp. for GNSS land stations)

Traffic Management for Connected and Automated Driving (TM4CAD)

Prioritisation of information needs

Risto Kulmala & Ilkka Kotilainen, Traficon

Why do we want to prioritise?

- Research questions set by CEDR:
  - *RQ4: **What kind of information is to be transmitted in the interaction** (in both directions) between a traffic management centre and vehicle?*
  - *RQ5: **Which information is to be provided by the NRA/roadside** and which information can be obtained by the sensors of the moving vehicle itself?*
- CEDR expectations on results:
  - *Develop recommendations based on understanding the technical constraints on the **ODD-relevant information that can be perceived and exchanged in real time** by the NRAs and the sensing systems on the CAD-equipped vehicles;*
  - *Integrate the very different perspectives of the CAD vehicle system developers and the road authorities and operators **to focus on the areas of intersection between them**;*
- Resources are limited, the stakeholders can not deploy everything immediately – a step-by-step approach is needed: start with the high priority easy-to-do local condition attributes first

Use cases/scenarios/actors

- Use cases <u>on motorways/highways:</u>
  - ALKS (L3)
  - Highway autopilot (L4)
  - Automated trucks on open roads (L4)
- In three scenarios:
  - traffic jam dissolving
  - adverse weather
  - static/dynamic roadworks zone
- With regard to three actors:
  - roadworks or (winter) maintenance operator
  - traffic manager
  - automated driving system developer/OEM

Information Priority Evaluation Method

- Combined for all three use cases as the requirements were very similar
- Separately for
  - Each actor
  - Each scenario
- Overall priority level extracted by qualitative comparison (low-medium-high) between the three actors and scenarios
  - Information need, and
  - Safety criticality
- In addition, we estimated the additional cost to the actor
  - Very crude estimate
    - - possibility cost savings; 0 no costs; + low costs; ++ medium costs; +++ high costs
  - Often the additional cost affected only one or two of the actors

Information needs

- We started with information needs for each stakeholder
- Seldom differences between scenarios for the same stakeholder
- Often differences between stakeholders

Scenario	Traffic Jam			Adverse weather area			Static/dynamic Road Work Zone		
	Actor and information need			Actor and information need			Actor and information need		
Local condition / ODD attribute	MO	TM	AV (ADS)	WMO	TM	AV (ADS)	RW or MO	TM	AV (ADS)
Variable message sign contents	***	***	***	-	***	***	-	***	***
Locations where V2I/I2V communications are available	*	***	***	*	***	***	-	***	***
Locations where GNSS differential correction signals are available	-	*	***	***	*	***	*	*	***
Locations where GNSS coverage is NOT available now, by GNSS service	-	*	***	**	*	***	-	*	***

Examples of desktop analysis results

Actor	Roadworks or Maintenance Operator			Traffic Manager			Automated Vehicle (Automated Driving System) developer			Overall priority level
	Priority evaluation criteria			Priority evaluation criteria			Priority evaluation criteria			
Local condition / ODD attribute	Information need importance	Safety critical	Additional work and cost	Information need importance	Safety critical	Additional work and cost	Information need importance	Safety critical	Additional work and cost	Priority
Locations of road boundaries	-	***	+++	***	**	+	***	***	0	HIGH
Zone boundaries	-	***	+++	***	**	+	**	***	0	HIGH
Roadside landmarks	-	***	+	**	*	++	***	***	0	HIGH
Special-purpose localization references	-	-	+++	*	*	+	*	*	0	LOW
Quality of pavement marking visibility	-	***	+++	*	**	++	***	***	+	HIGH
Load-bearing capacity of roadway or bridge structures	-	***	0	**	***	+	**	***	0	MEDIUM

Priority survey to ADS developers/OEMs Evaluation Results

- Survey conducted before the workshop
- Responses received: N = 8
- The questionnaire asked about four ODD attribute clusters information priorities for the CAD developers:
  - Physical attributes of the roadway and its environs
  - Operational attributes of the roadway
  - Digital infrastructure support
  - Dynamically varying ambient environmental conditions
- Following slides summarise the results of
  - TM4CAD analysis of the THREE actors and THREE scenarios OVERALL priority
  - Survey responses concerning priorities

Priorities of physical attributes of the roadway and its environs

Local condition / ODD attribute	TM4CAD analysis of overall priority level	ADS dev Survey (n=8)
Locations of road boundaries	HIGH	7H 1L
Zone boundaries	HIGH	6H 2L
Roadside landmarks	HIGH	7H 1L
Special-purpose localization references	LOW	8L
Quality of pavement marking visibility	HIGH	6H 1M 1L
Load-bearing capacity of roadway or bridge structures	MEDIUM	6M 2L
Road surface damage	MEDIUM	2H 5M 1L
Game fence locations and condition	LOW	8L
Vegetation obscuring sight angles or visibility of signs	LOW	1M 7L
Road geometry constraints	HIGH	7H 1L
Road shoulder conditions on both sides	HIGH	5H 2M 1L
Notifications of locations with occluded visibility	HIGH	7H 1L

Priorities of digital infrastructure support

Local condition / ODD attribute	TM4CAD analysis of overall priority level	ADS dev Survey (n=8)
Variable message sign contents	HIGH	7H 1L
Locations where V2I/I2V communications are available	HIGH	7H 1L
Locations where GNSS differential correction signals are available	MEDIUM	1H 5M 2L
Locations where GNSS coverage is NOT available now, by GNSS service	MEDIUM	2H 4M 2L
Electronic toll collection systems and their associated pricing	LOW	1M 7L
Locations of incidents that represent traffic impediments or safety hazards	HIGH	7H 1L
Emergency vehicle locations and direction/speed of travel of each one	MEDIUM	1H 5M 2L
Current average traffic speed and density by lane and road section	HIGH	6H 2L
Current percentage of heavy vehicles in traffic stream, by lane and road section	LOW	8L
Special events creating abnormal traffic conditions and their locations	HIGH	5H 1M 2L
Temporarily blocked or closed road locations	HIGH	7H 1L
Locations with high density of pedestrians	LOW	1H 2M 5L
Locations with high density of cyclists or users of micro-mobility devices	LOW	1H 2M 5L
Highway shoulder locations occupied by vehicles or debris	HIGH	5H 1M 2L
Locations with dynamic traffic access changes	HIGH	6H 1M 1L
Remote human support	HIGH	4H 4L

Priorities of dynamically varying ambient environmental conditions

Local condition / ODD attribute	TM4CAD analysis of overall priority level	ADS dev Survey (n=8)
Wind speed range	MEDIUM	1H 4M 3L
Visibility range with rain/snow/sleet/hail in visible light spectrum	HIGH	7H 1L
Visibility range with rain/snow/sleet/hail in lidar infrared spectrum	HIGH	6H 2L
Rainfall rate in mm/hr	HIGH	6H 2L
Snowfall rate in qualitative ranges	HIGH	7H 1L
Visibility range with other particulate obscurants in visible light spectrum	HIGH	7H 1L
Visibility range with other particulate obscurants in lidar infrared spectrum	HIGH	6H 2L
Predicted significant changes in key weather attributes	HIGH	7H 1L
Qualitative ambient lighting conditions	LOW	8L
Quantitative ambient lighting conditions	MEDIUM	5M 3L
Special challenging lighting conditions	MEDIUM	1H 4M 3L
Electromagnetic interference	HIGH	5H 3L
Wet pavement surface	HIGH	4H 1M 3L
Ice on pavement surface	HIGH	6H 2L
Cold pavement surface (potential for ice if wet)	HIGH	5H 3L
Road surface friction	HIGH	4H 1M 3L
Light to moderate snow/slush accumulation on surface	HIGH	6H 2L
Heavy snow/slush accumulation on surface	HIGH	6H 2L
Light to moderate flooding (puddles) on surface	HIGH	5H 1M 2L
Heavy flooding – potentially impassible to low-profile vehicles	HIGH	6H 2L

Priorities of operational attributes of the roadway

Local condition / ODD attribute	TM4CAD analysis of overall priority level	ADS dev Survey (n=8)
Temporary static signs	HIGH	7H 1L
Maintenance vehicles using portions of carriageway	HIGH	6H 2L
Work zones	HIGH	7H 1L
Incident recovery events (crash scenes, crime scenes, dropped loads, landslides, avalanches…)	HIGH	6H 2L
Availability of specific C-ITS information services	HIGH	6H 1M 1L
Availability of real-time merging guidance or assistance at motorway interchanges or entrance ramps	HIGH	7H 1L
Real-time lane-specific speed limit information availability at specific locations.	HIGH	7H 1L
Obstacles or debris on road surface	HIGH	6H 2L
Roadside objects that change their locations over time, such as parked vehicles or trash cans	MEDIUM	5M 3L
Routing advisory information	MEDIUM	5M 3L
Traffic rules and regulations in digital form, updated in real time	HIGH	6H 2L

What does the survey tell us?

- Mostly good agreement with TM4CAD estimates (always at least half in full agreement)
- Individual variety in responses
  - one respondent regarded for more than 90% of the attributes the priority as Low
  - issues of interpretation?
    - Urban use cases vs highway/motorway use cases
    - Some took into account the role of the road operator (according to written comments)
- Written comments
  - many referred to the difficulties and cost for providing the attribute
  - some questioned the trustworthiness of data
  - Some attributes regarded as more long term (e.g. remote control)

Next steps

- Discuss results with CEDR members
- Elaborate on quality requirements for each attribute
- Propose technical solutions for data exchange
- Discuss attribute information governance
- Finalise report 08/2022

Quality criteria for DOA and its attributes
Geographical coverage
Availability
Performance conditions
Coverage of data types
Timeliness (start)
Refreshment rate
Data transfer delay
Timeliness (update)
Latency (content side)
Location accuracy
Monitoring point density
Measurement accuracy
Reporting accuracy
Error Rate
Classification correctness (non-false positives)
Event coverage (true positives)
Missed events (false negatives)
Report coverage

Traffic Management for Connected and Automated Driving (TM4CAD)

Interactive part: what kind of information would YOU find most useful to help the ADS determine (in real time) whether the roadway segment ahead will be suitable for ADS driving

The most important and urgent?

Local condition / ODD attributes: Physical infrastructure	TM4CAD analysis of overall priority level	ADS dev Survey (n=8)
Locations of road boundaries	HIGH	7H 1L
Zone boundaries	HIGH	6H 2L
Roadside landmarks	HIGH	7H 1L
Special-purpose localization references	LOW	8L
Quality of pavement marking visibility	HIGH	6H 1M 1L
Load-bearing capacity of roadway or bridge structures	MEDIUM	6M 2L
Road surface damage	MEDIUM	2H 5M 1L
Game fence locations and condition	LOW	8L
Vegetation obscuring sight angles or visibility of signs	LOW	1M 7L
Road geometry constraints	HIGH	7H 1L
Road shoulder conditions on both sides	HIGH	5H 2M 1L
Notifications of locations with occluded visibility	HIGH	7H 1L

The most important and urgent?

Local condition / ODD attribute: digital infrastructure	TM4CAD analysis of overall priority level	ADS dev Survey (n=8)
Variable message sign contents	HIGH	7H 1L
Locations where V2I/I2V communications are available	HIGH	7H 1L
Locations where GNSS differential correction signals are available	MEDIUM	1H 5M 2L
Locations where GNSS coverage is NOT available now, by GNSS service	MEDIUM	2H 4M 2L
Electronic toll collection systems and their associated pricing	LOW	1M 7L
Locations of incidents that represent traffic impediments or safety hazards	HIGH	7H 1L
Emergency vehicle locations and direction/speed of travel of each one	MEDIUM	1H 5M 2L
Current average traffic speed and density by lane and road section	HIGH	6H 2L

The most important and urgent?

Local condition / ODD attribute: digital infrastructure	TM4CAD analysis of overall priority level	ADS dev Survey (n=8)
Current percentage of heavy vehicles in traffic stream, by lane and road section	LOW	8L
Special events creating abnormal traffic conditions and their locations	HIGH	5H 1M 2L
Temporarily blocked or closed road locations	HIGH	7H 1L
Locations with high density of pedestrians	LOW	1H 2M 5L
Locations with high density of cyclists or users of micro-mobility devices	LOW	1H 2M 5L
Highway shoulder locations occupied by vehicles or debris	HIGH	5H 1M 2L
Locations with dynamic traffic access changes	HIGH	6H 1M 1L
Remote human support	HIGH	4H 4L

The most important and urgent?

Local condition / ODD attribute: Environmental conditions	TM4CAD analysis of overall priority level	ADS dev Survey (n=8)
Wind speed range	MEDIUM	1H 4M 3L
Visibility range with rain/snow/sleet/hail in visible light spectrum	HIGH	7H 1L
Visibility range with rain/snow/sleet/hail in lidar infrared spectrum	HIGH	6H 2L
Rainfall rate in mm/hr	HIGH	6H 2L
Snowfall rate in qualitative ranges	HIGH	7H 1L
Visibility range with other particulate obscurants in visible light spectrum	HIGH	7H 1L
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Predicted significant changes in key weather attributes	HIGH	7H 1L
Qualitative ambient lighting conditions	LOW	8L
Quantitative ambient lighting conditions	MEDIUM	5M 3L

The most important and urgent?

Local condition / ODD attribute: Environmental conditions	TM4CAD analysis of overall priority level	ADS dev Survey (n=8)
Special challenging lighting conditions	MEDIUM	1H 4M 3L
Electromagnetic interference	HIGH	5H 3L
Wet pavement surface	HIGH	4H 1M 3L
Ice on pavement surface	HIGH	6H 2L
Cold pavement surface (potential for ice if wet)	HIGH	5H 3L
Road surface friction	HIGH	4H 1M 3L
Light to moderate snow/slush accumulation on surface	HIGH	6H 2L
Heavy snow/slush accumulation on surface	HIGH	6H 2L
Light to moderate flooding (puddles) on surface	HIGH	5H 1M 2L
Heavy flooding – potentially impassible to low-profile vehicles	HIGH	6H 2L

The most important and urgent?

Local condition / ODD attribute: operational infrastructure	TM4CAD analysis of overall priority level	ADS dev Survey (n=8)
Temporary static signs	HIGH	7H 1L
Maintenance vehicles using portions of carriageway	HIGH	6H 2L
Work zones	HIGH	7H 1L
Incident recovery events (crash scenes, crime scenes, dropped loads, landslides, avalanches…)	HIGH	6H 2L
Availability of specific C-ITS information services	HIGH	6H 1M 1L
Availability of real-time merging guidance or assistance at motorway interchanges or entrance ramps	HIGH	7H 1L
Real-time lane-specific speed limit information availability at specific locations.	HIGH	7H 1L
Obstacles or debris on road surface	HIGH	6H 2L
Roadside objects that change their locations over time, such as parked vehicles or trash cans	MEDIUM	5M 3L
Routing advisory information	MEDIUM	5M 3L
Traffic rules and regulations in digital form, updated in real time	HIGH	6H 2L

Conclusions and further steps

Continue the dialogue?

- Breakout session ARTS22 (18-21 July 2022, LA)
- Presentation ITS World Congress (18-21 September 2022, LA)
- Presentation SIP-adus (11-13 October, Kyoto)
- Session TRA (14-17 November, Lissabon)
- Workshops 4, 5, 6, 7
- Final event, March/April 2023, tbd

Traffic Management for Connected and Automated Driving

TM4CAD

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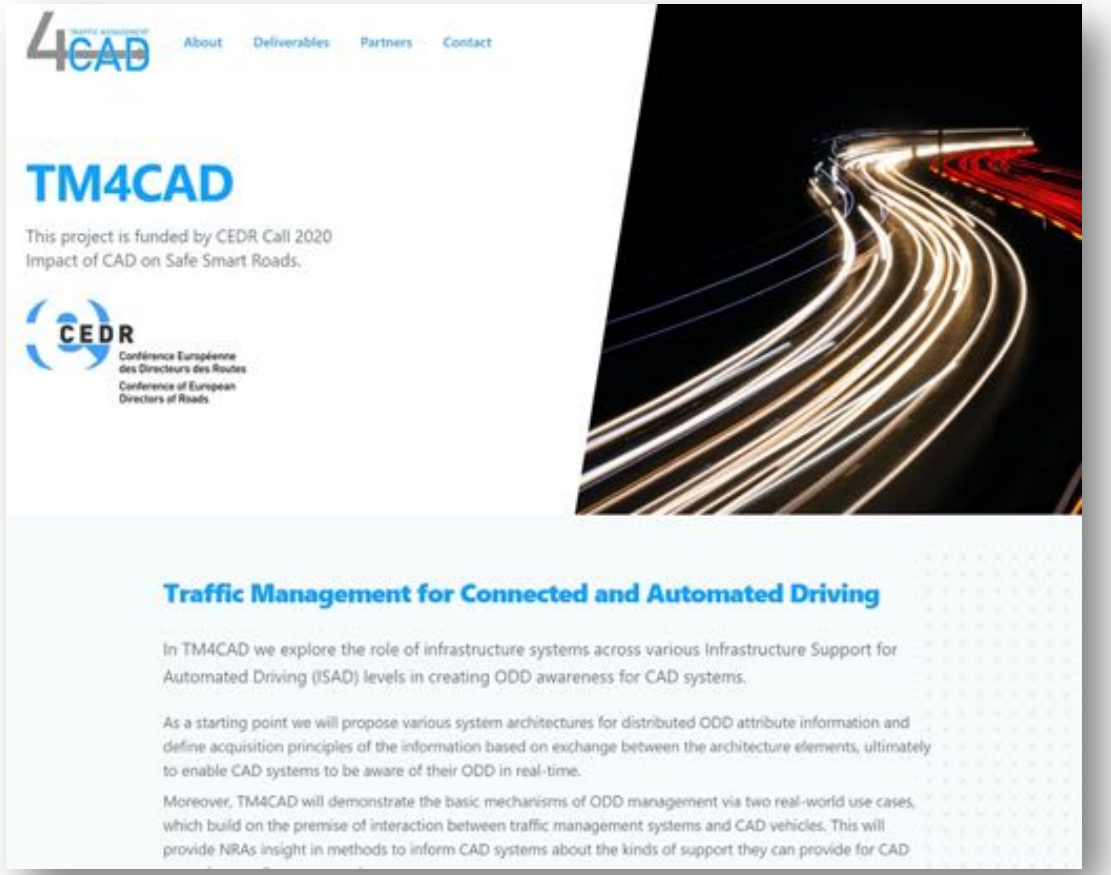
Project website:

https://tm4cad.project.cedr.eu/



Hi-Drive
Designing Automation

Adressing challenges towards the deployment of higher automation

Luisa Andreone, Stellantis-CRF, Enablers Leader
Aria Etemad, Volkswagen, Coordinator

CEDR TM4CAD 3rd workshop
10 June 2022

© Volkswagen

Hi-Drive
Designing Automation

PUSH TOWARDS HIGHER AUTOMATION.

- Robust and reliable automated driving
- Extended and defragmented ODDs
- Interoperability across countries and brands

Project Facts

€60 MILLION BUDGET

€30 MILLION FUNDING

48 MONTHS DURATION starting in July 2021

40 PARTNERS among them OEMs, automotive suppliers, research institutes, associations, traffic engineering, deployment organisations and mobility clubs

14 COUNTRIES involved: Belgium, France, Finland, Germany, Greece, Hungary, Italy, Israel, Netherlands, Norway, Spain, Sweden, Switzerland, United Kingdom

eucar
EUROPEAN COUNCIL FOR AUTOMOTIVE R&D

Supported by the European Council for Automotive R&D

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101006664

Partners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MAGYAR AUTÓKLUB
1900
RACC

THE CONCEPT

Enablers **Vehicles** **Operations** **Effects**

Methodology **Users**

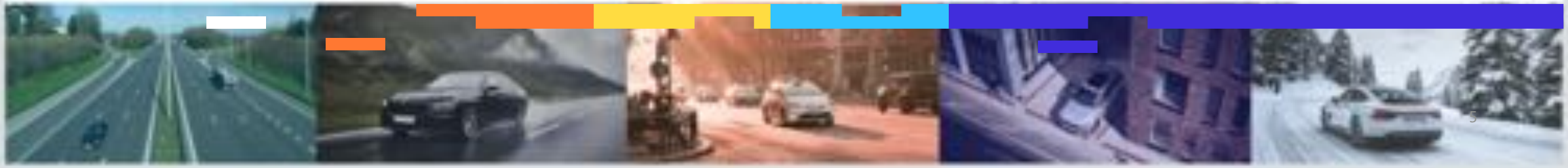
Phase 1	Phase 2	Phase 3

Outreach Standardisation, User Education, Acceptance Survey, Business Models, Showcases

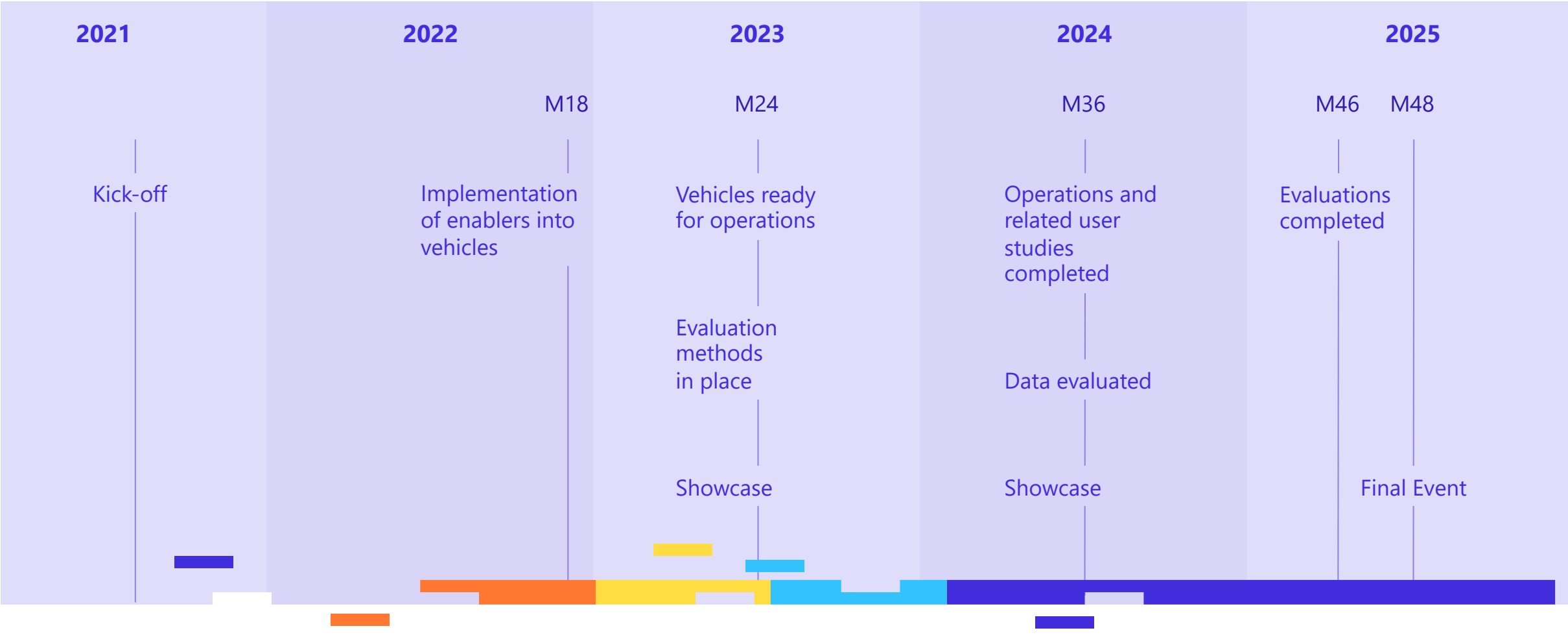
Collaboration Code of Practice for the Development of ADF and Road Testing Procedures

Motorway Chauffeur **Urban Chauffeur** **Cross-border Scenarios** **Edge Cases**

Transition to



Timeline


2021
2022
2023
2024
2025
M18
M24
M36
M46
M48
Kick-off
Implementation of enablers into vehicles
Vehicles ready for operations
Evaluation methods in place
Showcase
Operations and related user studies completed
Data evaluated
Showcase
Evaluations completed
Final Event

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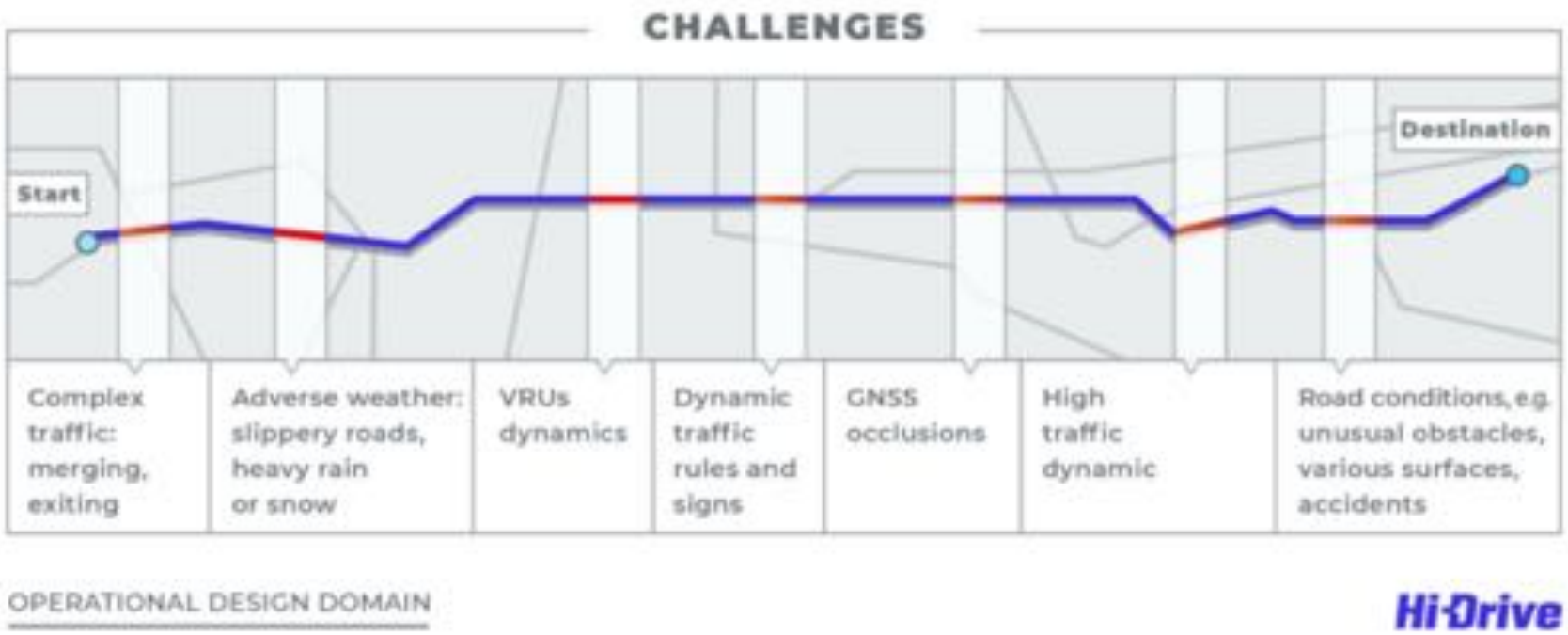
Hi-Drive

Technology Enablers for CAD vehicles to operate in defragmented ODDs.

Extend and Defragment ODDs
Enablers Cards and KPIs
Connectivity & Digital Infrastructure
High Precision Positioning
Resilience to Cyber threats
Machine Learning for ADs

Hi-Drive Technology Enablers for defragmentation of Operational Design Domains



Hi-Drive Technology Enablers beyond vehicles' sensing

CONNECTIVITY

"THE SIXTH SENSE BEYOND SENSORS"

- DEFRAGMENT ODDS where vehicle sensors cannot sort out a driving context
- EXTEND ODDS where vehicle sensors cannot see
- ANTICIPATE ODDS EXIT/ENTRY with digital data from traffic infrastructure

HIGH PRECISION POSITIONING

"POSITIONING SHALL ALWAYS BE AVAILABLE"

- HIGH PRECISION POSITIONING sub-meter absolute positioning
- LOCALIZATION SENSOR FUSION HD Maps & vehicle / infrastructure sensors

Hi-Drive Technology Enablers: beyond vehicles' sensing

CYBERSECURITY OF V2X DATA

"TRUST IS THE THUMB UP OR DOWN"

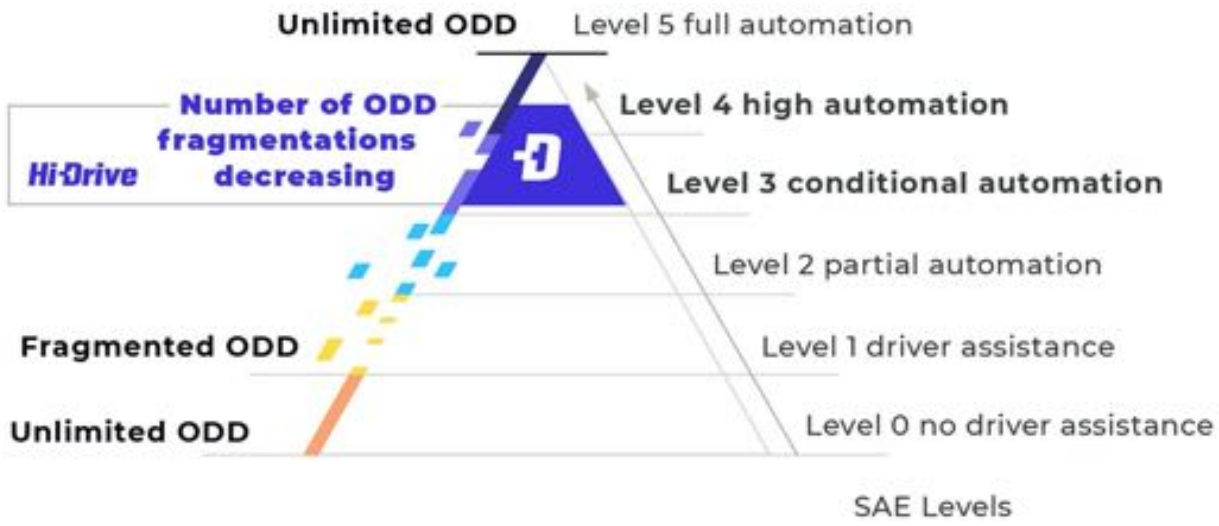
- THREAT ANALYSIS AND RISK ASSESSMENT for V2X data vulnerabilities
- CYBERSECURITY BY DESIGN RECOMMENDATIONS on V2X cyber-risks mitigation

CONTEXT LEARNING

"LEARNING FROM EXPERIENCE IS GROWTH"

- MACHINE LEARNING TOOLKIT semi-automatic annotation of road agents
- PERCEPTION OF ROAD AGENTS traffic scenario and road agents
- VEHICLE DECISION MAKING for manoeuvres and trajectory planning
- DRIVER MONITORING postures and distraction

Operational Design Domain – ODD

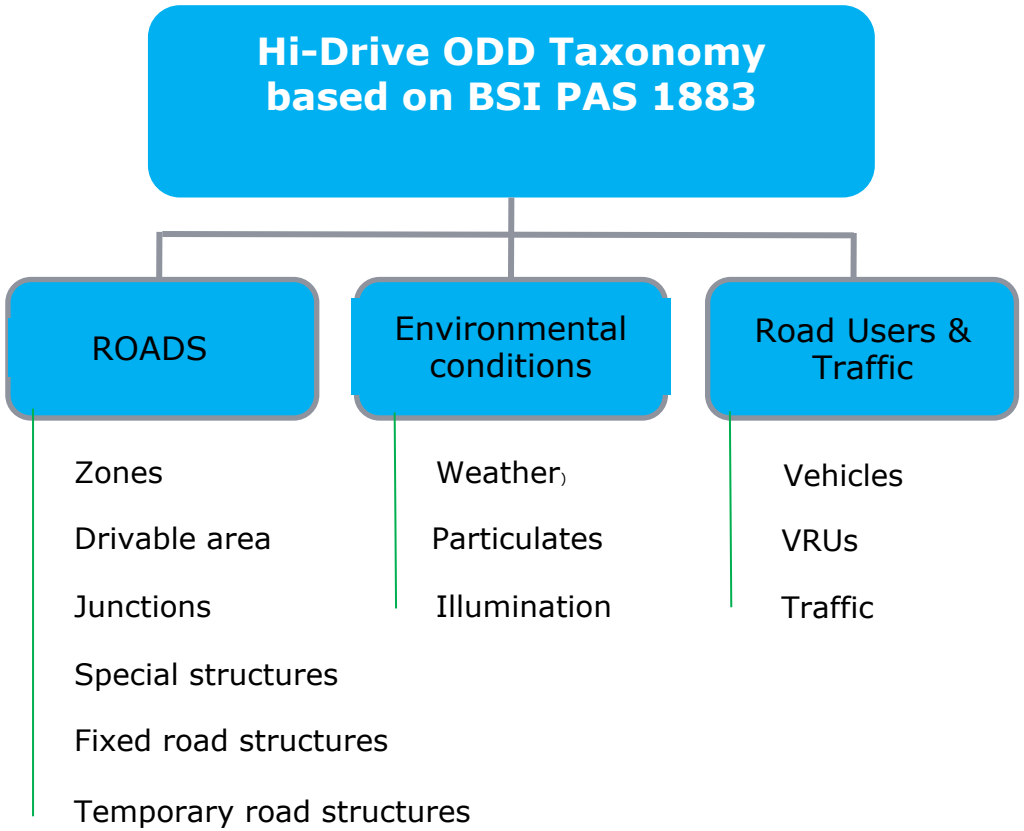


ODD - “Operating conditions under which a given driving automation system […] is specifically designed to function […] to environmental, geographical, and time-of-day restrictions, and/or the requisite presence or absence of certain traffic or roadway characteristics.” *

*SAE J3016 (2021)

Hi-Drive Operational Design Domains: work in progress

Work in course in the Hi-Drive Task Force led by ICCS



From Automated Driving Functions (ADFs):

About ODD attributes:

- Which specific ODD attributes are needed by ADFs?
- At which level of granularity are the ODD attributes needed?
- At which level of road coverage are the ODD attributes needed?

THANK YOU FOR YOUR KIND ATTENTION.

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Hi-Drive

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101006664.