

Cooperative Automated Driving at Signalised Intersection and Transition Areas

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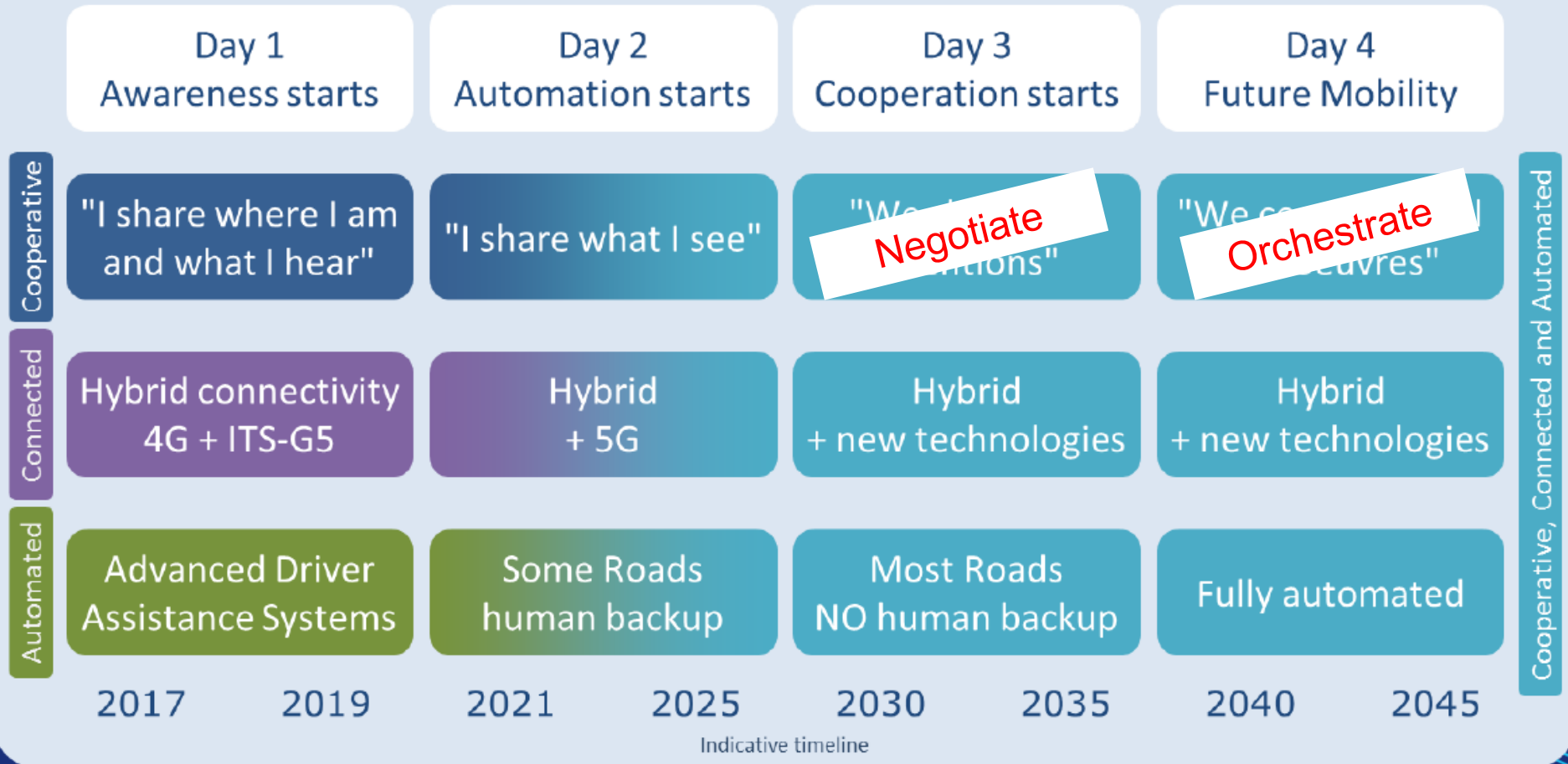
Definitions

- Autonomous Driving:** Autonomy means, that one is able and allowed to make decisions independently and on one's own mind. In the case of autonomous driving a single vehicle can make its own driving decision independently.
- Automated Driving:** Automation deals about the execution of processes and procedures without human intervention. Hence automated driving implies driving without the intervention of human drivers. Sometimes a further differentiation between fully automated driving and the different automation levels according SAE is done.
- Connected Driving:** In the case of connected driving information is exchanged between automated as well as non-automated vehicles and other traffic participants and/or infrastructure in an automated way.
- Cooperative Driving:** Cooperative driving means, that single vehicles and drivers act cooperatively within traffic. This implies, that single traffic participants are coordinating their microscopic aims and actions in the light of improved overall macroscopic effects.

Implications of definitions

- *Connected driving* itself does not necessarily imply *cooperative driving*. Single traffic participants can theoretically use the additional information for their own individual advantage at the cost of others.
- *Autonomous driving* does not intrinsically cause improved traffic. If everybody decides on his own without a *cooperative coordination* with other traffic participants, then chaos and traffic collapses may be a consequence. Normally autonomy is only appropriate in the case of low densities.
- *Automated driving* can lead to significant improvements in traffic, because *cooperative behaviour* can be enforced for robots much easier than for human beings. Robots follow their instructions much more precisely than humans, unless these are autonomous robots which decide to do differently.
- *Connected driving* can accelerate the introduction of *automated driving* significantly, because it enables approaches for collective learning to identify and resolve inappropriate behaviour and driving strategies quickly.

Towards Cooperative, Connected and Automated Mobility



Projects overview

MAVEN (MG3.6a)

- ✓ Managing Automated Vehicles Enhances Network
- ✓ 01-09-2016 ~ 31-08-2019
- ✓ Budget: EUR 3.149.661,25
- ✓ Nine partners from five countries: DE, NL, CZ, BE, UK

TransAID (ART-05)

- ✓ Transition Areas for Infrastructure-Assisted Driving
- ✓ 01-09-2017 ~ 31-08-2019
- ✓ Budget: EUR 3.836.353,75
- ✓ Seven partners from 6 countries: DE, UK, BE, NL, EL, ES



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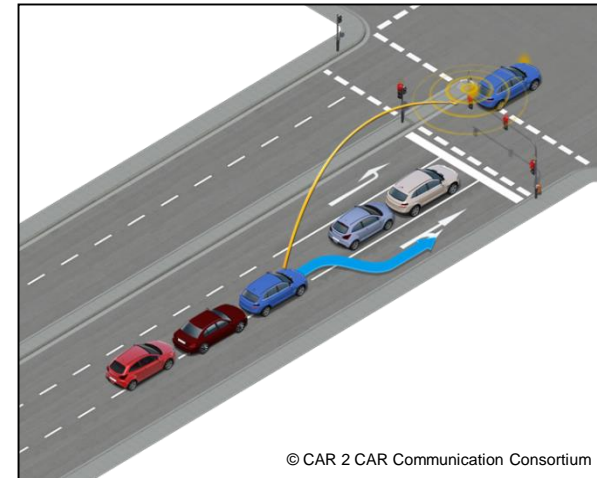
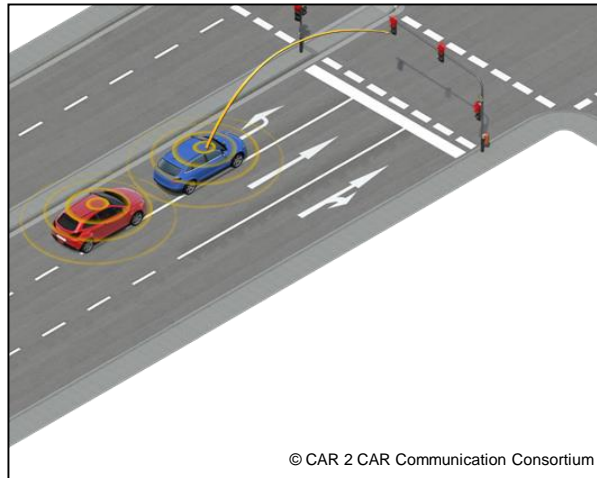
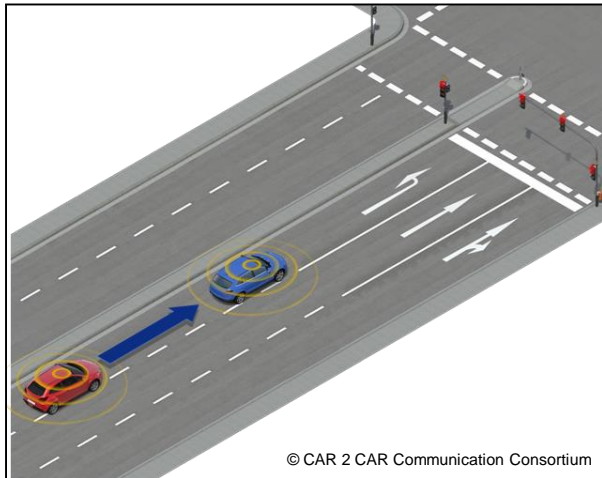
MAVEN use cases [1/2]

1. Platoon management

- ✓ Forming, joining, progression, leaving, breaking a platoon

2. Infrastructure-to-vehicle interactions

- ✓ Negotiation (signal timing vs. arrival pattern), speed advisory, lane advisory



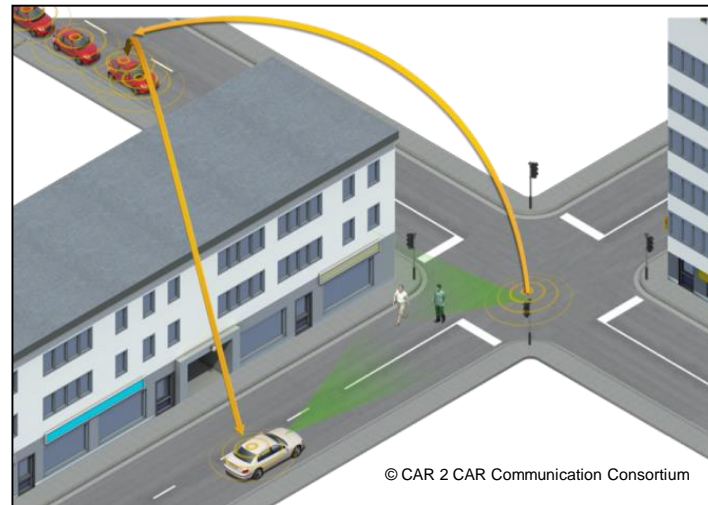
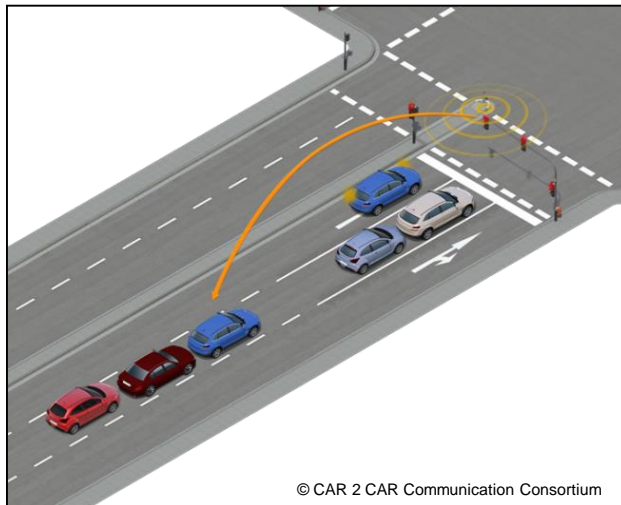
MAVEN use cases [2/2]

3. Traffic control optimization (and scheduling)

- ✓ Signal optimization, priority management, queue estimation, green wave

4. Conventional traffic and vulnerable road users

- ✓ Detection of non-cooperative vehicles, VRUs, emergency situations

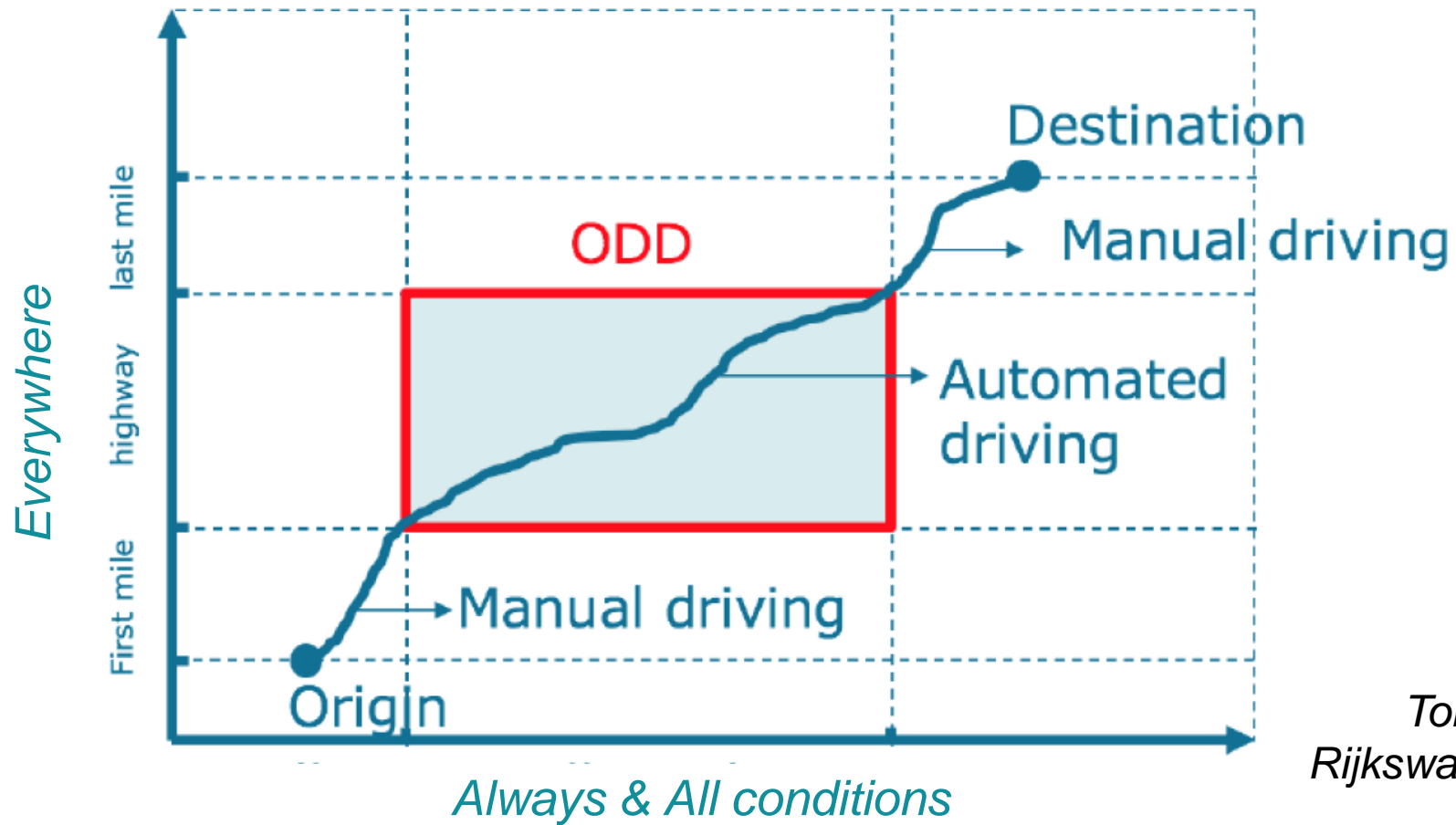




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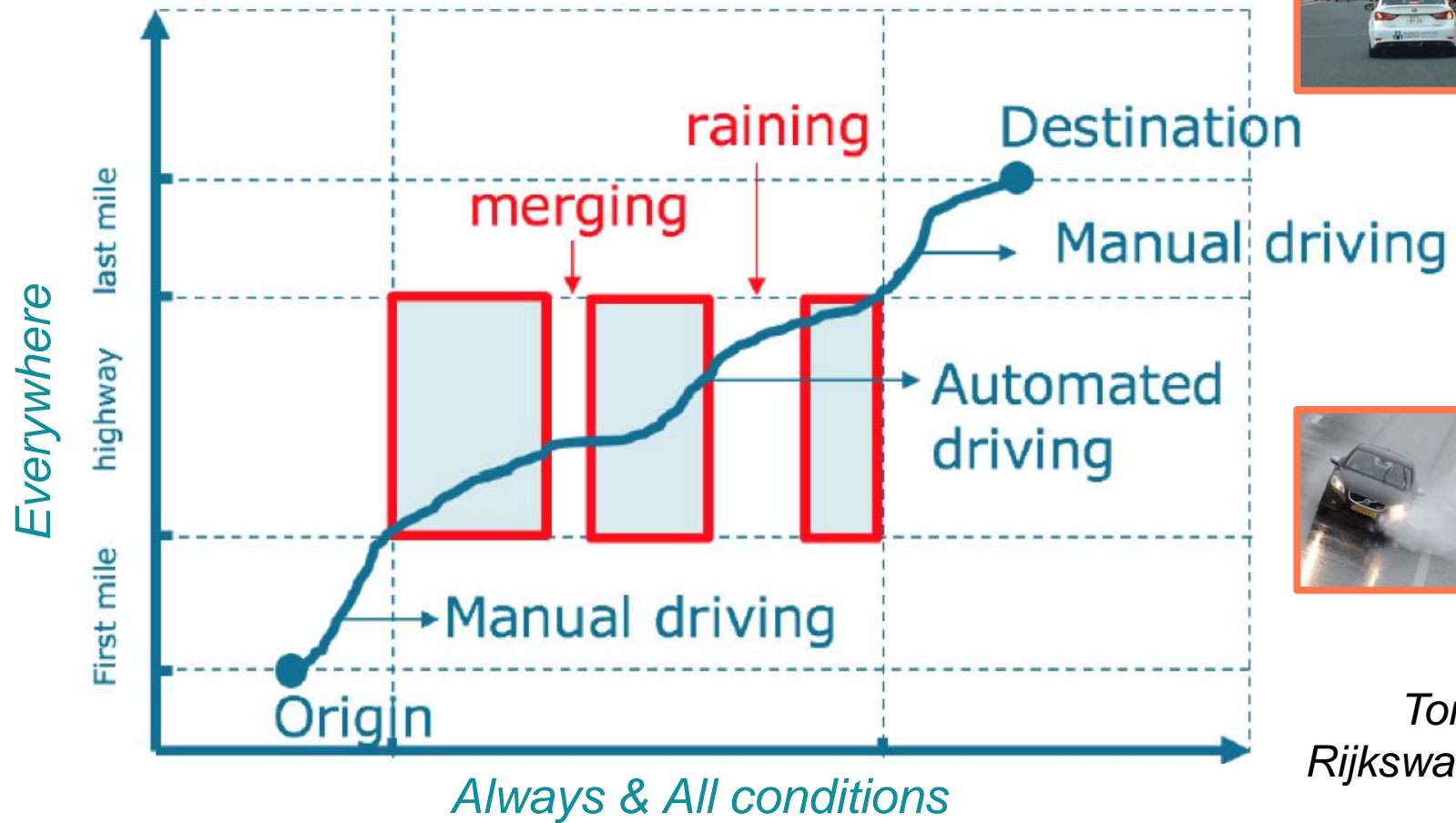


Considering Operational Design Domain (ODD)



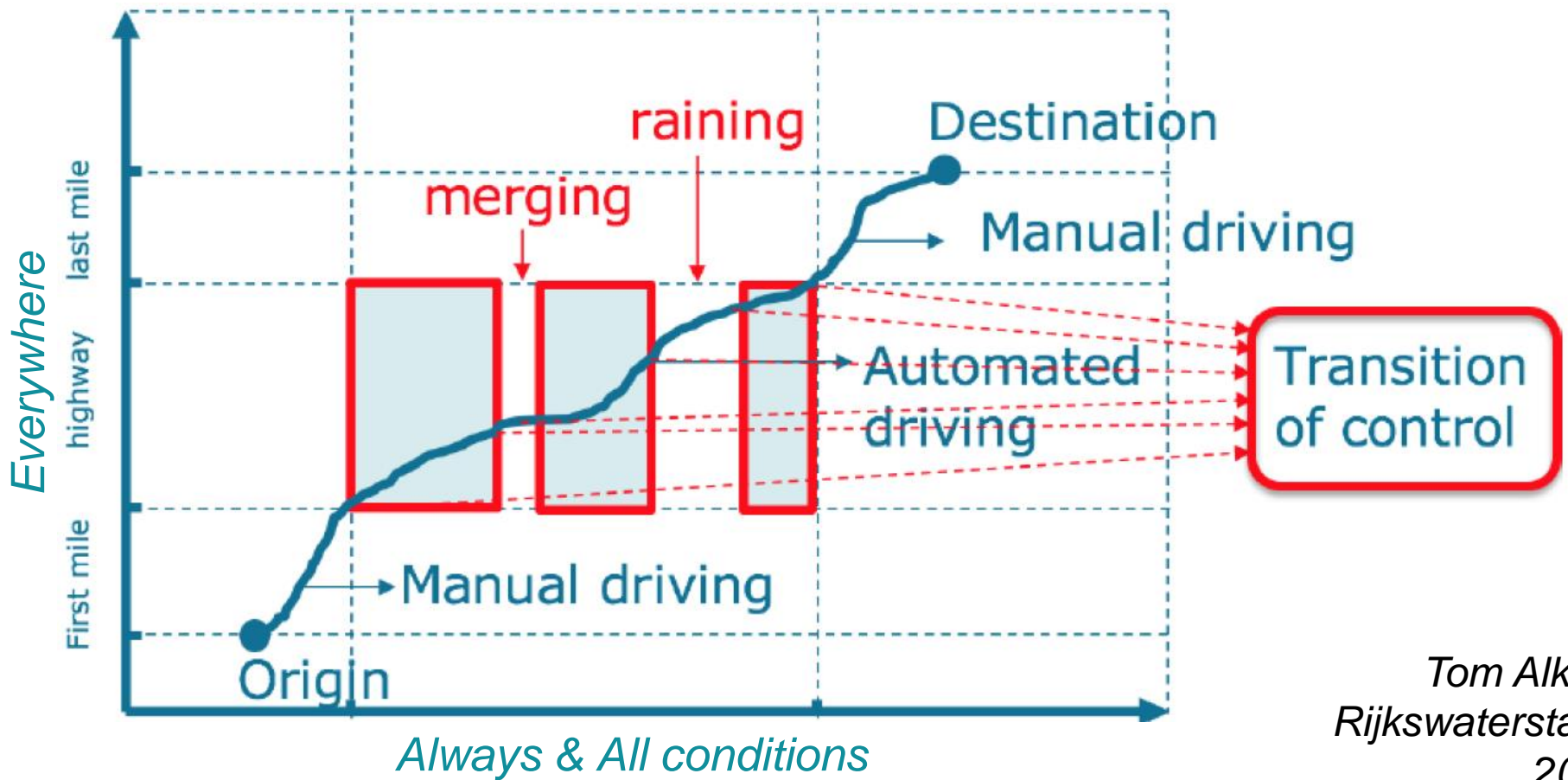
Tom Alkim,
Rijkswaterstaat,
2017

Considering Operational Design Domain (ODD)



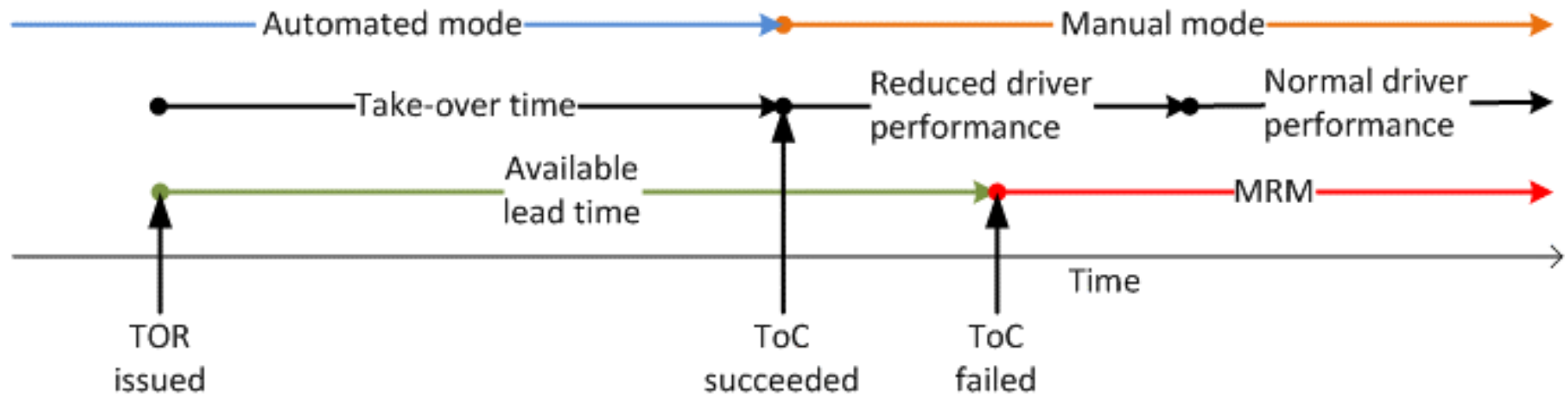
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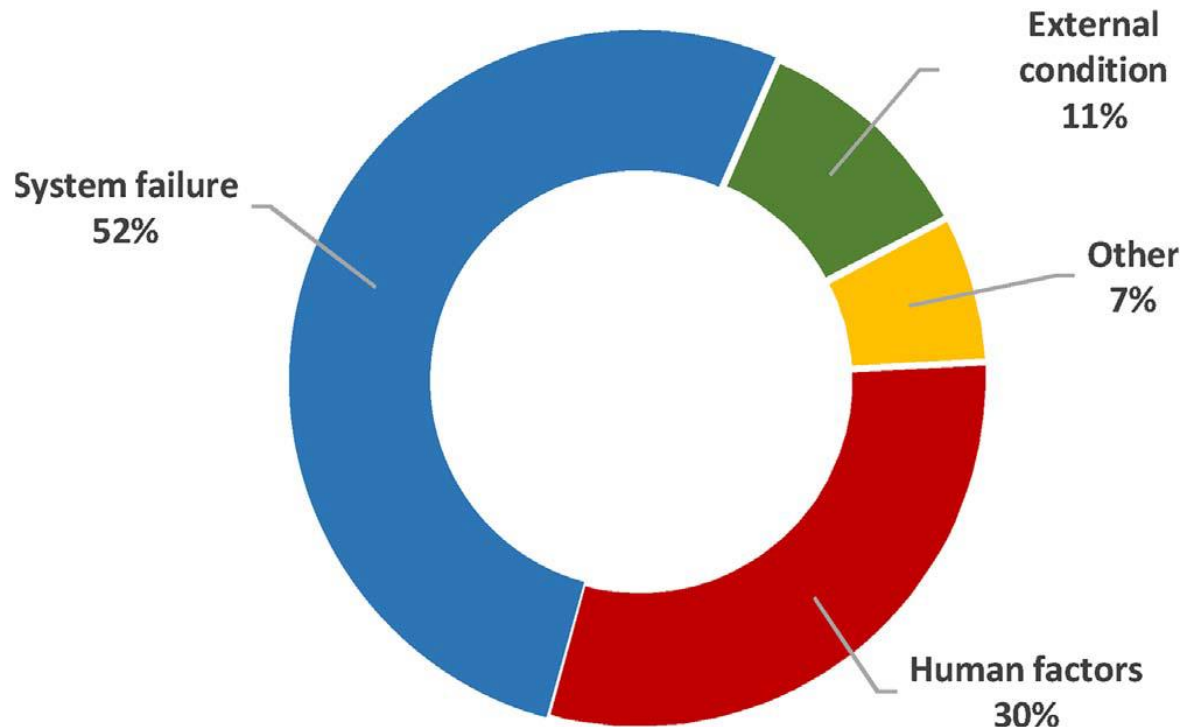


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Transition of Control (ToC) process



Disengagement reports 2017

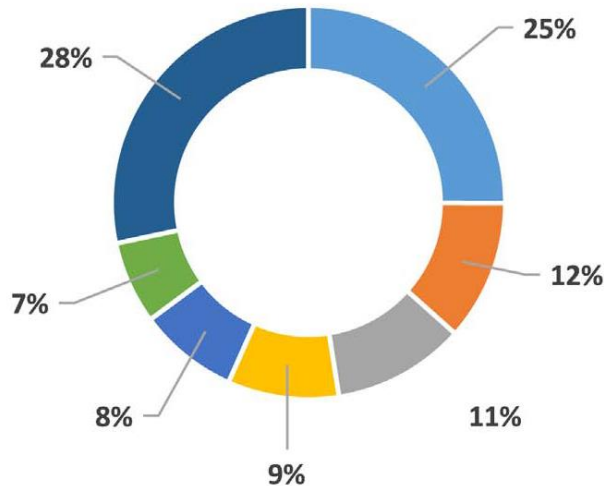


Favaro et al. (2017), Autonomous vehicles' disengagements: Trends, triggers, and regulatory limitations, Accident Analysis & Prevention, Vol. 110, pp. 136-148

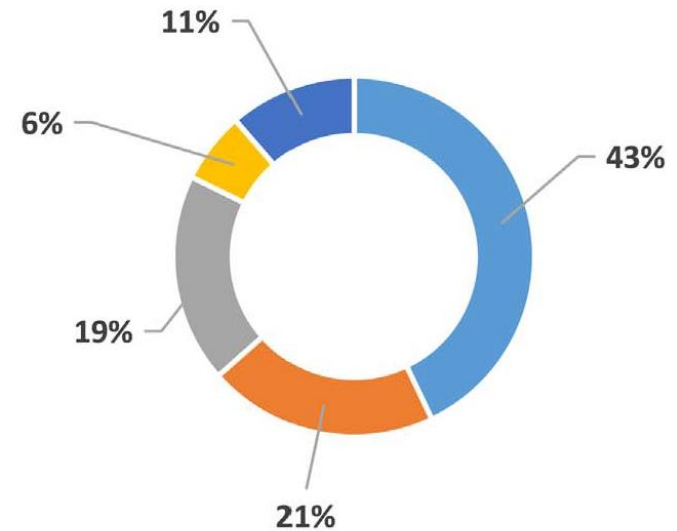
Disengagement reports 2017

System failure

External condition



- software discrepancy
- perception discrepancy
- planner not ready
- traffic light detection
- lane change
- unwanted maneuver of vehicle
- Other System Failure factors*

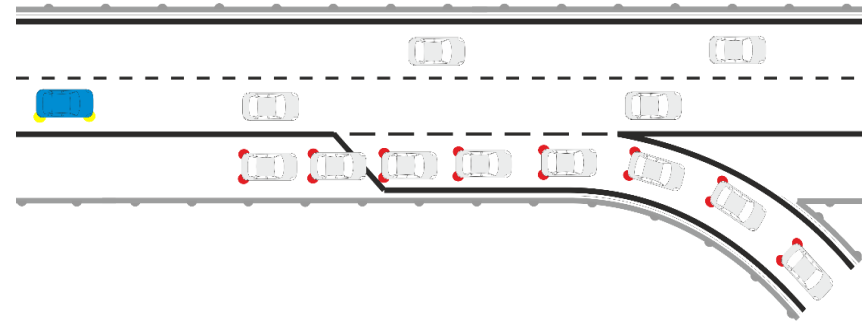
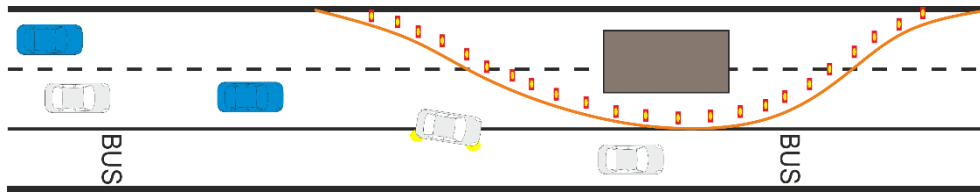


- poorly marked lanes
- construction zone
- heavy pedestrian traffic
- weather condition
- other external condition factors**

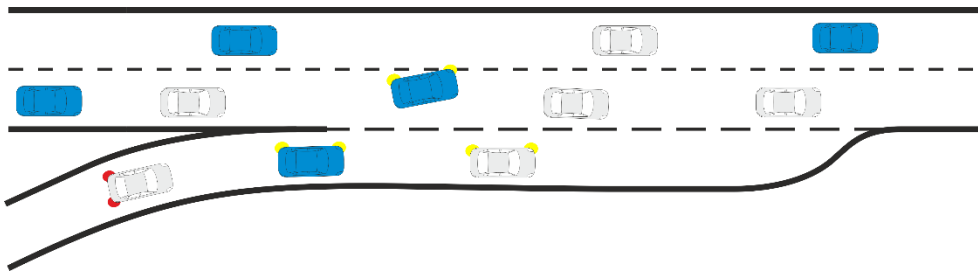
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TransAID use cases (1/3)

Provide vehicle path information

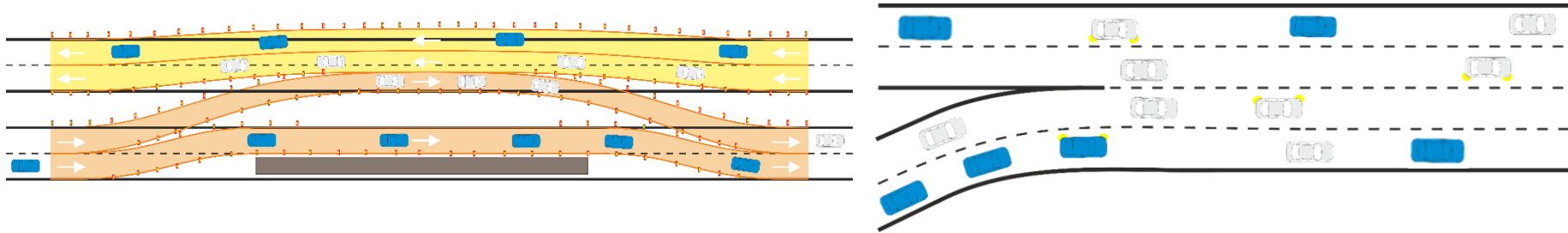


Provide speed, headway and/or lane advice

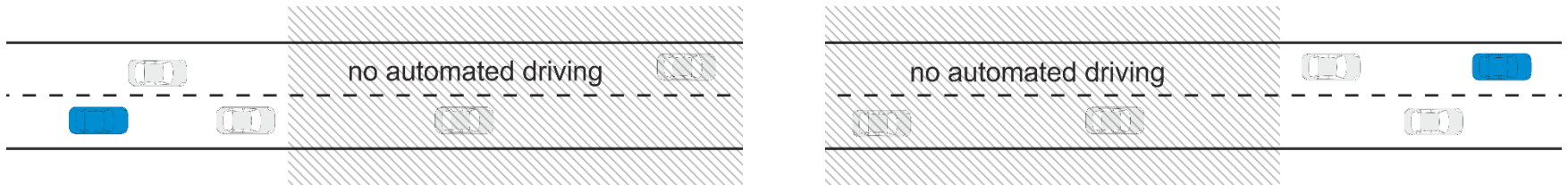


TransAID use cases (2/3)

Routing & traffic separation



Orchestration, distribution and scheduling



Examples V2X extensions

❑ V2I – Cooperative Awareness Message

- ✓ Vehicle route at intersection (intention);
- ✓ Platoon properties (size, length, roles, speed, headway, composition, etc.);
- ✓ Acknowledgments of compliance to lane changes and speed advisory (negotiation).

❑ I2V – Lane Advice Message

- ✓ Suggests the lane a vehicle or platoon should change to at an intersection;
- ✓ Indicates target lane, distance to stop line, and time for starting the manoeuvre;
- ✓ Combined with lane-specific Green Light Optimal Speed Advisory (GLOSA).

❑ V2X – Collective Perception

- ✓ Sharing abstract descriptions of objects detected by vehicle or infrastructure sensors;
- ✓ Created improved awareness even with low market penetration.

Infrastructure Support Levels 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
Digital infrastructure	A	Cooperative driving	Based on the real-time information on vehicles 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
	B	Cooperative perception	Infrastructure is capable of perceiving microscopic traffic situations and providing this data to AVs in real-time	X	X	X	
	C	Dynamic digital information	All dynamic and static infrastructure information is available in digital form and can be provided to AVs	X	X		
Conventional 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			
	E	Conventional infrastructure / no AV support	Conventional infrastructure without digital information. AVs need to recognise road geometry and road signs				

Note: many use cases are fully vehicle-based or have a large vehicle-component.

MAVEN: transition phases for public authorities

1. Awareness: understand need, urgency and system functionality.
2. Policy & regulation: form an opinion, assess strategic plans and define a course.
3. Digital data (ISAD level D/C): start providing open traffic & infrastructure related data.
 - MAVEN: provide SPATEM and MAPEM data.
4. Traffic management: develop guidelines and implement new practices for vehicle guidance and control.
5. Infrastructure (ISAD level B): implement the basic infrastructure necessary to enable cooperative perception.
 - MAVEN: Install roadside sensors, comms technology and computational resources.
6. Infrastructure (ISAD level A): implement the advanced infrastructure necessary to enable cooperative driving.
 - MAVEN: upgrade UTC systems with sophisticated I2V algorithms.

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