Traffic Management for Connected and Automated Driving (TM4CAD)

Implementation Challenges

17 November 2022, Lisbon

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.

Deliverables and Milestones

Deliverables

- D2.1 - Report on ODD-ISAD architecture and NRA governance structure to ensure ODD compatibility, March 2022
- D3.1 - Information exchange between traffic management centres and automated vehicles - information needs, quality and governance, August 2022
- D4.1 - Report on technical implementation aspects of ISAD and ODD management use cases, January 2023
- D5.1 - NRA and traffic centre requirements for automated vehicles, March 2023

Workshops

- WS1: Project kick-off, refinement of working assumptions, 09/2021
- WS2: ODD/ISAD architecture proposal validation, 02/2022
- WS3: Vehicle manufacturers perspective workshop, 06/2022
- WS4: CEDR CAD WG R&D 2020 Initiatives, 06/2022
- WS5: TM4CAD implementation challenges, 09/2022
- WS6: Joint final event CEDR CAD WG R&D 2020 Initiatives, 03/2023

Workshop objectives

1. Introduce assumptions on information needs and quality related to information exchange between traffic management centres and automated vehicles;

2. Interactive discussion and review of use case examples for traffic management for connected automated vehicles;

3. Determine practical and technical implications for physical and digital infrastructure and Automated Driving Systems (ADS).

Agenda

13.30	Welcome, introductions, objectives of the meeting, logistics	Jaap Vreeswijk (MAPtm)
13.50	Information needs and quality related to information exchange between traffic management centres and automated vehicles	Risto Kulmala (Traficon)
14.10	Use case examples TM4CAD + discussion	Jaap Vreeswijk (MAPtm) Hironao Kawashima (Keio University)
15.10	Road operator perspective	Serge van Dam (Chair CEDR CAD WG, Rijkswaterstaat)
15.30	*Break*	
16.00	Operating scenarios for testing Automated Driving Systems in challenging conditions (HiDrive project)	Christina Anagnostopoulou, Angelos Amditis (ICCS)
16.20	AV Roadway Management in the US: opportunities for international learning & collaboration	William (Billy) Riggs (University of San Francisco)
16.40	Requirements to automated vehicle manufacturers and infrastructure evolution path + discussion	Sven Maerivoet (TML) Siddartha Khastgir (WMG) Steven Shladover
17.40	Wrap-up	
18.00	Meeting end	
19.30	Optional: joint dinner	

Importance of ODD in Cooperative Automated Driving (CAD)

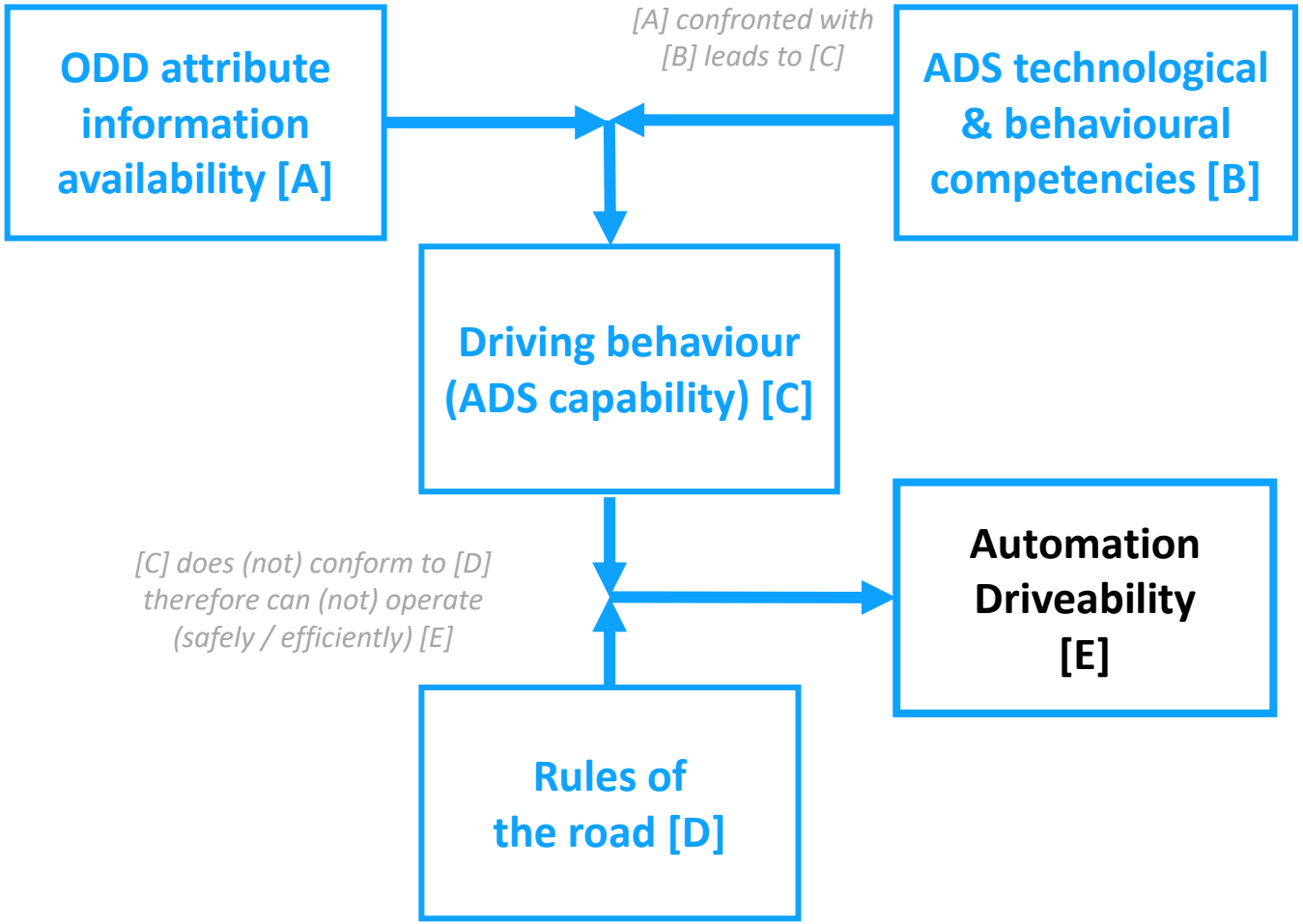
- At least as important as level of automation in determining CAD system functionality and complexity
- **Defined by each CAD system developer** based on their design constraints, not by any other entity
- **Different for every CAD system**, based on limitations of its technology
- To ensure safe operations, 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)

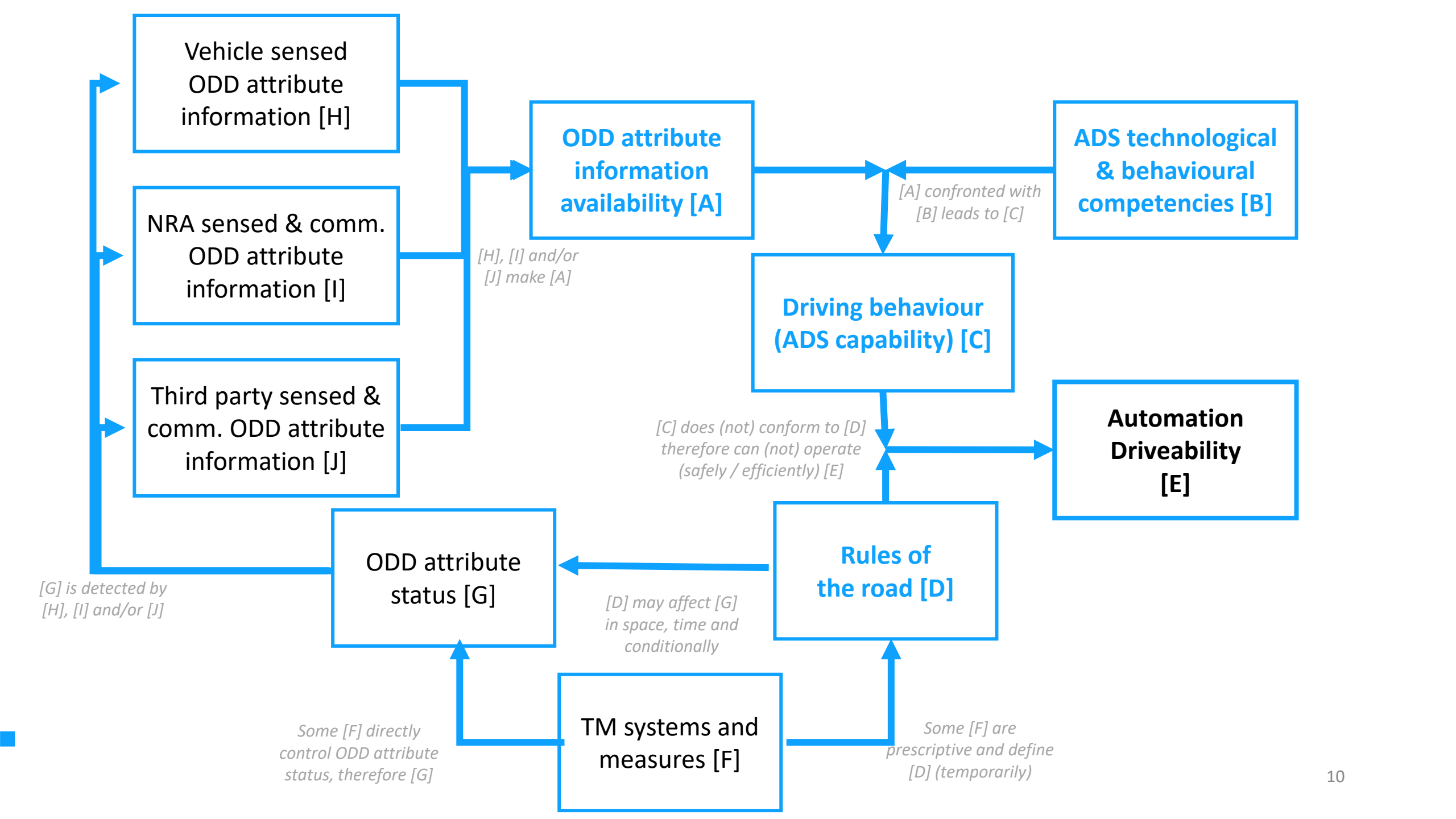
Need for real-time ODD awareness

- CAD system **continuously monitors ODD attributes** where it is operating to determine whether it can continue to operate
  - Safety cases and regulations 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
  - Situations beyond vehicle sensor range (~100 m)

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
  - Some can be detected by onboard sensors, within limited range
- Off-board measurements will require infrastructure investment
- Connectivity implicitly becomes a requirement, to inform CAD vehicles


ODD attribute information availability [A]
[A] confronted with [B] leads to [C]
ADS technological & behavioural competencies [B]
Driving behaviour (ADS capability) [C]
[C] does (not) conform to [D] therefore can (not) operate (safely / efficiently) [E]
Automation Driveability [E]
Rules of the road [D]


Vehicle sensed ODD attribute information [H]
NRA sensed & comm. ODD attribute information [I]
Third party sensed & comm. ODD attribute information [J]
ODD attribute information availability [A]
[H], [I] and/or [J] make [A]
ADS technological & behavioural competencies [B]
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Driving behaviour (ADS capability) [C]
[C] does (not) conform to [D] therefore can (not) operate (safely / efficiently) [E]
Automation Driveability [E]
Rules of the road [D]
[D] may affect [G] in space, time and conditionally
ODD attribute status [G]
[G] is detected by [H], [I] and/or [J]
TM systems and measures [F]
Some [F] directly control ODD attribute status, therefore [G]
Some [F] are prescriptive and define [D] (temporarily)

Traffic Management for Connected and Automated Driving (TM4CAD)

Information needs and quality related to information exchange between traffic management centres and automated vehicles

Risto Kulmala, Traficon

Objectives and scope

- 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?*
  - *RQ7: **How to define and measure the quality/correctness** of such information?*
- CEDR expectations on results:
  - *Determination of the **information needs and who is to provide this information** in the bidirectional interaction between TMC and vehicle;*
  - *Descriptions of the **properties of this information (availability, reliability, accuracy, detail, latency, standards, …)** and the required/desired reaction of the vehicles;*
  - *Integration of 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: ADS/scenarios/actors

- ADS <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

- Utilise the attributes of the DOA framework from TM4CAD (D2.1)
- 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	-	*	***	**	*	***	-	*	***

Validation of TM4CAD expert assessments

- Investigating 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
- Survey targeting OEM ADS developers
- OEM workshop 10 June 2022 Aachen
- CAD WG / PEB workshop 24 June 2022 Bern

Example: 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

Another example: 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

Information quality

- Build on EIP, EIP+ and EU EIP quality recommendation for traffic related information
- Complement with results of Finnish study
- Compile list of quality criteria
- Study quality wishes of ADS
- Propose quality recommendation with EU EIP C-ITS as starting point
- Propose quality measurement methods

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

Quality recommendations – Example

Quality Criteria for Distributed ODD Awareness Framework	Traffic jam dissolving	Adverse weather	Road works
Measurement accuracy	depends on indicator	depends on indicator	depends on indicator
Reporting accuracy	± 5%	± 10%	± 5%
Error Rate	< 2%	< 5%	< 2%
Classification correctness (non-false positives)	96%	92%	99%
Event coverage (true positives)	94%	90%	98%
Missed events (false negatives)	4%	5%	3%
Report coverage	97%	97%	97%

Observations on recommendations

- DOA recommendations usually higher than for conventional information or C-ITS
- Data transfer delay a new quality indicator
- Location accuracy, error rate, latency, timeliness
  - Higher than likely possible with roadside equipment alone
  - Need of vehicle-based data – for location accuracy the only option!

- For liability reasons, ADS will only utilize external data (not provided by in-vehicle sensors) that they trust
  - Data security, reliability, veracity

Quality monitoring and management methods

nr	Method
1	Continuous monitoring of equipment performance and availability
2	Manual verification of events or conditions
3	Reference testing of data collected
4	Time-space oriented reference test methods
5	Monitoring of data completeness and latency
6	Regular sampling of message or data content completeness and correctness
7	Verification and calibration of traffic / weather conditions prognosis
8	Surveys of perceived quality by users
9	Collection of direct user feedback
10	Monitoring of service use statistics

Conclusions

- Challenging quality and trust requirements for road operators
- Some practically impossible to meet without access to vehicle data, i.e. automated vehicles are also part of the solution
- The Hi-Drive results Q4/2022 are to be taken into account
- Update deliverable D3.1 by 03/2023
- Disseminate results to related projects
  - Horizon Europe CCAM
  - NAPCORE
  - CEDR Data Call 2022 projects

- TM4CAD Deliverable D3.1 *Information exchange between traffic management centres and automated vehicles – information needs, quality and governance*, Version 1.0, 23 October 2022
- Available at https://tm4cad.project.cedr.eu/

Traffic Management for Connected and Automated Driving

TM4CAD

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Traffic Management for Connected and Automated Driving (TM4CAD)

Implementation Challenges - Use case examples

Hironao Kawashima – Keio University

Jaap Vreeswijk - MAPtm

Use cases: ADS/scenarios/actors

- ADS <u>on motorways/highways:</u>
  - ALKS (L3)
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- In three scenarios:
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  - adverse weather
  - static/dynamic roadworks zone
  - tunnel closure
- With regard to three actors:
  - roadworks or (winter) maintenance operator
  - traffic manager
  - automated driving system developer/OEM

Other use cases from other projects

- INFRAMIX
  - Dynamic lane assignment (incl. speed recommendations)
  - Construction site / roadworks zone
  - Bottlenecks (on-ramps, off-ramps, lane drops, tunnels, bridges, sags)

- TRANSAID:
  - Prevent ToC/MRM by providing vehicle path information (rule breaking maneuvers)
  - Prevent ToC/MRM by providing speed, headway and/or lane advice
  - Prevent ToC/MRM by traffic separation
  - Manage by guidance to safe spot
  - Distribute ToC/MRM by scheduling ToC's

- C-Roads
  - Automated Vehicle Guidance: SAE level guidance
  - Automated Vehicle Guidance: Platoon support for automated vehicles

Use cases – objective perspective

- Safety perspective – short term – safe introduction of ADS
  - Avoid unsafe driving behaviour and/or too many (late) disengagements
- Facilitating perspective – medium term – support safe operation of ADS
  - Help ADS to overcome OD (awareness) limitations
- Operations perspective – longer term – better compliance through ADS
  - Manage traffic volumes and traffic flow dynamics

Use cases – situational perspective

- Locations
  - Pre-defined road sections (e.g. tunnels, merging areas, road work zones) are excluded from the usable OD
- Conditions
  - Local condition is present in an area or road section which is a known operational limitation / safety risk for ADS
- Location-conditions
  - Pre-defined road sections are excluded from the usable OD when certain conditions are present (e.g. darkness, heavy traffic, narrow lanes)

Use cases – NRA instruments perspective

- Regulation (pre-trip)
  - “ADS not allowed in tunnels” or “ADS not allowed in case of fog”
  - “ADS shall be able to act safely in all (e.g. weather or traffic) conditions”
  - “ADS shall comply to (e.g. access) constraints set by the road operator”

- Operations (on-trip)
  - Regular signage
  - Provision of digital information (e.g. C-ITS, DATEX, Digital Twin)
    - Local conditions (e.g. weather, traffic jams, work zones)
    - Driving instructions (e.g. speed management, lane closure)
    - Guidance information (e.g. path information, traffic separation)

What are some of the implications?

- Specify in regulation the locations that are excluded
- Specify in regulation the conditions that are excluded
- Specify in regulation the basic rules of the road (incl. constraints set by RO)
- Specify in regulation the minimal driving performance expectations

- NRA and ADS developers seek agreement on information need
- NRA and ADS developers seek agreement on quality requirements

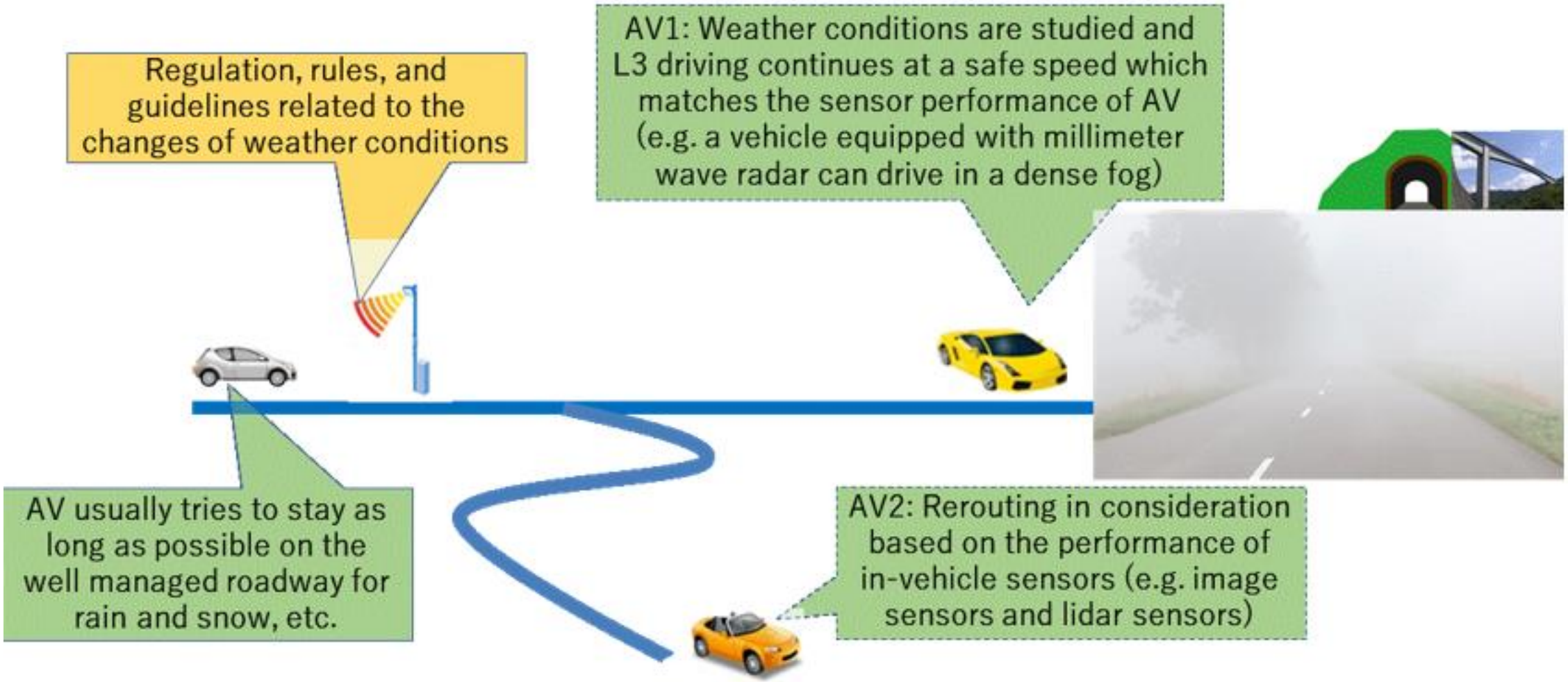
- Digital road operator is “OD-aware”
  - Has a wider view of the network than vehicle sensors have and monitors critical OD attributes (values)
  - Is able to predict these values and foresee critical hotspots/level of service
  - Publishes information through signage and digitally

Basic Assumption

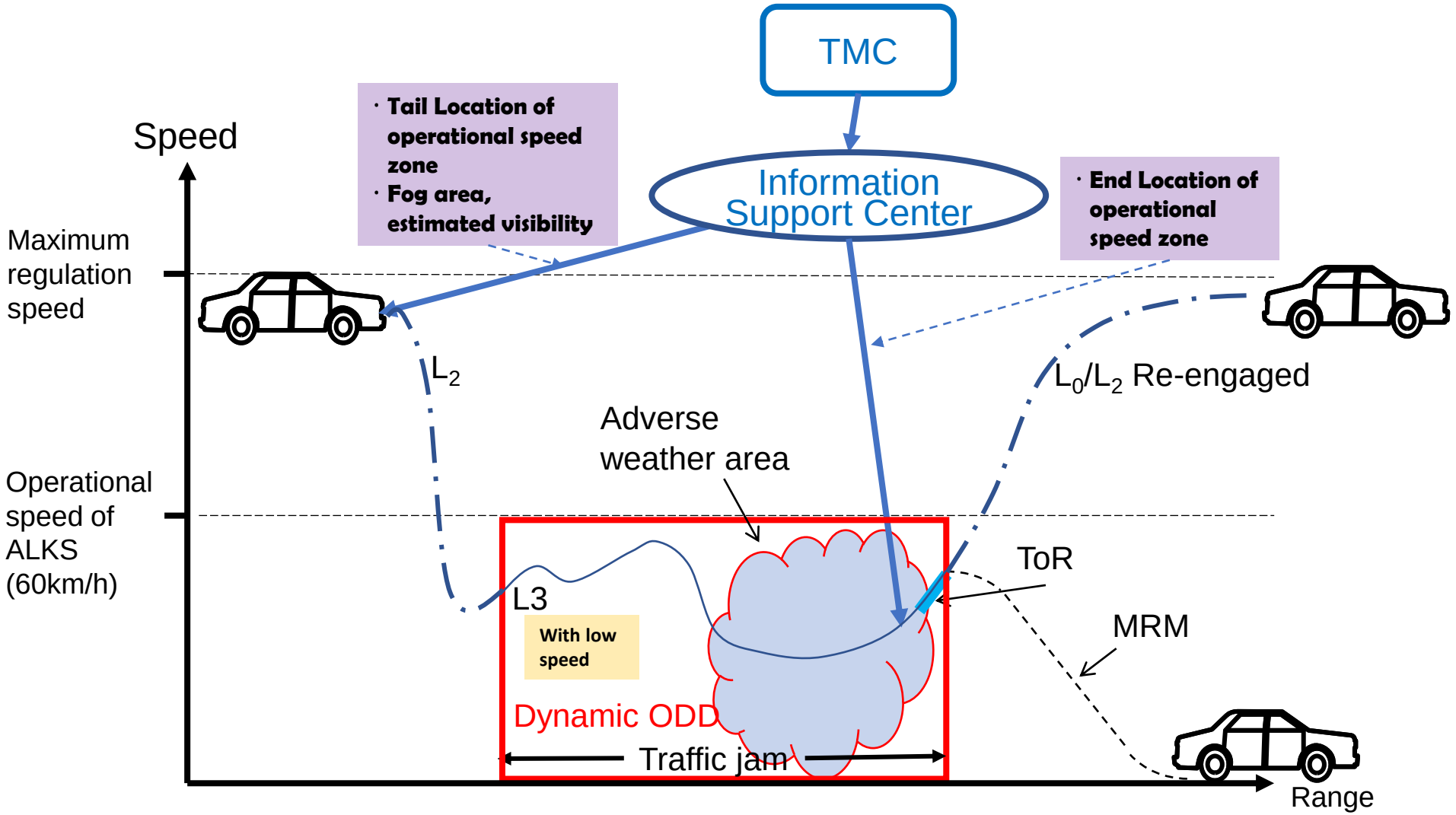
AV has operational scenarios for the travel. This implies that ODD attributes are selected from DOA to form ODD conditions and ODD condition is specified by parameters such as speed range, deceleration and acceleration limits, payload, for example. The scenario based approach is proposed by the patent (Pub. No: US 2021/0387647 AI, and ODD are called “Permissible ODD”.

Partitioning of DOA to subsets corresponding to use cases and traffic situations.

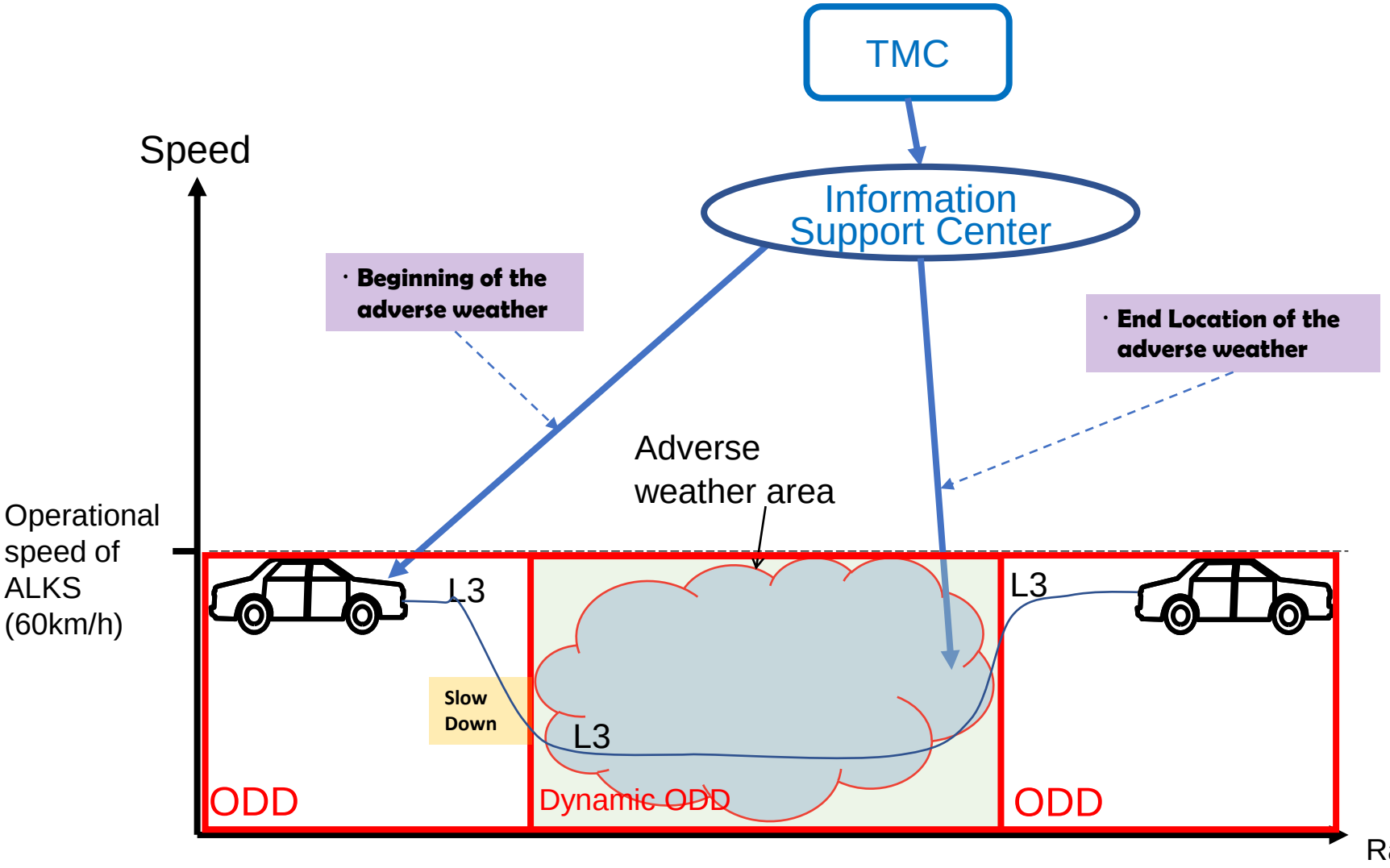
1. Infrastructure change
2. Roadworks
3. Adverse weather
4. Route change



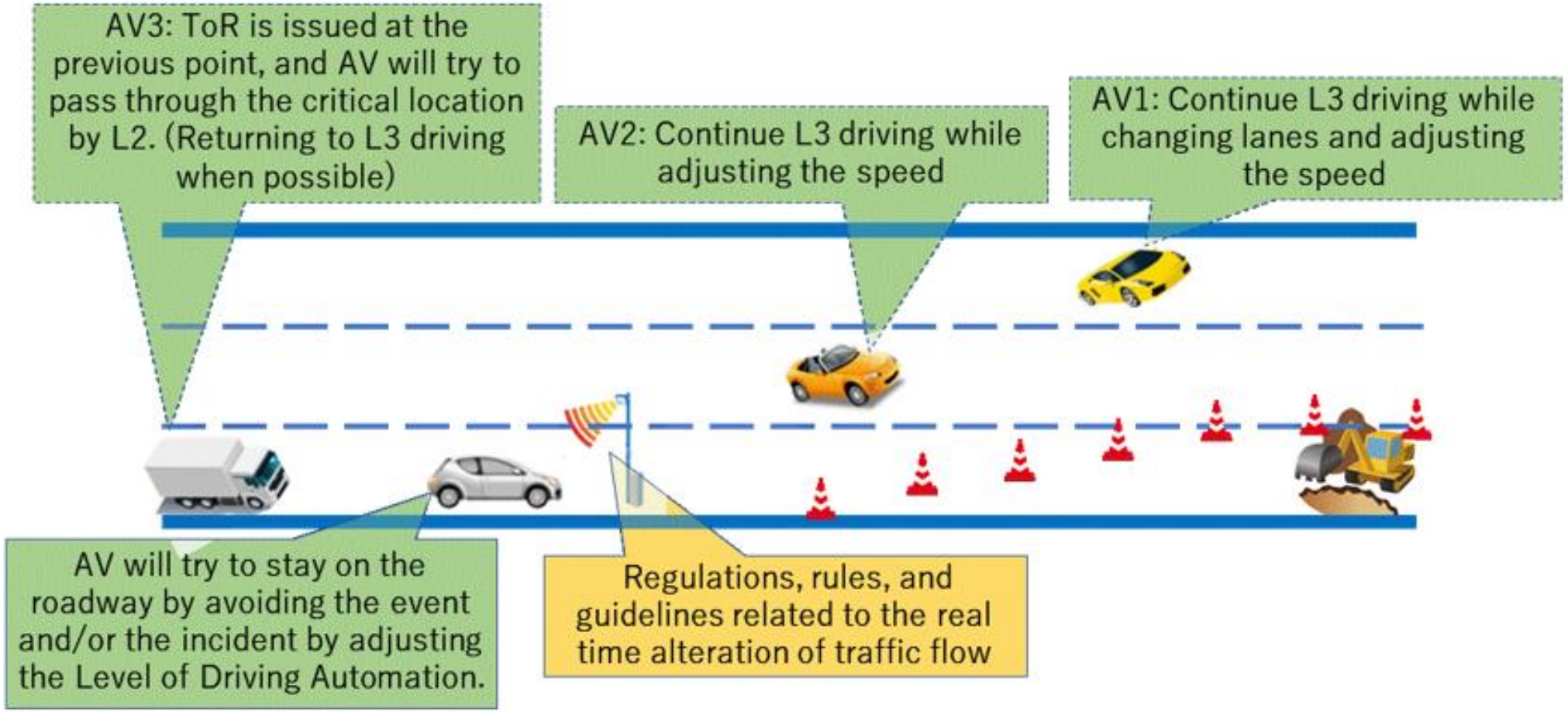
Provision of Information concerning weather conditions and the decisions made by AVs corresponding to DOA_{BW}
(which lasts for hours and at a very wide area)



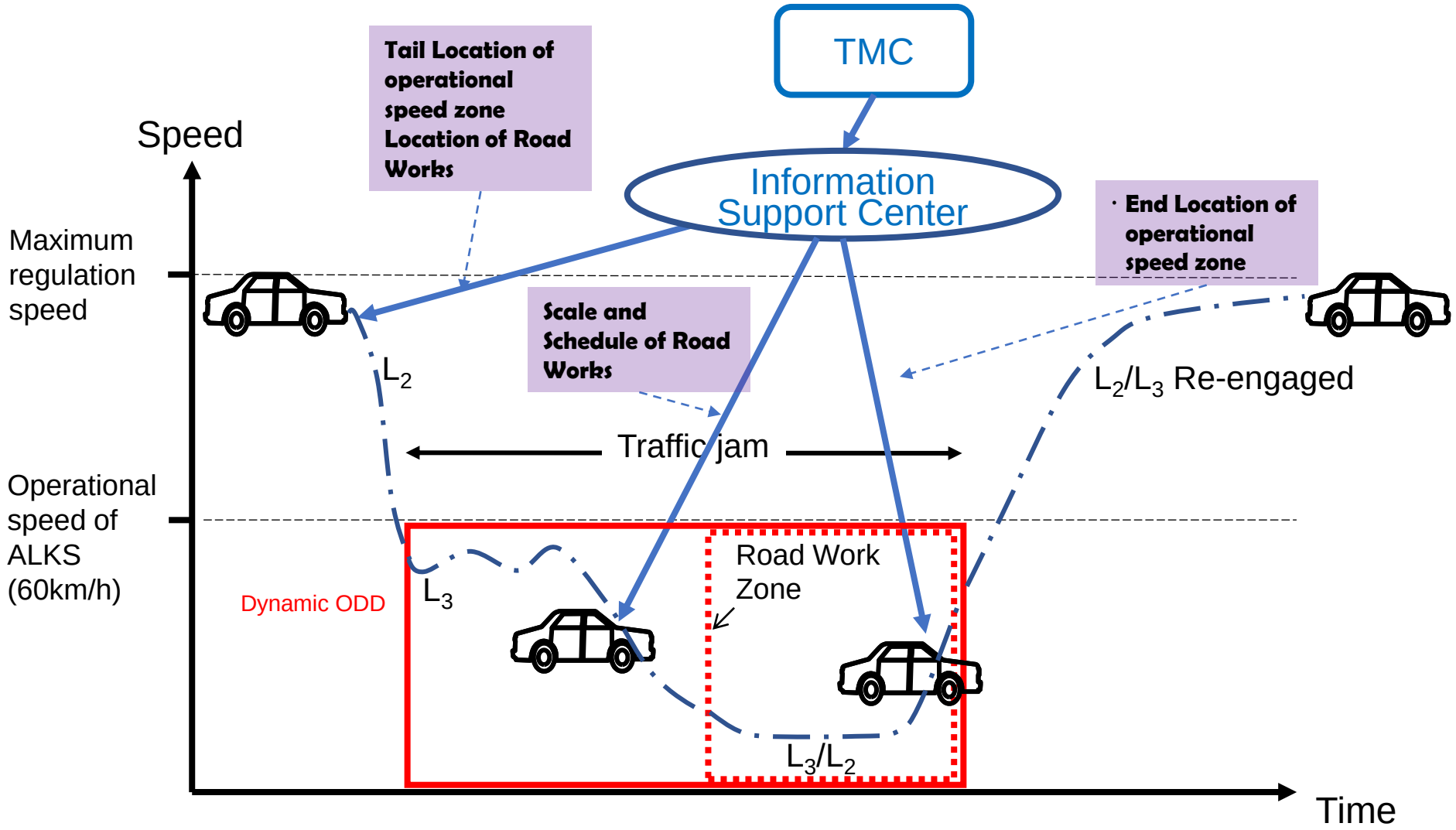
Schematic depiction when Dynamic ODD Management is necessary in the case of adverse weather in combination with traffic jam and its dissolution : an example of an ADS with L_3 capability (ALKS) only at low speed. According to the current regulation is possible after L_0



Schematic depiction when Dynamic ODD Management is necessary in the case of adverse weather in combination with traffic jam and its dissolution : an example of an ADS with L3 capability (ALKS) only at low speed. According to the current regulation the speed changes at the beginning and the end of adverse weather is not possible.



Provision of Information concerning events and incidents and the decisions made by AVs corresponding to DOA_{RW}
(regarding to traffic situation which lasts for relatively short period of hours and relatively short sections)



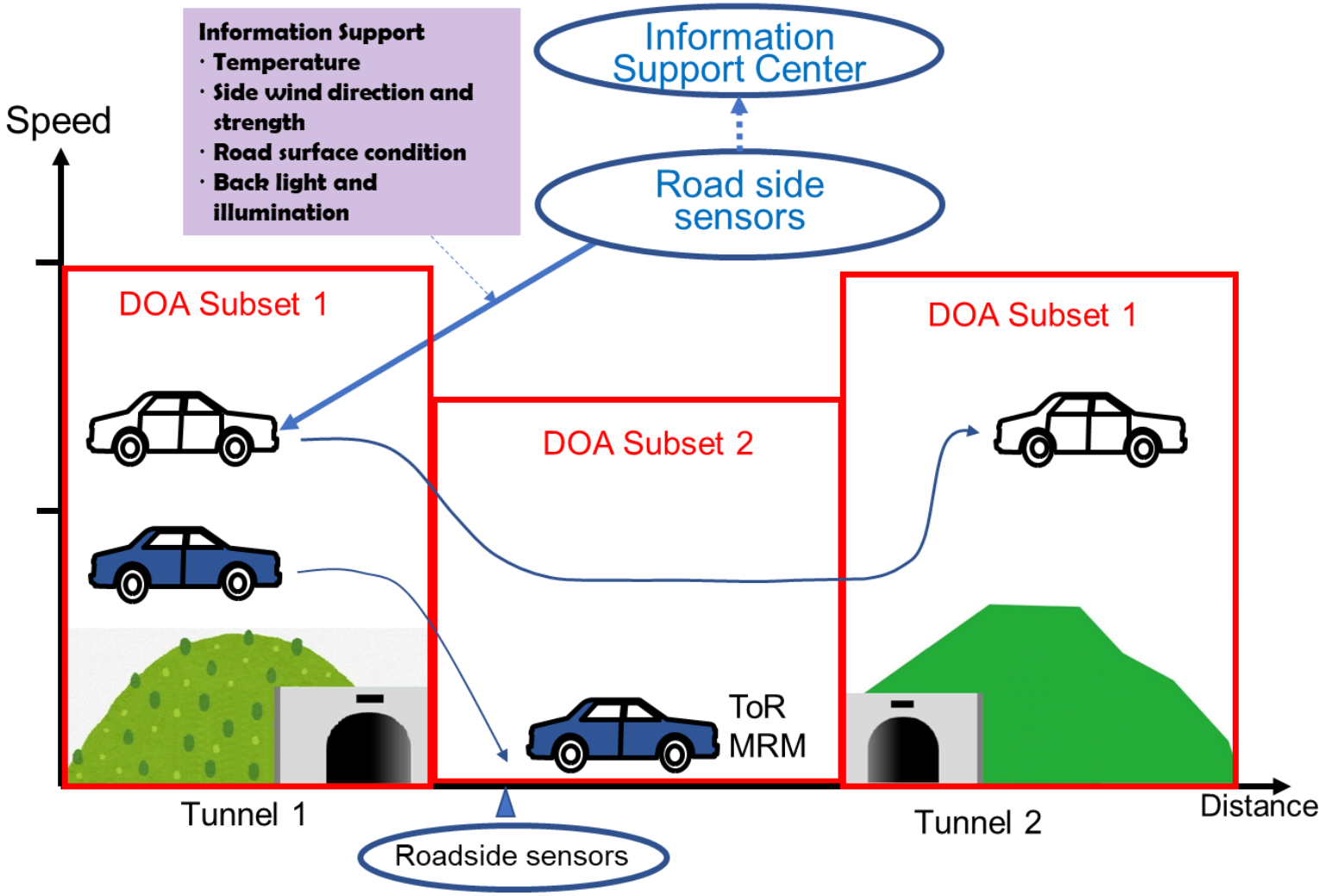
Schematic depiction when Dynamic ODD Management is necessary in the case of road works in combination with traffic jam and its dissolution : an example of an ADS with L_3 capability (ALKS) only at low speed and sufficient information from infrastructure. According to the current regulation the speed change at L_3 and transition to L_2 are possible after L_0.

Location based ODD management by AV and the necessary support from infrastructure.

At the location where multiple tunnels exist, ODD values for AV changes drastically.

For example, inside the tunnel the temperature is stable but the lens of in-vehicle camera might be misted when AV reaches to the exit of the tunnel where the temperature is very low.

The following schematic chart is the conceptual model to assist AVs when ODD values change at the exit of tunnel.



A new concept of traffic management when AVs are involved

- Elements of Information Support for realizing the ODD Management for AV

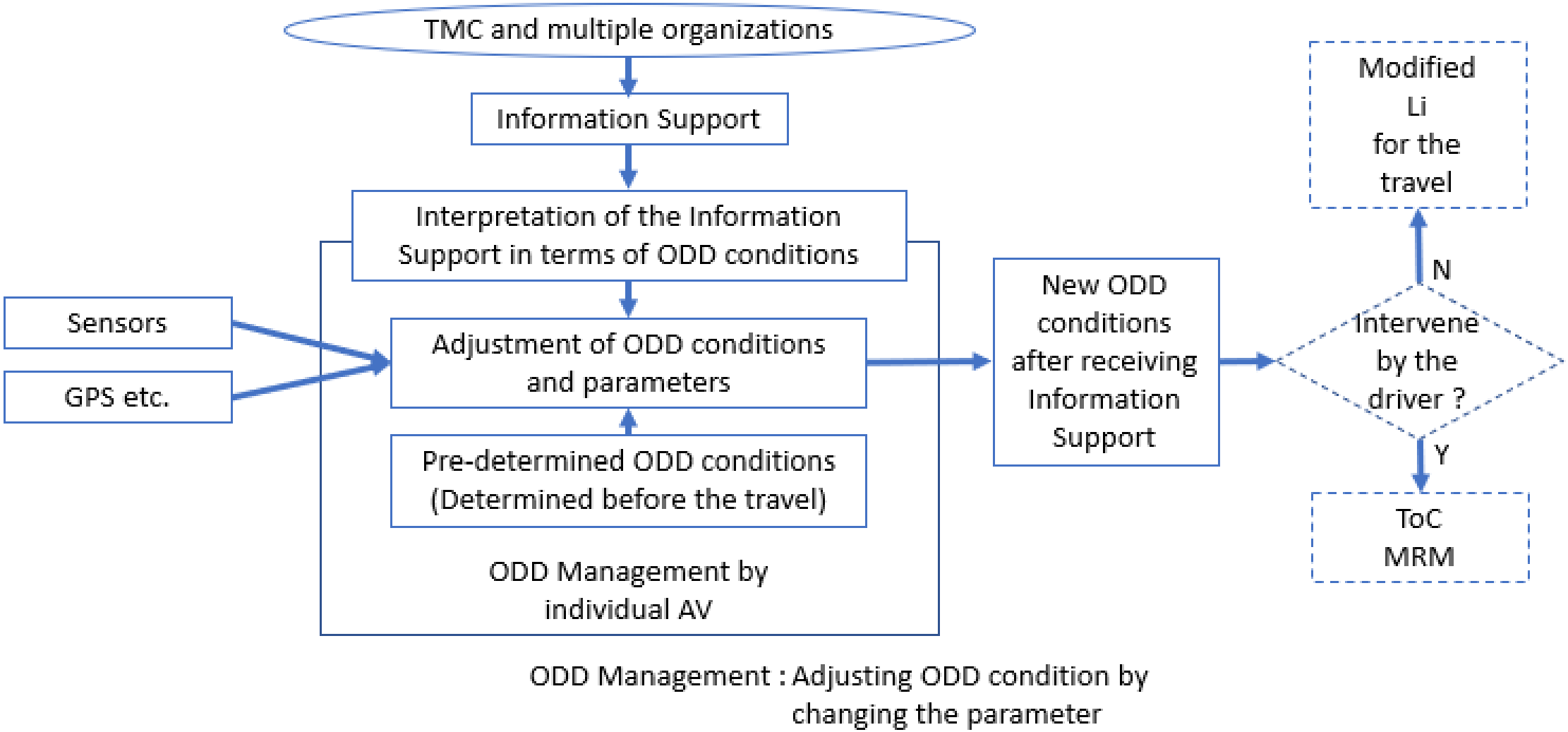
1. Sources of the Information Support
   - TMC of the region
   - Weather Bureau (National Weather Service)
   - Meteorological Agency
   - Regional traffic information service
   - V2I information and V2V2I information

2. Possible organization to transmit the Information Support
   - TMC
   - Management Center of OEM
   - Management Center of private third party
   - Management Center of public and private sectors

- Elements of introducing the interpretation mechanism for realizing the ODD Management for AV

1. Outline of the interpretation mechanism
   - Corresponding of the Information Support with the ODD conditions
   - Amend the ODD parameters based on the given ODD conditions
   - If the Information Support indicates the need to amend ODD conditions outside of the given conditions, then select or combine the DOAi and identify the new ODD conditions and parameters if possible and if not possible recommend manual driving.

2. Possible organization to conduct the interpretation
   - AI of AV
   - Management Center of OEM
   - Management Center of private third party
   - Management Center of public and private sectors



Conceptual Model for Dynamic ODD Management of individual AV whenever the Information Support is provided

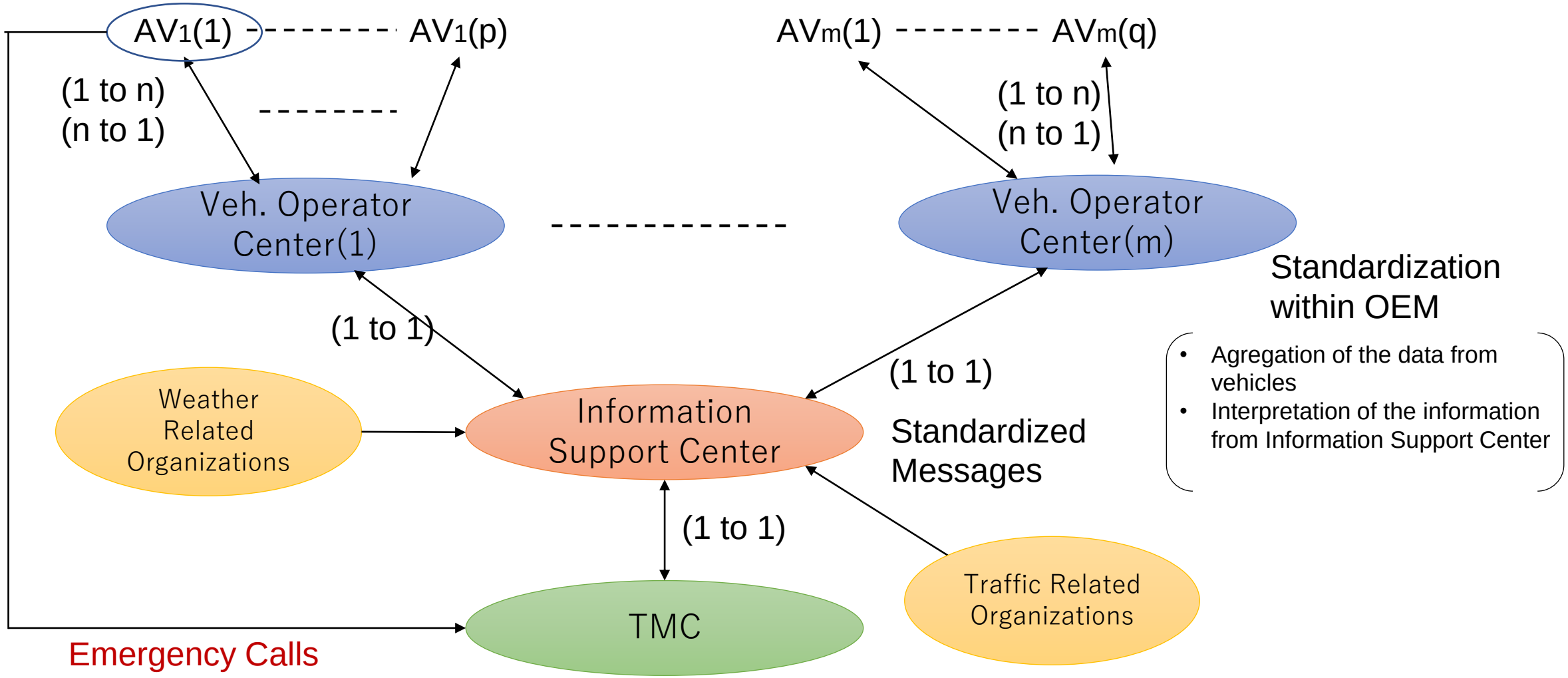


Figure Hypothetical structure for message exchanges between AVs and TMC

Objectives of the discussion

- Discuss use case examples and categorisation
- Find common views on basic mechanisms and instruments
- Determine practical and technical implications for NRAs and ADS developers

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CEDR
Conférence Européenne
des Directeurs des Routes
Conference of European
Directors of Roads

Presentation for TM4CAD on 17.11.2022
by

CEDR Connectivity, Automation & Data Working Group

Conférence Européenne des Directeurs des Routes
Conference of European Directors of Roads

NRAs' CONCERNS ABOUT ALKS

MH

- **Level 3/partial automation:** This requires very clear agreements on humans as a fallback option (especially for unplanned takeovers)
- **Unplanned Transition of Control (ToC):** It is currently unclear how manufacturers will deal with an unplanned takeover from system to human
- **Minimal Risk Condition (MRC) / Minimal Risk Maneuver (MRM):** It is currently unclear what these two will look like in real life. However: a full stop in lane in running traffic is undesirable
- **Geofencing of ODD:** The vehicle will need to be able to judge whether it is inside or exiting the ODD. At present, it is still unclear how manufacturers will monitor this, what information this will require, and whether they will be able to limit the availability of the system based on geographic location
- **Sensor horizon (forward detection range):** at higher speeds (up to 130 km/h), it become crucial that the system can anticipate the conditions and pro-actively act appropriately or transfer control in time

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CHALLENGING SCENARIOS FOR AVS REGARDING ACTIVATING/DE-ACTIVATING AUTOMATION FUNCTIONS

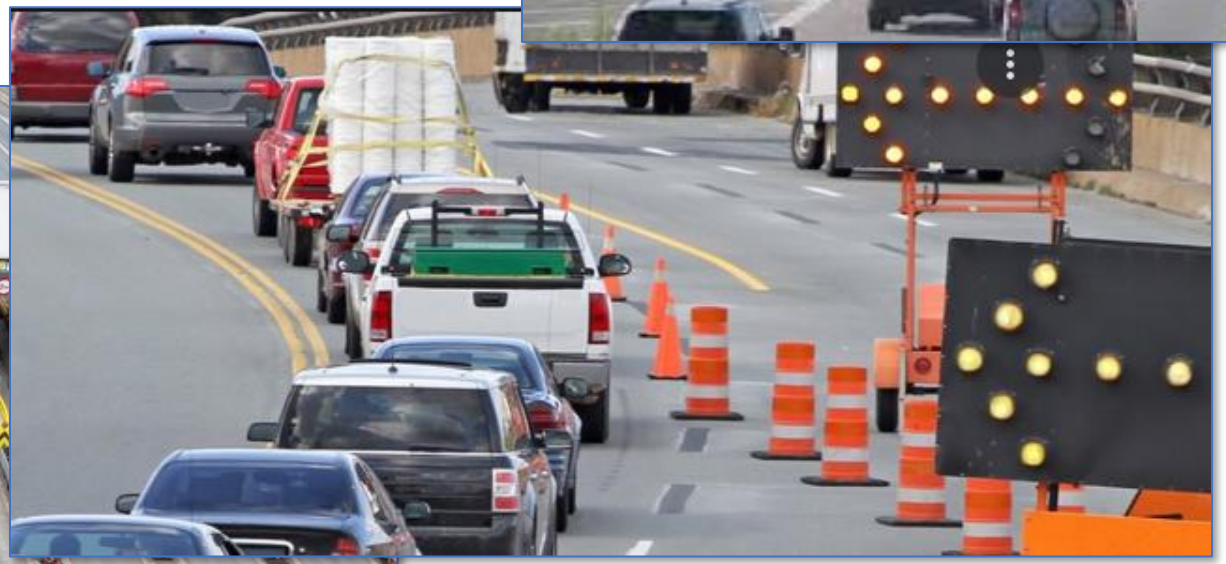
MH

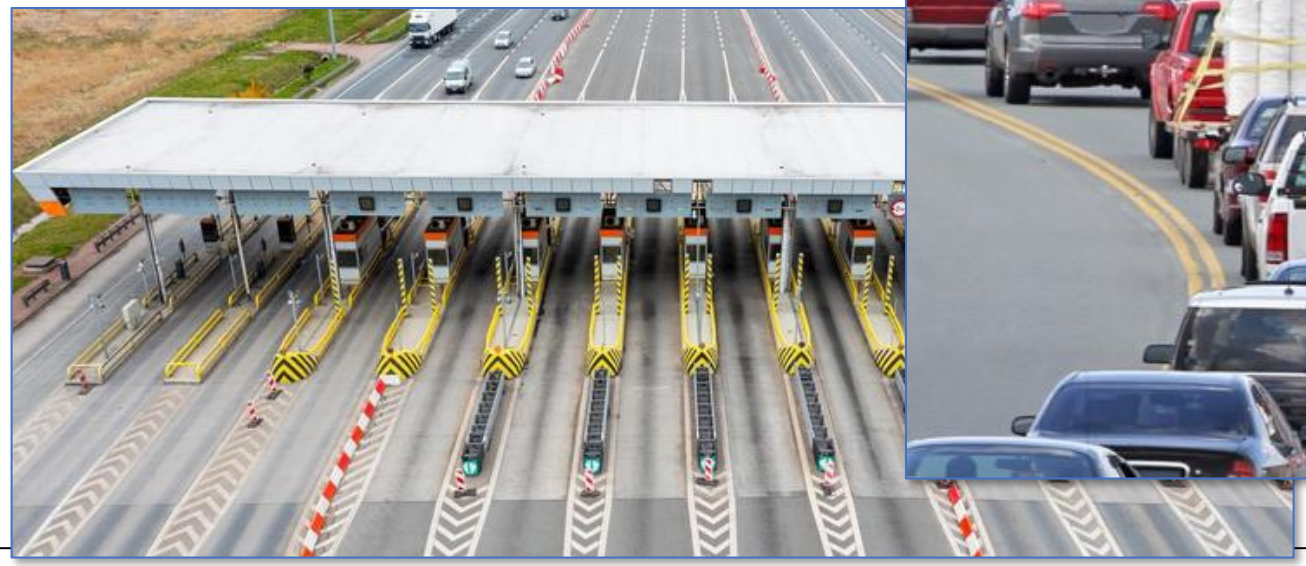
- Roadworks (short-/longterm)
- Tunnels (under/over 500m)
- Incidents (accidents, carriageway / lane closures, diversions, etc.)

CHALLENGING SCENARIOS FOR AVS REGARDING ACTIVATING/DE-ACTIVATING AUTOMATION FUNCTIONS

MH

- Toll gates
- Bridges with reduction/expansion of lanes
- Network node, access/exit, merging section, etc.





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Challenging scenarios for AVs regarding activating/de-activating automation functions

MH

- Weather conditions
- Road conditions
- Road marking quality and differences
- … many more

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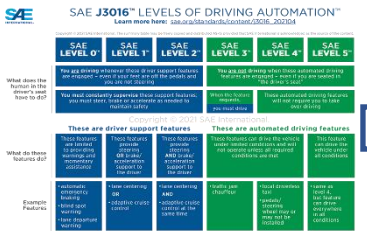
EXTENDED
ODD / INFRASTRUCTURE / USER INTERACTION

Operational Design Domain

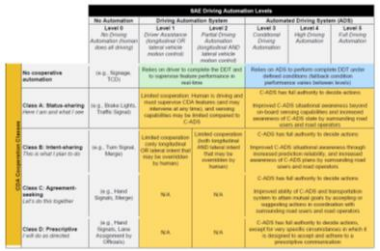
Infrastructure Suitability

Automotive Industry

Road Operators

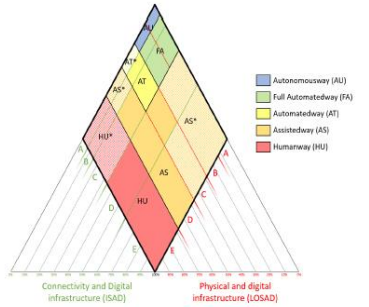


Levels of Driving Automation – SAE J 3016

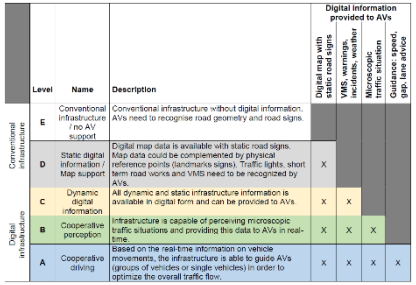


Cooperation classes – SAE J 3216

Levels of Service for Automated Driving



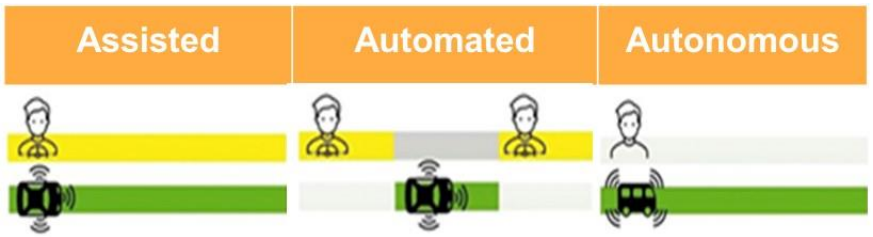
Infrastructure Support for Automated Driving



Level	Name	Description	Digital information provided to AVs: Digital map with static road signs	VMS, warnings, incidents, weather	Microscopic traffic situation	Guidance speed, gap, lane advice
Conventional infrastructure	E	Conventional infrastructure / no AV support	Conventional infrastructure without digital information. AVs need to recognise road geometry and road signs.				
Digital infrastructure	D	Static digital information / Map support	Digital map data is available with static road signs. Map data could be complemented by physical reference points (landmarks signs). Traffic lights, short term road works and VMS need to be recognized by AVs.	X			
	C	Dynamic digital information	All dynamic and static infrastructure information is available in digital form and can be provided to AVs.	X	X		
	B	Cooperative perception	Infrastructure is capable of perceiving microscopic traffic situations and providing this data to AVs in real-time.	X	X	X	
	A	Cooperative driving	Based on the real-time information on vehicle movements, the infrastructure is able to guide AVs (groups of vehicles or single vehicles) in order to optimize the overall traffic flow.	X	X	X	X

Users

User Communication



PRE-DEVELOPMENT / RESEARCH & INNOVATION STAGE

- The existing infrastructure is either physical (tunnels, bridges, etc.) or digital (connectivity, networks) while ODD is a concept with physical and digital characteristics
- Infrastructure can support automated driving (ISAD) by enabling broader ODDs
- ODD corresponds with infrastructure suitability (which involves elements of physical and digital infrastructure)
- Major R&I goal is to get to link ODD directly with ISAD
- To achieve that, NRAs have already successfully worked with OEMs e.g. in CCAM platform on these ISAD/ODD clarifications

➡ Cooperative and connected systems require cooperative and connected stakeholders!

CEDR
Conférence Européenne des Directeurs des Routes
Conference of European Directors of Roads

Thank you for your attention!

For further engagement and information, please contact:

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Rijkswaterstaat
Ministerie van Verkeer en Waterstaat

ASFINAG

Operating scenarios for testing Automated Driving Systems in challenging conditions

Anastasia Bolovinou, **Christina Anagnostopoulou**, Hendrik Weber, Innamaa Satu, Johannes Hiller, **Angelos Amditis**, Jean Louis Sauvaget

CEDR TM4CAD 5th Workshop

17th November 2022, Lisbon

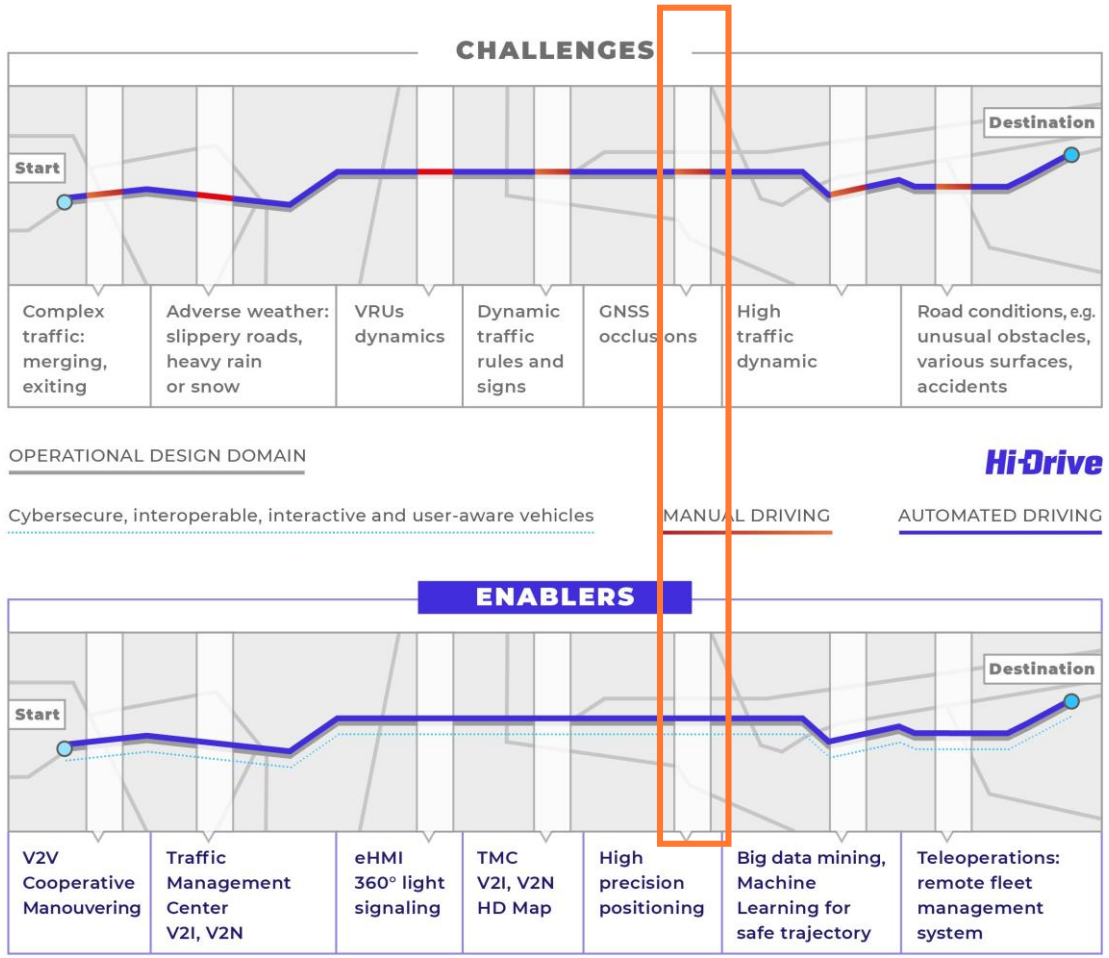
Intro: Hi-Drive project objectives

Scope

- Successor of the EU-funded project L3Pilot
- Extend the ODDs and reduce the frequency of the takeover requests by selecting and implementing technology enablers.
- Interoperability across countries and brands

Means

- Advance the state of the art of Automated Driving (AD) technologies.
- Test, demonstration, and evaluation of robust high automation functions.
- Builds on extended and continuous Operational Design Domains (ODDs).



Hi-Drive Operations

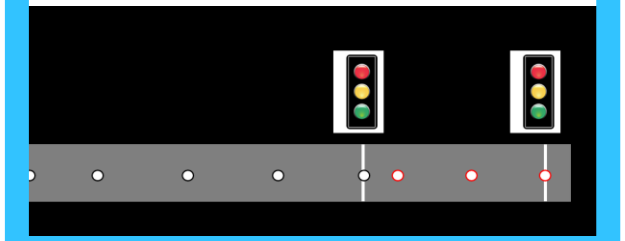
Test tracks

Open roads testing

…challenging ODDs

Virtual

… generation synthetic data for testing the enablers



Intro: Hi-Drive types of experiments

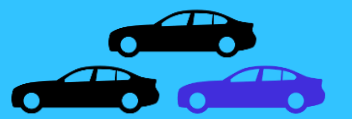
Hi-Drive new technology component (**Enabler**)

Advanced AD function

- **Connectivity (V2X)**
- **High-precision positioning**
- **Context learning via ML**
- **Cybersecurity**

Pilot studies

Test on public road
incl. manual driving, automated driving with enabler on/off)



Enabler tests

Tests in closed / controlled environments.

User focused studies

Different types of user oriented studies
Simulator, test track, public roads, etc.

Simulation

Impact Assessment studies and Simulation based enabler tests.

From ADF description to Use Cases and Test scenarios

ADF description

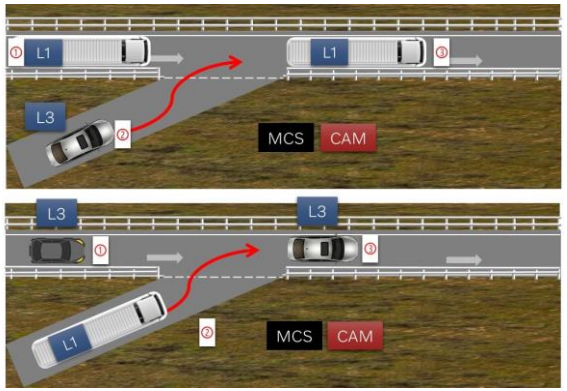
- **ADF ODD**
- **ADF capabilities**
- **ADF limitations**
- **ADF on-board HMI**

Four ADF types are considered: Motorway, Urban, Rural and Parking

Image © 2022 Euro NCAP

Use Cases

- **Short description**
- **Type of ODD extension (opt.)**
- **Execution domain**
- **Evaluation area**



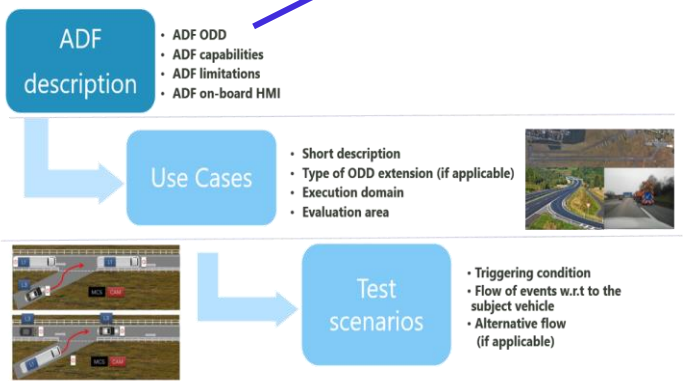
Test scenarios

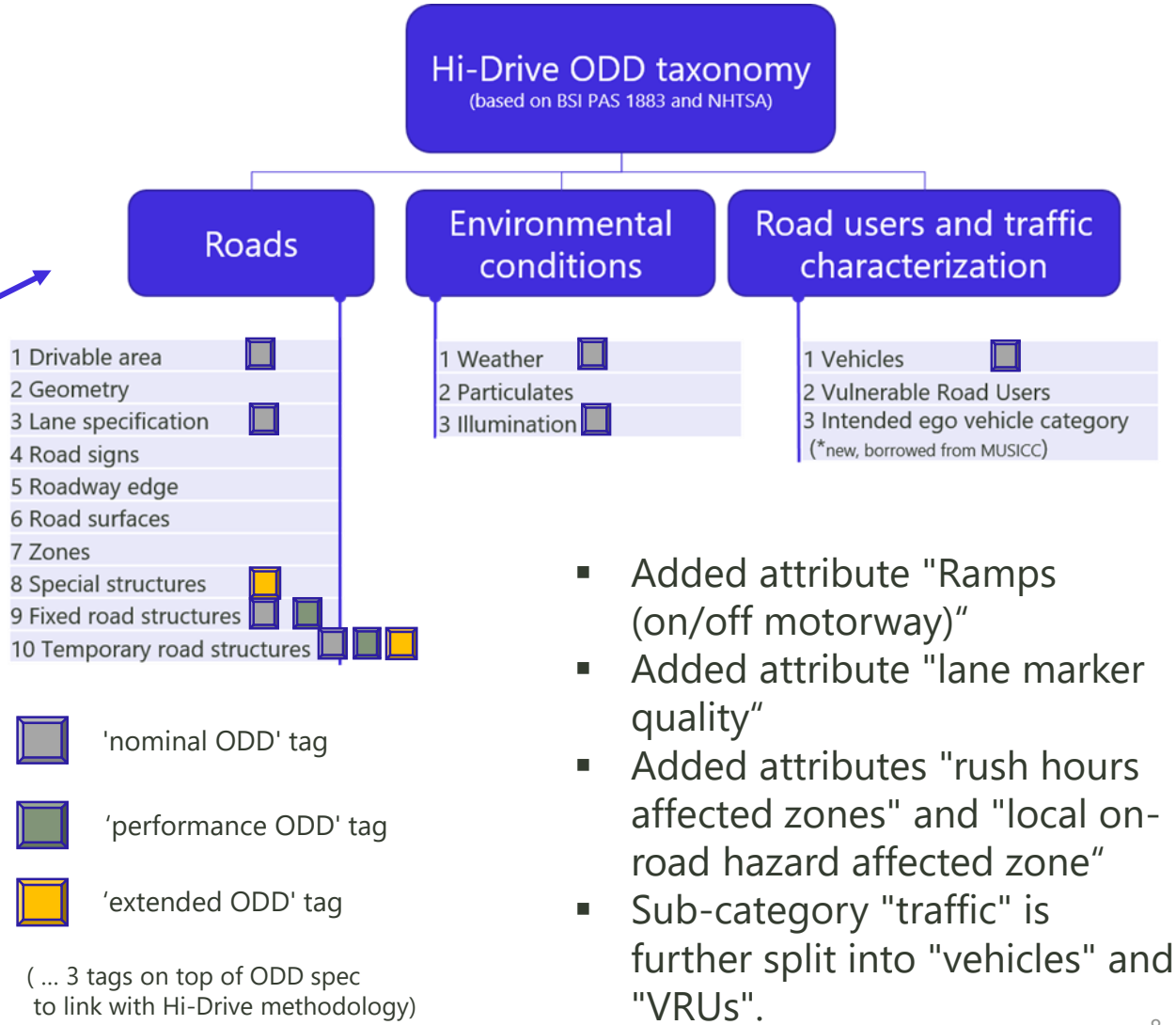
- **Triggering condition (per ISO 34502 draft guidelines)**
- **Flow of events w.r.t the subject vehicle**
- **Alternative flow (if applicable)**

Hi-Drive

Specifying ODD for Hi-Drive purposes

- Light adaptation of BSI PAS 1883
- Combining elements from
  - SAE AVSC and
  - MUSICC project





(… 3 tags on top of ODD spec
to link with Hi-Drive methodology)

- Added attribute "Ramps (on/off motorway)"
- Added attribute "lane marker quality"
- Added attributes "rush hours affected zones" and "local on-road hazard affected zone"
- Sub-category "traffic" is further split into "vehicles" and "VRUs".

ODD spec extract

_Drivable area		
a) Motorway roads		
	with active traffic management (smart motorways);	
	without active traffic management.	**X**
b) Ramps (on/off motorway)	**X**	
c) Radial roads		
d) Distributor roads		
e) Minor roads		
_Road surfaces		
a) Dry	**X**	
b) Damp	**X**	
c) Wet	X	
d) Snow-covered		
e) Icy		
f) Leaves		
g) presence of holes in the asphalt		
h) type		
	i) uniform (e.g.asphalt)	**X**
	ii) segmented (e.g. cobblestones)	

- X indicates ODD extension to be tested
- X indicates (nominal) ODD
- **X** indicates (nominal) ODD to be tested

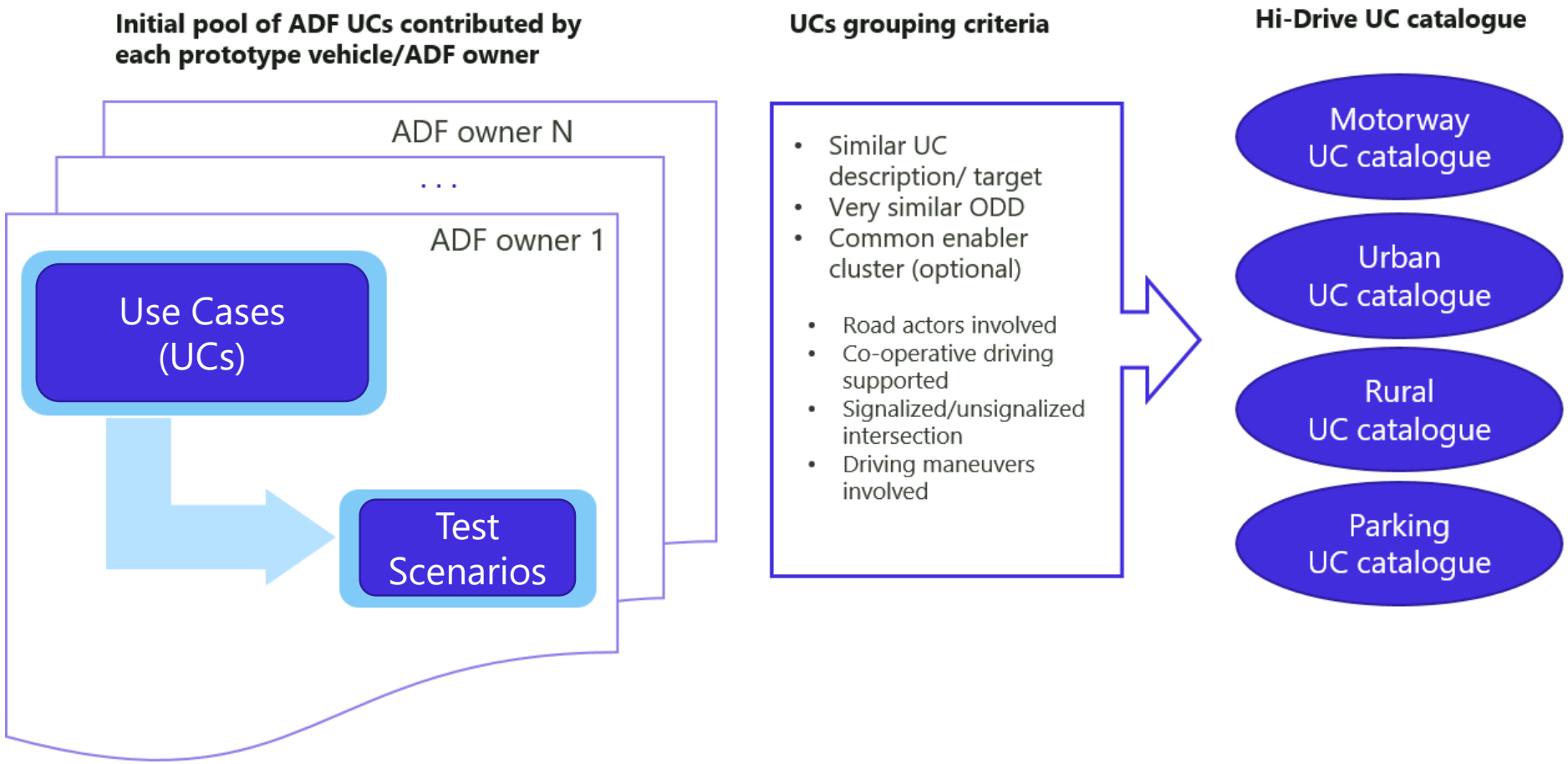
Additional info (part of Hi-Drive ADF description):

Special ODD conditions to be tested (Y/N)	**Testing ODD transition (e.g., weather turns from sunlight to snow) : Yes** **Testing ODD new attribute that was not handled before (e.g., motorway on-ramp entry) : Yes** **Testing ODD violation (e.g., deteriorate lane markings) : No**

ODD extension types

	ADF type				
ODD extension type	**Motorway**	**Urban**	**Rural**	**Parking**	**ODD attributes considered in ODD "extension" (indicative)**
On-ramp	8	1	0	0	Drivable Area/Ramps/on_ramp
Off-ramp	6	0	0	0	Drivable_Area/Ramps/off_ramp
Temporary or special road structure or road hazard	5	8	0	0	Drivable_area/Intersection/unsignalized; Drivable_area/roundabout SpecialStructure/BridgeAbove; SpecialStructure/Tunnel; TemporaryRoadStructure/road works Local on-road hazard/traffic_inc Local on-road hazard/unusual_object Road signs/dynamic_signage
Challenging environmental condition (heavy rain or snow)	1	5	1	0	Illumination/cloudiness Illumination/position_of_sun/in_front Rainfall/Moderate_Rain
Challenging road condition (e.g. deteriorate lane markings)	2	7	1	0	Geometry/Upslope; Geometry/Downslope LaneSpecificaiton/LaneMarkerQual/poor Road_surface/Damp RodwayEdge/solid_barriers Illumination/atrif_illum/strretlight;oncoming vehicle
New type of traffic agent (vehicle or VRU)	1	7	0	1	VRUs/Motorcycles
Visibility blockage due to traffic buildings or road furniture or other vehicle	2	1	1	0	Fixed road structures/buildings Fixed road structures//non_static_roadside_object (trashcan)
GNSS interruption	3	2	0	1	GNSS_loss (currently not in Hi-Drive ODD; part of ADF feature)
Traffic lights	1	2	0	0	V2I-connected traffic lights (currently not in Hi-Drive ODD; part of ADF feature)
Cross-border	1	0	1	0	V2I-weather info (currently not in Hi-Drive ODD; part of ADF feature)

Hi-Drive UC catalogue generation



An example of one UC cluster, one UC belonging to this cluster and associated test scenarios

Motorway/MtU UC catalogue

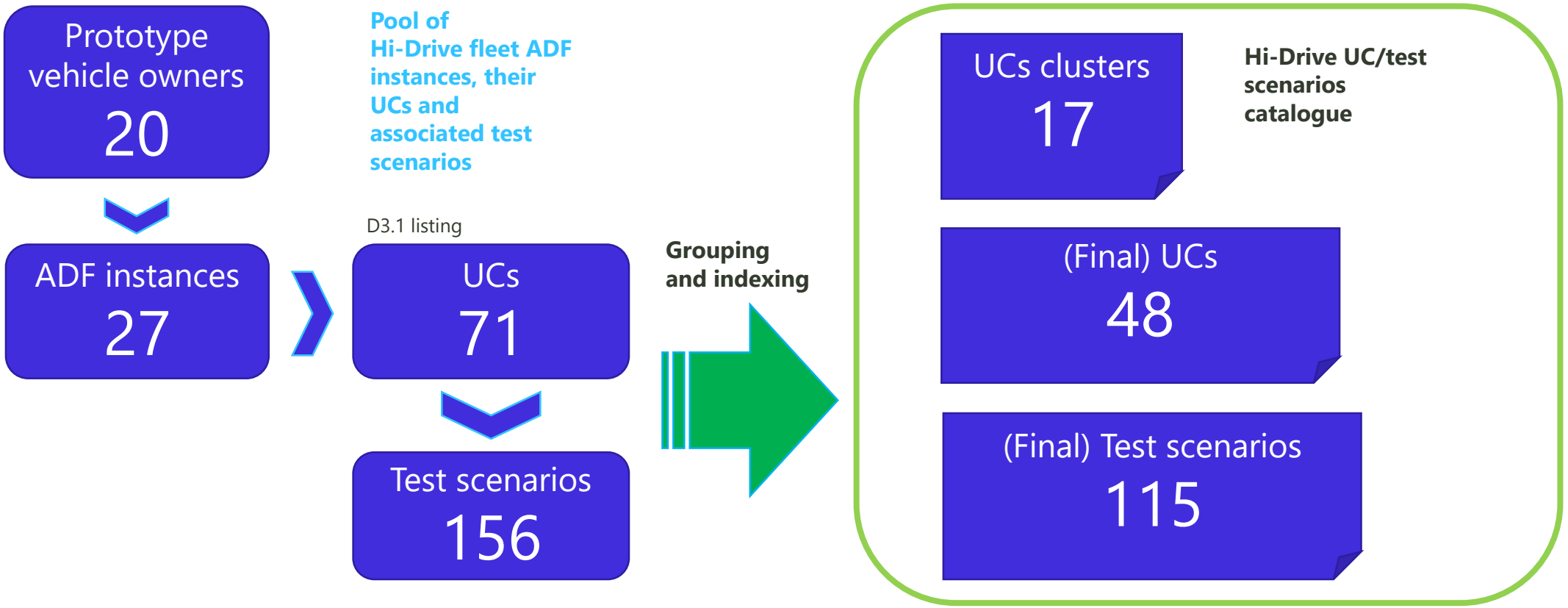
UC cluster	ID	Short Description	Associated enablers IDs	Test Scenarios (A "trigger" is here loosely defined as a driving environment condition change, e.g. ODD dynamic entities, actions by other traffic agents which then activates an action by the AV; w.r.t to open road tests, we are using the term "trigger" in a not strict manner: in reality, no actual trigger is pulled, changing of conditions simply do or do not occur)	ODD extension type (only if applicable)*	Test scenario execution domain
Cooperative lane merging/exiting /overtaking	UC.M.1	Cooperative Lane Merging on Motorway entry via V2V- **On-ramp** AD vehicle **(2 actors)**	E.2.3.1.a E.2.4.2.a (each enabler is tested independently)	**Trigger**: On-ramp vehicle sends merge request. 1. The motorway vehicle accepts the merge request and decelerates. The on-ramp vehicle merges. (supported by HYU-1, HYU-2, FEV, Honda) a. The motorway truck is notified with a warning to adapt its speed to support the merge request and decelerates. The on-ramp vehicle merges (supported by VCC for speeds up to 60kph). 2. The motorway vehicle rejects the merge request and continues without decelerating. The on-ramp vehicle merges after the motorway vehicle has passed (supported by HYU-1, FEV, Honda) 3. the motorway vehicle accepts the merge request and changes lane. The on-ramp vehicle merges (FEV is possibly supporting this motorway vehicle behavior) (supported by HYU-1 only)	▪ on-ramp	Controlled Track
			E.2.3.1.b			Controlled Track Virtual
			E.2.3.1.c			Controlled Track
			E.2.3.1.e			Controlled Track Virtual

Hi-Drive UC catalogue clusters

(17 clusters overall)

ADF type	UC cluster	Number of UCs
Motorway	**Cooperative** lane merging/exiting/overtaking	8
	Lane merging / exiting /interchange / lane changing	5
	Lane Keeping (different challenging scenarios)	5
	AD system identifies challenging operational domain condition or recognizes driver state	4
	Special or temporary road infra crossing	2
	Cooperative routing - Handling an event notification about an event in the range of 0.5-2kms ahead	2
Urban	**Cooperative** non-signalized intersection transit with early AD reaction to V2N	5
	Cooperative signalized intersections transit via V2I	1
	Cooperative routing - handling an event notification (about 0.2-2kms ahead)	2
	Non signalized intersection transit	2
	Lane keeping / overtaking	2
	Urban canyon driving	1
	Pedestrian awareness/interaction via eHMI	3
Rural	2-directional rural road section	1
	Cooperative overtaking via V2V	1
	Arctic uninterrupted driving against specific conditions	2
Parking	Automated Valet Parking	2

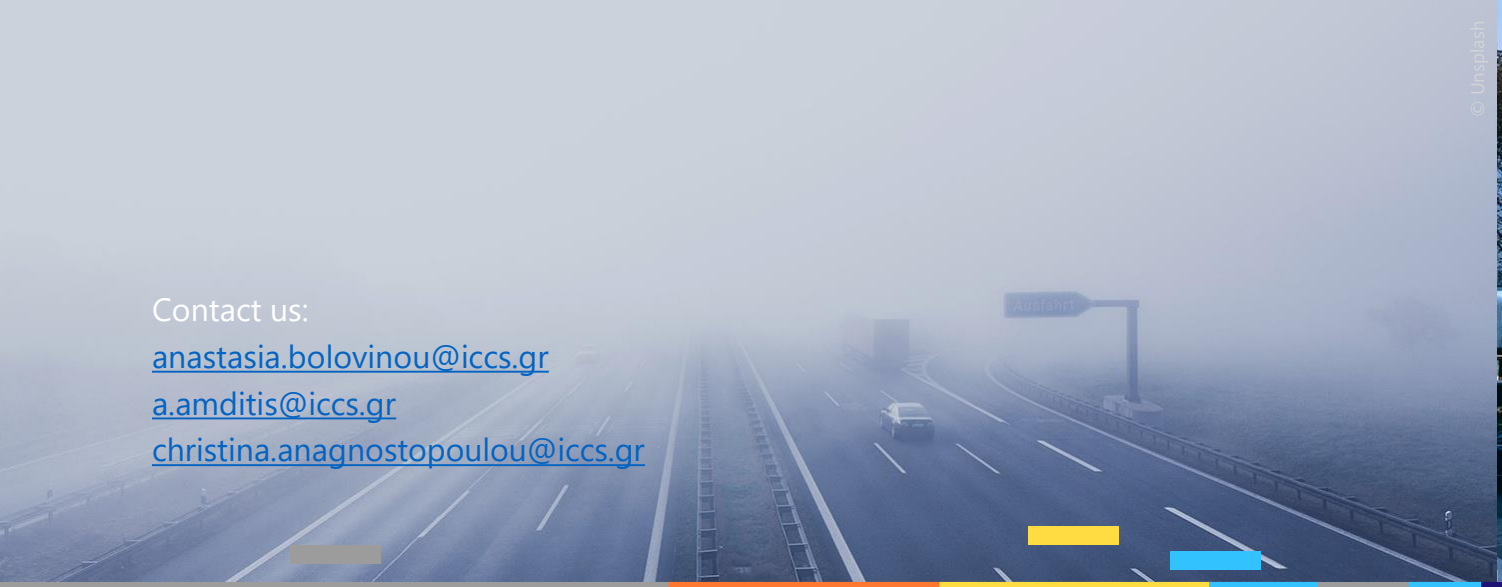
Hi-Drive UCs & associated Test Scenarios Catalogue



Outlook

|Operations' data analysis to follow

- Vehicle data analysis & Impact assessment: Safety, Efficiency, Disturbance, ODD Extension
- Vehicle data analysis & User evaluation: Comfort, Interaction
- Input from user evaluation to effects evaluation and vice versa
- Common set of questions for users in all experiments



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THANK YOU FOR YOUR KIND ATTENTION.

Find out more:

https://www.hi-drive.eu/downloads/

www.Hi-Drive.eu Twitter@_HiDrive_ LinkedInHi-Drive

Hi-Drive

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

AV Roadway Management in the US: opportunities for international learning & collaboration

William Riggs, PhD, AICP, LEED AP

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AV Roadway Management in the US: opportunities for international learning & collaboration

1. Regulation to Deployment / Speed to Scaling

2. Lessons from Pilots / Tech

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Regulatory Context - Federal vs. State Roles

- The ***federal government*** is responsible for oversight and administering vehicle safety standards
  - Primary regulator is the U.S. Department of Transportation, including:
    - National Highway Traffic Safety Administration ("***NHTSA***")
    - Federal Motor Carrier Safety Administration ("***FMCSA***")
  - Other agencies have jurisdiction over relevant areas of law
    - Federal Communications Commission ("***FCC***") recently decided to reallocate part of the 5.9 GHz spectrum reserved for vehicle safety technologies
    - Federal Trade Commission ("***FTC***") regulates privacy, including vehicle data
- ***States*** are responsible for regulating design and operation of AVs
  - For example: licensing, registration, insurance, traffic enforcement

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Federal Regulation of AVs

- ***Safety standards***
  - NHTSA administers Federal Motor Vehicle Safety Standards ("FMVSS"), which establish preemptive safety performance standards
  - AVs may not have equipment designed for human drivers (steering wheels, mirrors, etc.) – can apply for ***exemptions*** from specific FMVSS
  - Recent NHTSA rule amended the "crashworthiness" FMVSS standards to accommodate AVs without traditional manual controls

- ***Data reporting***
  - NHTSA Standing General Order requires manufacturers to report crash data
  - Companies can submit testing data through the AV TEST Initiative

- ***AV trucking***
  - FMCSA rulemaking on autonomous CMVs expected later this year

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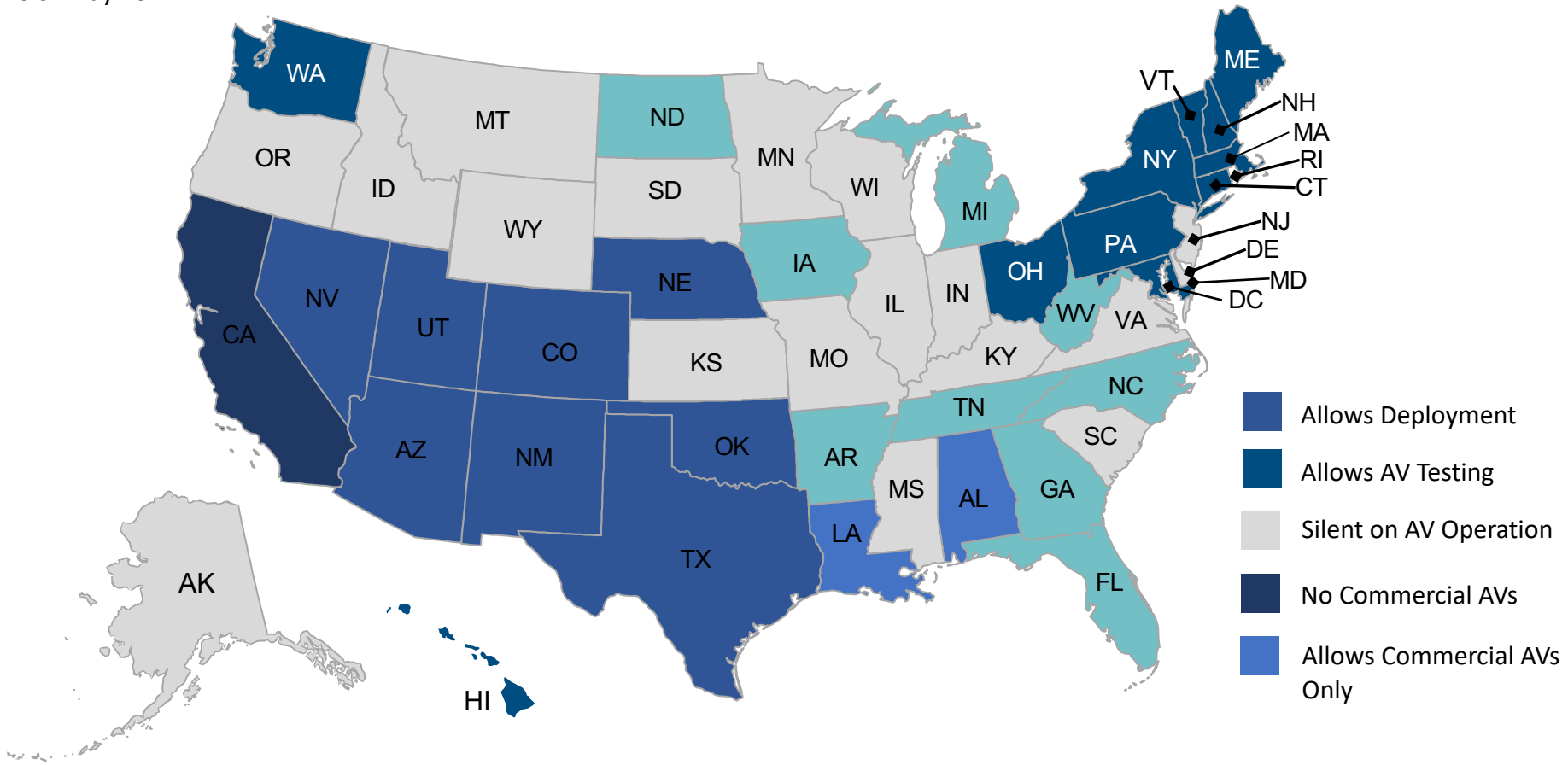
As of May 2022



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State Regulation of AVs

- Majority of U.S. states have legal frameworks authorizing AV operation
  - Different legal mechanisms are used, e.g., legislation, regulation, executive order, and other formal or informal policies

- Approaches vary significantly. For example:
  - Arizona, Nevada, Georgia, Florida, and others allow ***self-certification*** and other minimum requirements for driverless operation
  - Pennsylvania, New York, Vermont, and Massachusetts allow AV testing but require a ***human driver to be present*** in the vehicle
  - California has a complex ***permitting regime*** requiring separate permits from the DMV and Public Utilities Commission for passenger services
  - Louisiana and Alabama limit AV operation to ***commercial AVs***, while California prohibits operation of AVs over 10,000 lbs

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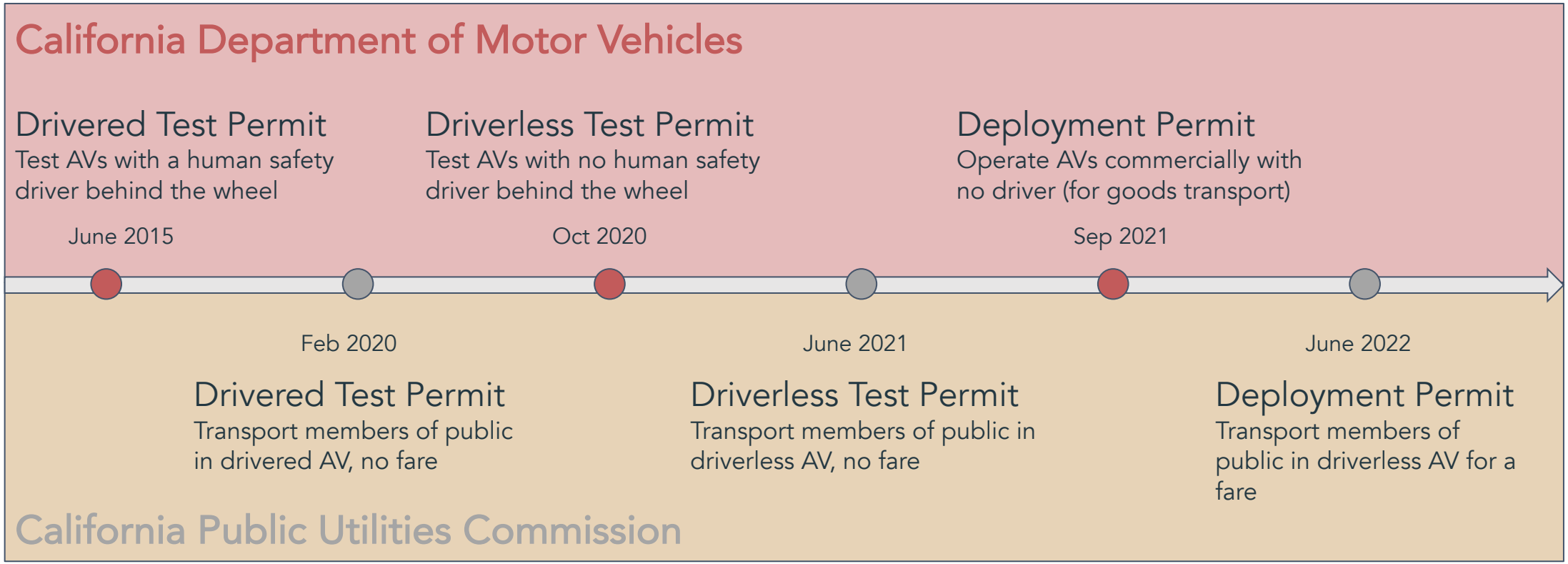
Regulatory Progress

Over the last 7 years, Cruise has received six total permits from the CA DMV and CPUC, each of which has afforded Cruise incremental flexibility in deployment, and in creating programs like the Research Rider Pilot.



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Role of Local Governments

- Most state laws regulating AVs explicitly **preempt** local laws
  - Cities and municipalities often have authority to regulate in certain areas, such as traffic enforcement
  - Typically, state codes have a uniform traffic control section giving local governments leeway to deviate from certain standards
    - Ex. weight limits on local bridges

- Despite preemption, cities can (and do) play a role in AV deployment. Many cities have used ODD restrictions / place-based zoning to control where deployments are allowed physically (gray area)

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Collaborative & Creative ODD Development

Under the Driverless Test Permit, USF and Cruise launched the Research Rider Pilot in Cruise's initial ODD below, offering a free service for USF students to assess the impact of AVs on rider travel behavior.

ODD Parameters	
Geography	The ODD included the geofenced area at left within the City and County of SF.
Roadway Type	The ODD included local and arterial roads and excluded steep hills, bridges, tunnels, overpasses, underpasses, and roundabouts.
Speed Range	Cruise vehicles operated at a maximum speed of 30 MPH.
Weather Conditions	The ODD excluded heavy fog, heavy rain, heavy smoke, hail, sleet, and snow.
Time of Day	The ODD was 10:30 PM - 5 AM, and later expanded slightly.

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Roadway / traffic changes can trigger policy conflict

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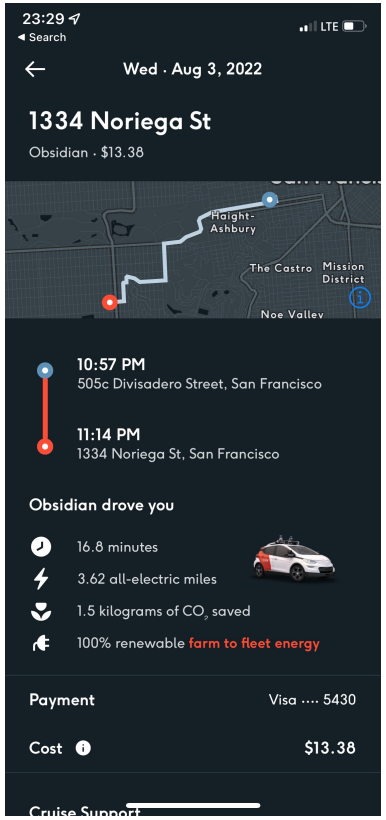
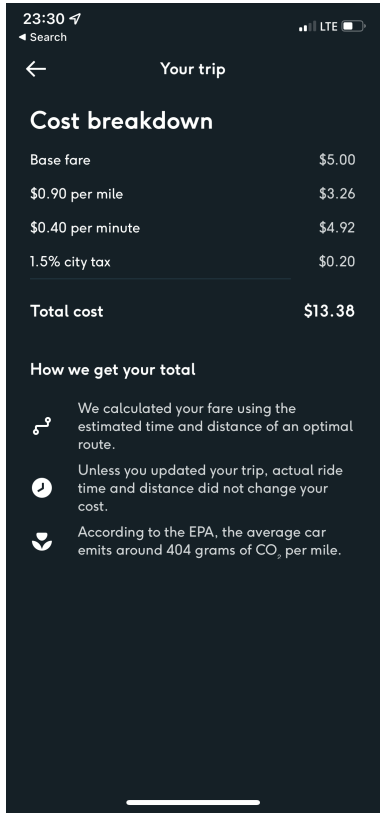
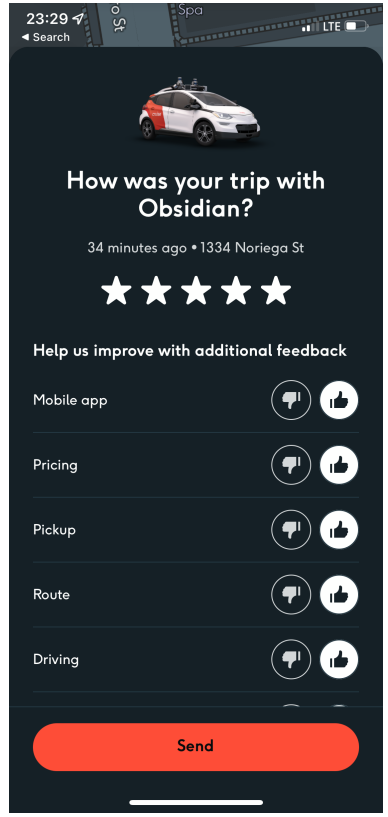
Opportunity / Challenge Consumer Facing Shared Product (Non-binary transit solution)







NEW lyft PRICING
EFFECTIVE NOVEMBER 1

$5.00
CLASSIC RIDE
Travel anywhere within the service area!

Private ride or for groups up to 4 passengers

No stops before reaching final destination

$3.00
SHARED RIDE
Select a shared ride and receive an even greater discount when traveling in the service area!

Up to two (2) passengers

Possible stops before reaching final destination

$1.00
SHARED RIDE
Those traveling to and from Old Town Monrovia, the Metro Gold Line Station, or any hospitals within the service area will pay just $1.00!

News

Lyft in Monrovia is Almost Too Successful

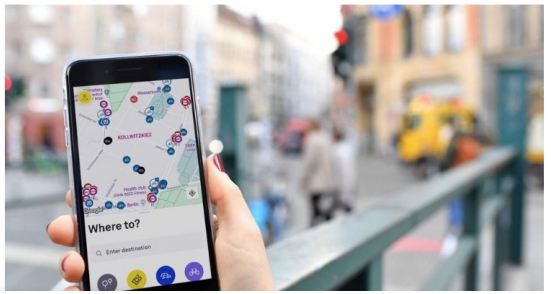
By **Susan Motander** - August 9, 2018

Share

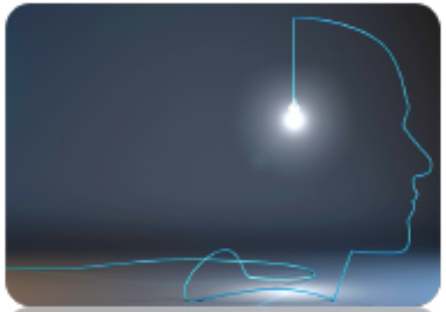
Forbes Billionaires Innovation Leadership Money Business Small Business Lifestyle Lists

Watch Out, Uber. Berlin Is The New Amazon For Transportation (With Lower Fares)

Julie Walmsley Contributor
Transportation



Behavior Change Tactics



- Engage in Transportation Demand Management and use social / financial incentives
- Partner rail agencies and local govs on public service announcements that drive multimodal travel decisions (Train/Walk/Bike)
- Social media messaging
- Engage influencers
- Early educational programming to highlight benefits

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Lessons / Opportunities

- Lesson: **Scaffolded or Layer Cake process to allowed for quicker / more agile deployments with tiered approvals**
- Opportunity: **Creativity on ODD development and evolution**
- Lesson: "**Mobility Playbooks" / "Sand are a start but must have tactical goals to improve traffic flow / operations**
- Challenge / Opportunity: **lack of focus on consumer facing products for public sector / travel behavior**

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CCTA / I680 Project – VTA AAV: Leveraging Infrastructure Improvements (Signs, Lines, Potholes) for Improvements in Mixed Flow Traffic But May Decrease Total Capacity

Optimized but less efficient?

Research Rider Pilot Project

https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4195380

Limited VMT Increase / Transit Supplement

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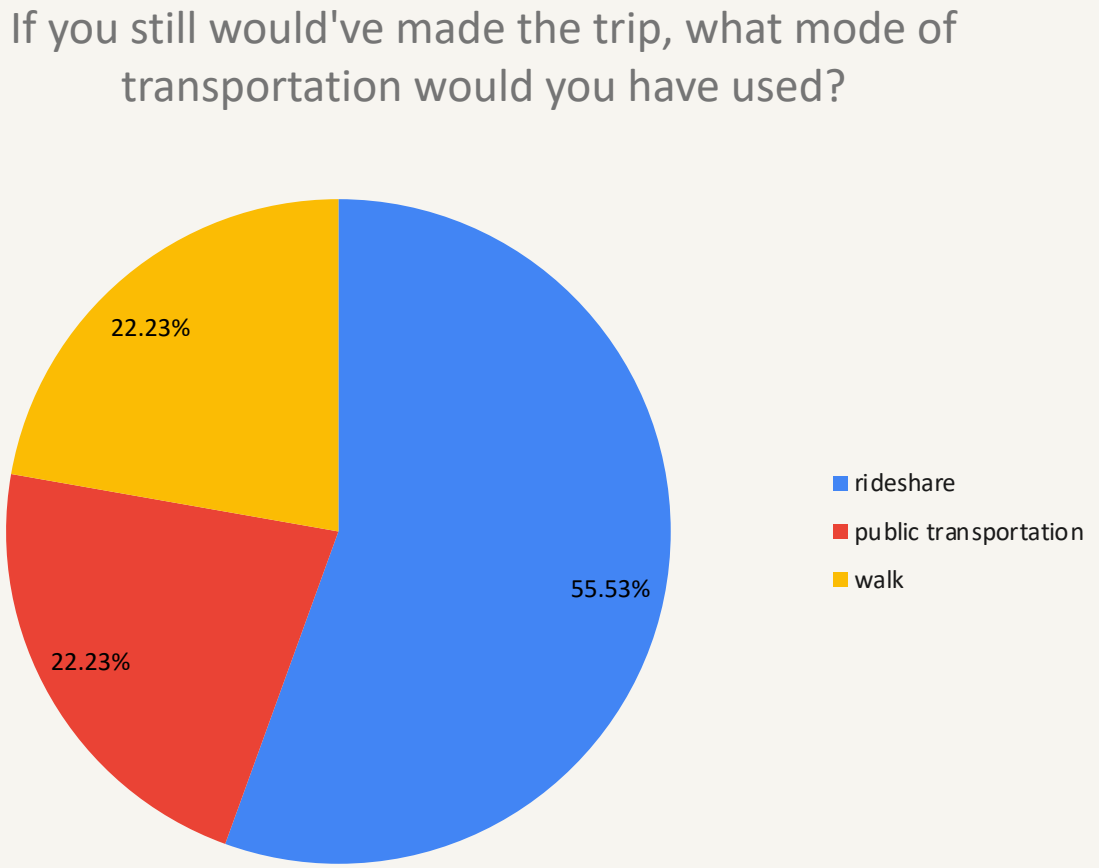
76% of riders would have made the trip via other means even if an AV were not available.

55% of riders would have used rideshare. Others would have walked or taken transit.



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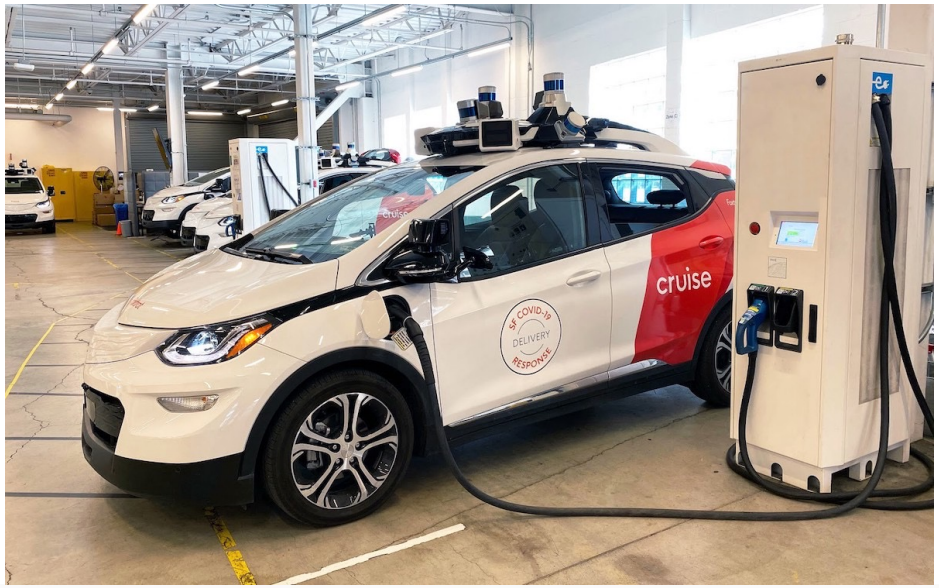
Charging Infrastructure Debate

Anticipatory Data – Construction Emergency Management Etc.



Curbside / Pickup and Drop off Challenges

Sharing of Curbs

Dealing with VREs

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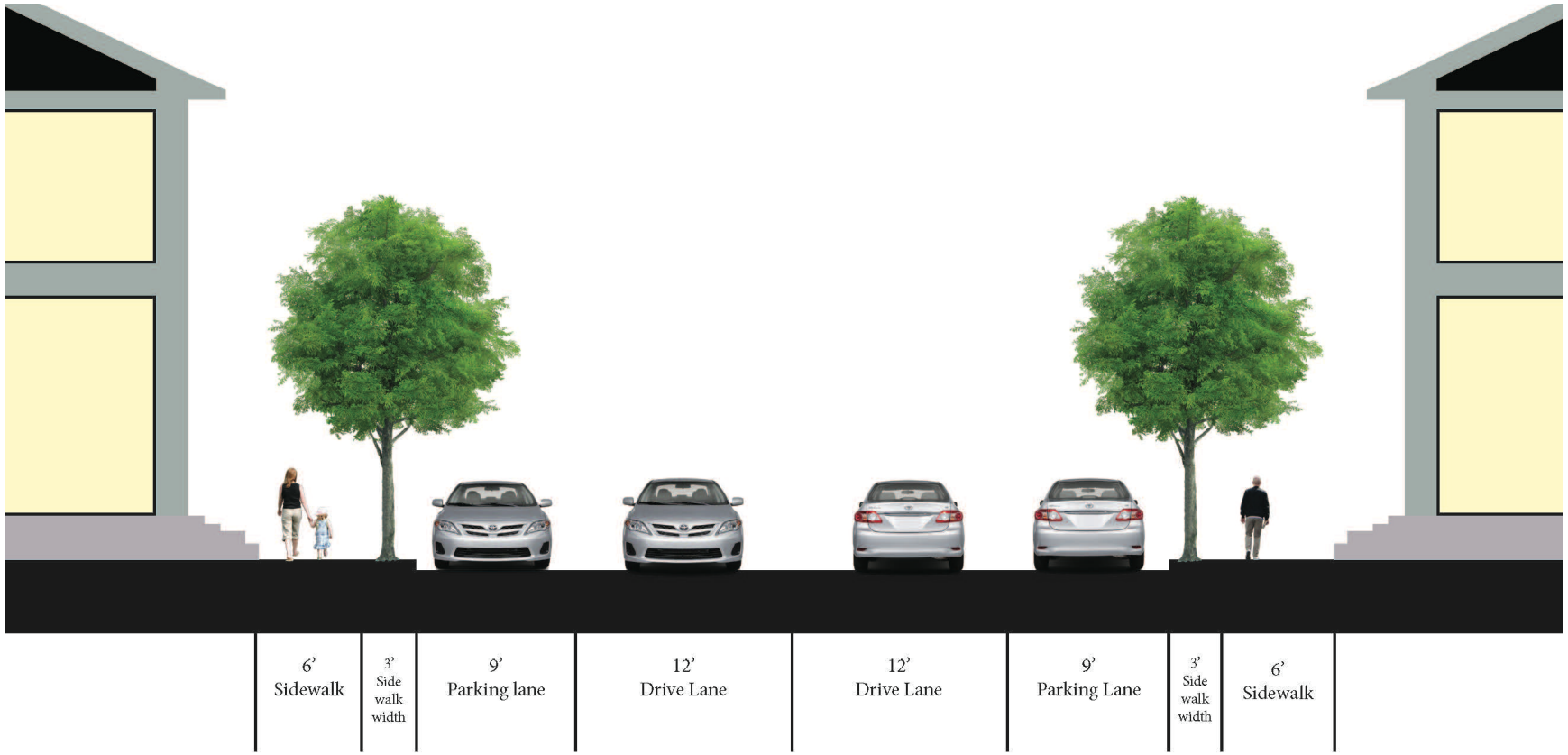
Need for anticipatory evasion may limit ROW Recapture Concepts

Thin Lanes | Remove Parking | Think Shared

http://bit.ly/avstreets



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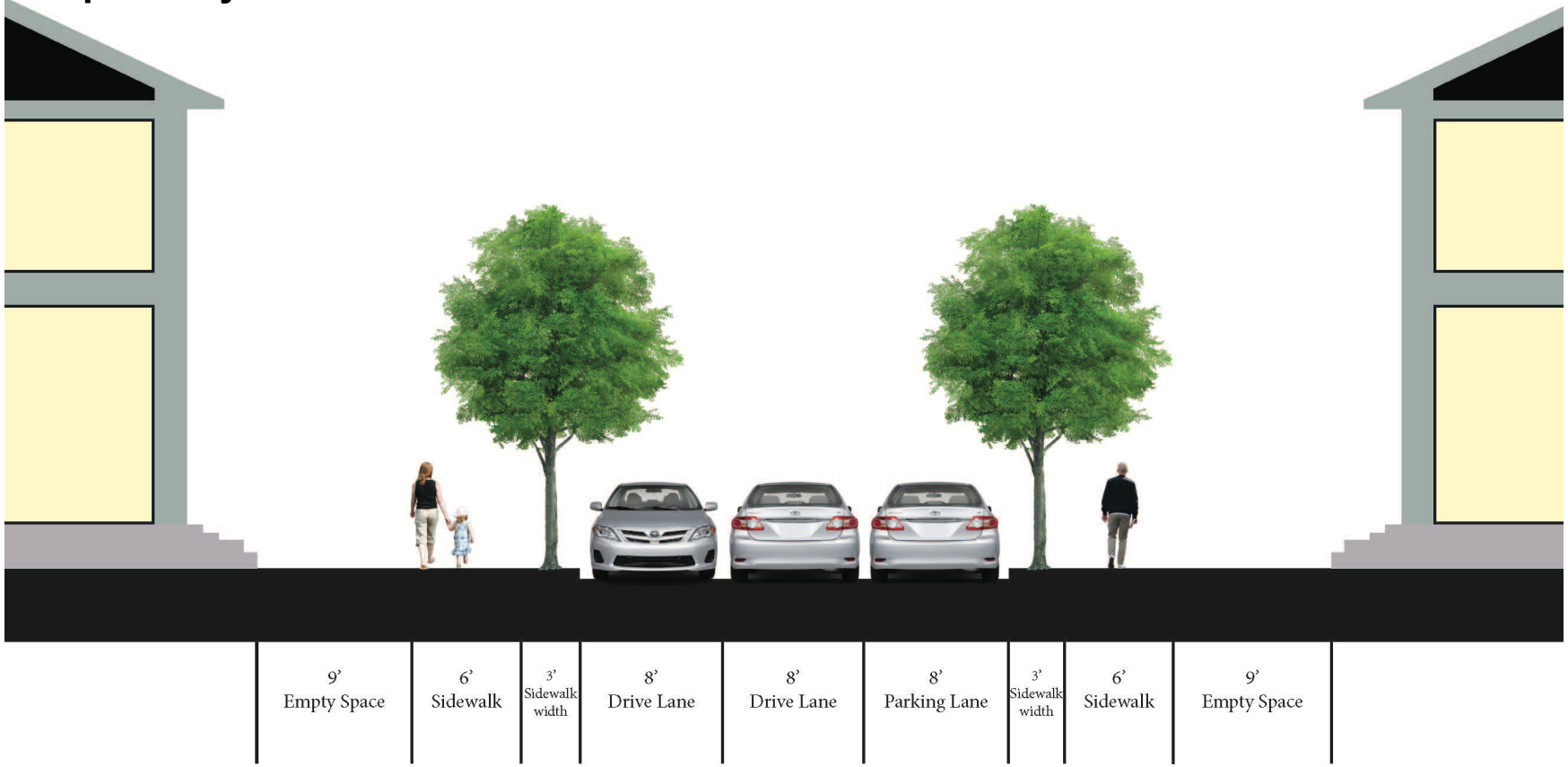
Need for anticipatory evasion may limit ROW Recapture Concepts

Thin Lanes | Remove Parking | Think Shared

http://bit.ly/avstreets



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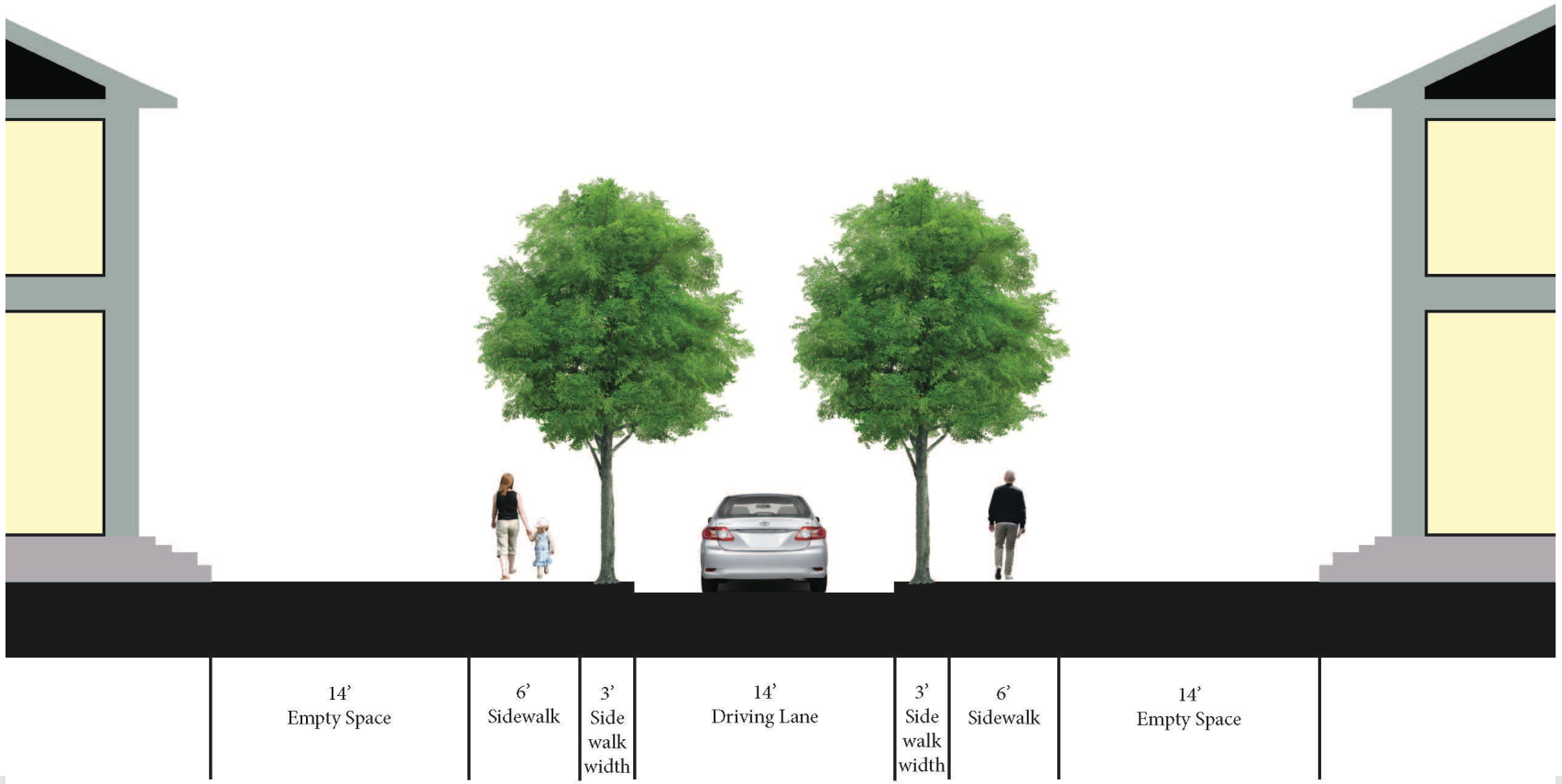

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Lessons / Opportunities

- Lesson: signs lines and potholes; small number of AVs can meter / alter mixed flow; reduce speeds (GHG) but also may decrease vs. increase capacity (similar to ADAS findings
- Lesson: may not increase trips / VMT; capture latent travel
- Lesson: limited need for V2X/V2 in early pilots; need increases as tech is refined
- Opportunity: data / reporting – what is reported? Is it useful? Is it necessary? Does it need to be dynamic? How can approvals be changed / augmented efficiently. Emergency management / construction data (not even dynamic) a start
- Opportunity: Pick and drop off / Curb availability / use of transit stops?
- Opportunity: 3D mapping

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