KIVI WEBINAR

WHAT IS THE IMPACT OF AUTONOMOUS DRIVING ON TRAFFIC SAFETY?

DR. IR. OLAF OP DEN CAMP

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SMART SOLUTIONS
FOR CLIENTS & PARTNERS

KNOWLEDGE TRANSFER (10%)
Knowledge exploitation by spin-offs, licences, in partnership with other companies

DEVELOP FUNDAMENTAL KNOWLEDGE (10%)
Together with universities

KNOWLEDGE APPLICATION (40%)
Contract research for and with clients

KNOWLEDGE DEVELOPMENT (40%)
In public-private partnership with partners from the golden triangle

WE DO THIS BY TAKING A **MULTIDISCIPLINARY** APPROACH

TNO TURNOVER
(MLN EURO)
535

TNO NUMBER OF EMPLOYEES

3431

Source: TNO annual report 2019

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TNO Helmond, the Netherlands

Technical Lead Safety Assessment Framework (Methodology & Tools)

Nanyang Technological University, Singapore

- *ERTRAC Safe Road Transport Roadmap, Towards Vision Zero: Roads without Victims*, ERTRAC Working Group Road Transport Safety & Security, https://www.ertrac.org/uploads/documentsearch/id58/ERTRAC-Road-Safety-Roadmap-2019.pdf , 2019
- *StreetWise, Scenario-Based Safety Validation of Connected and Automated Driving*, Hala Elrofai, Jan-Pieter Paardekooper, Erwin de Gelder, Sytze Kalisvaart, Olaf Op den Camp, July 2018, www.tno.nl/StreetWise
- *Scenario Categories for the Assessment of Automated Vehicles*, E. de Gelder, O. Op den Camp and N. de Boer, 2020. [Online]. Available: http://www.cetran.sg/publications
- *Nudging Concepts for Traffic Safety: In-vehicle implementations and Field Trial Outcomes*, Dr. Olaf Op den Camp (TNO) and Dr. Mikael Ljung Aust (Volvo Cars Safety Centre), 29th Aachen Colloquium Sustainable Mobility 2020
- *Cyclist Target and Test Setup for Evaluation of Cyclist-Autonomous Emergency Braking*, Olaf Op den Camp, Sjef van Montfort, Jeroen Uittenbogaard and Joke Welten, Int. J. Automotive Technology, Vol. 18, No. 6, pp. 1085-1097, 2017.

ERTRAC WG Road traffic safety and security

P.E.A.R.S. Steering Committee

EARPA FG Connectivity, Automation and Safety

SAE iAMTS WG1 scenarios

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CONTENTS

- **BASICS FOR VEHICLE SAFETY**
- **HISTORIC TRENDS IN TRAFFIC CASUALTIES**
  CAUSES OF ACCIDENTS
- **TRENDS IN VEHICLE AUTOMATION**
- **SAFETY ASSESSMENT - CHALLENGES AND NEEDS**
- **TNO STREETWISE SCENARIO-BASED SAFETY ASSESSMENT**
- **CONCLUSION**

BASICS FOR VEHICLE SAFETY

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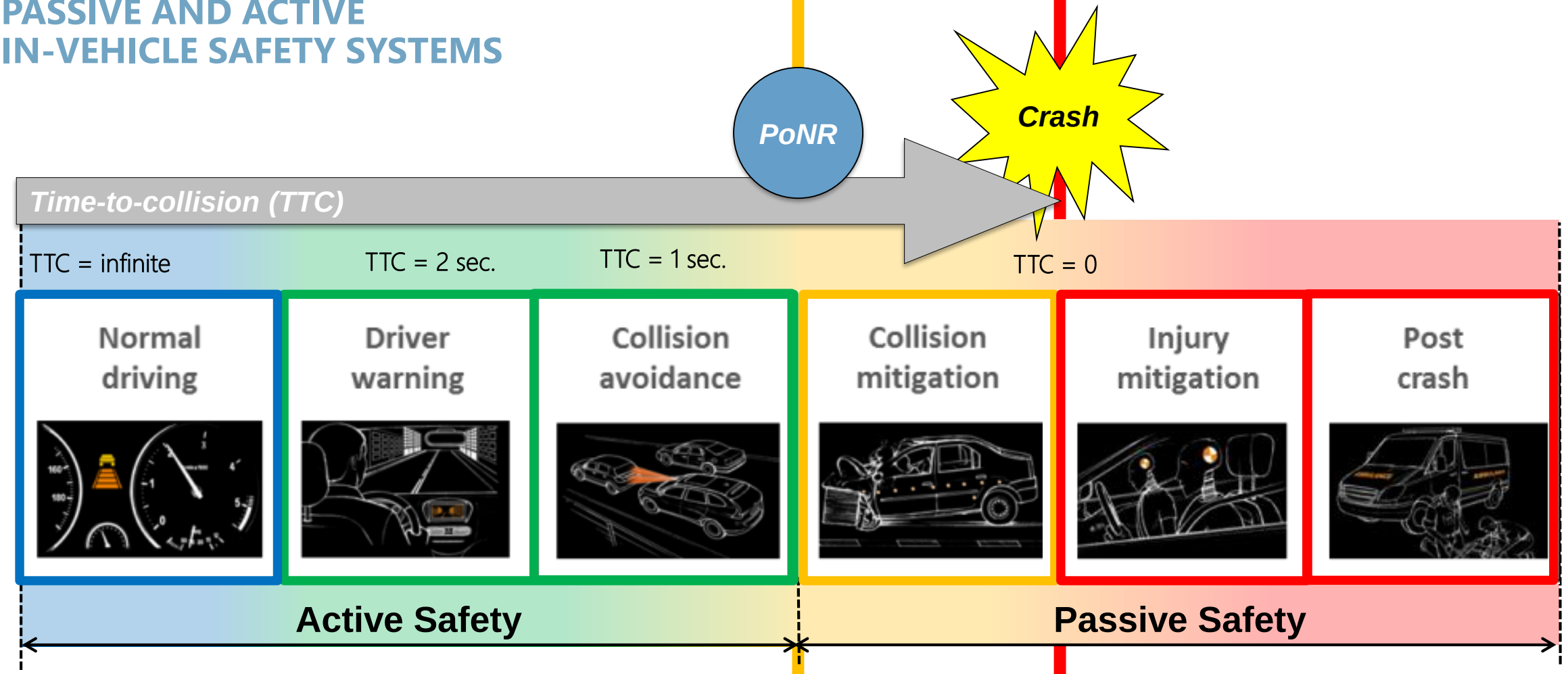
PASSIVE AND ACTIVE IN-VEHICLE SAFETY SYSTEMS



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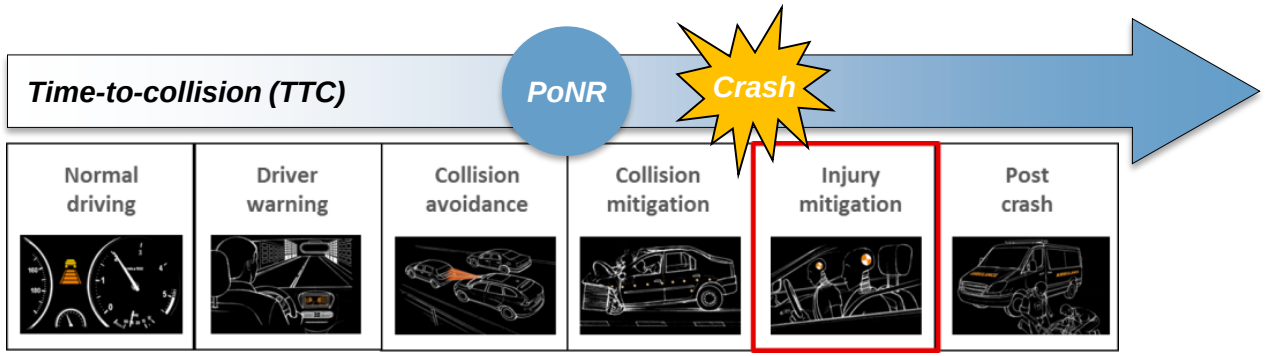
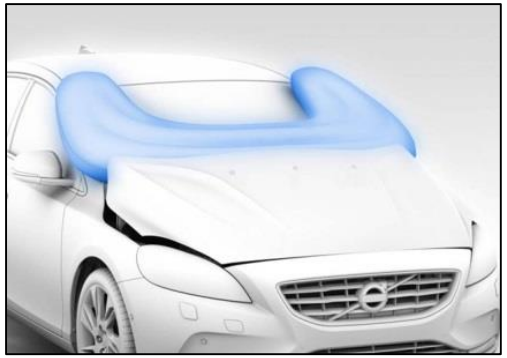
SAFETY SOLUTIONS

- Injury mitigation:
  - Pop-up bonnet



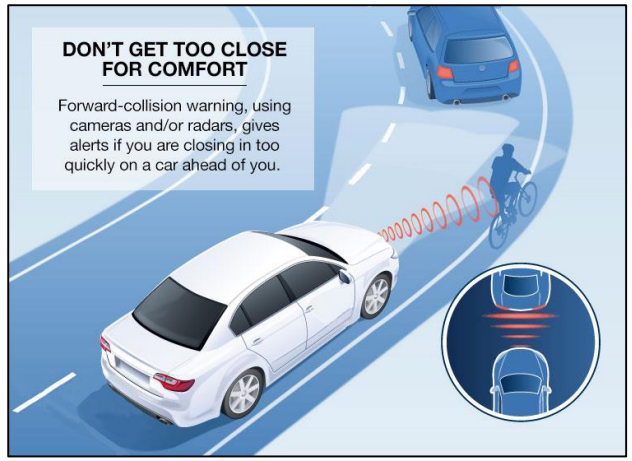
  - Windshield airbag

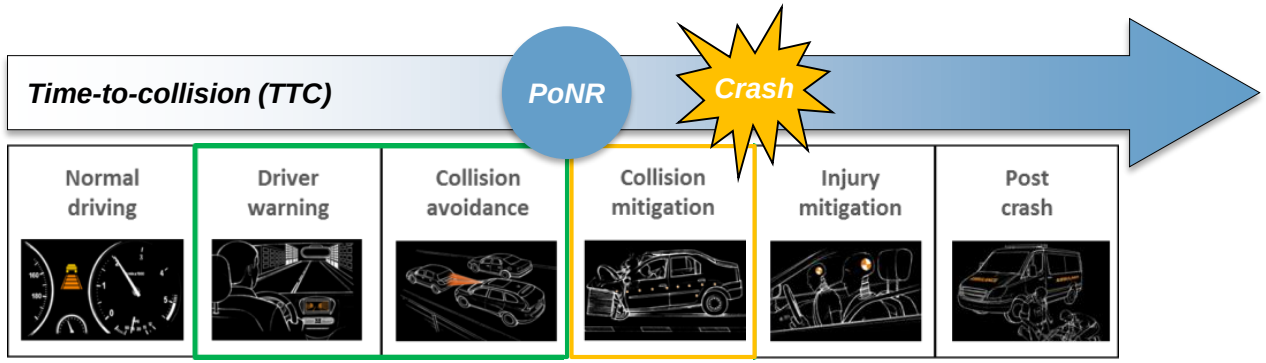


  - Personal protection equipment

SAFETY SOLUTIONS

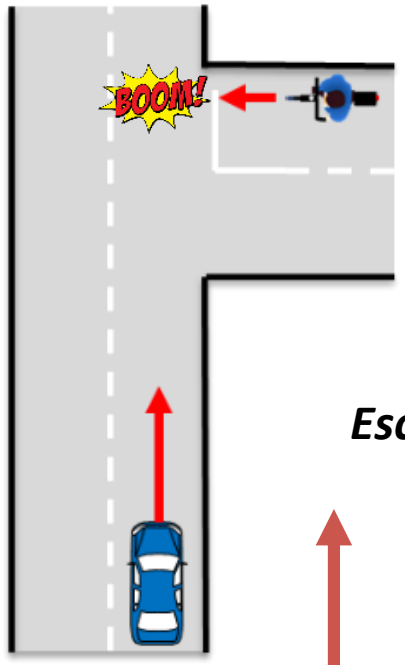
- Collision avoidance / mitigation:
  - Forward collision warning

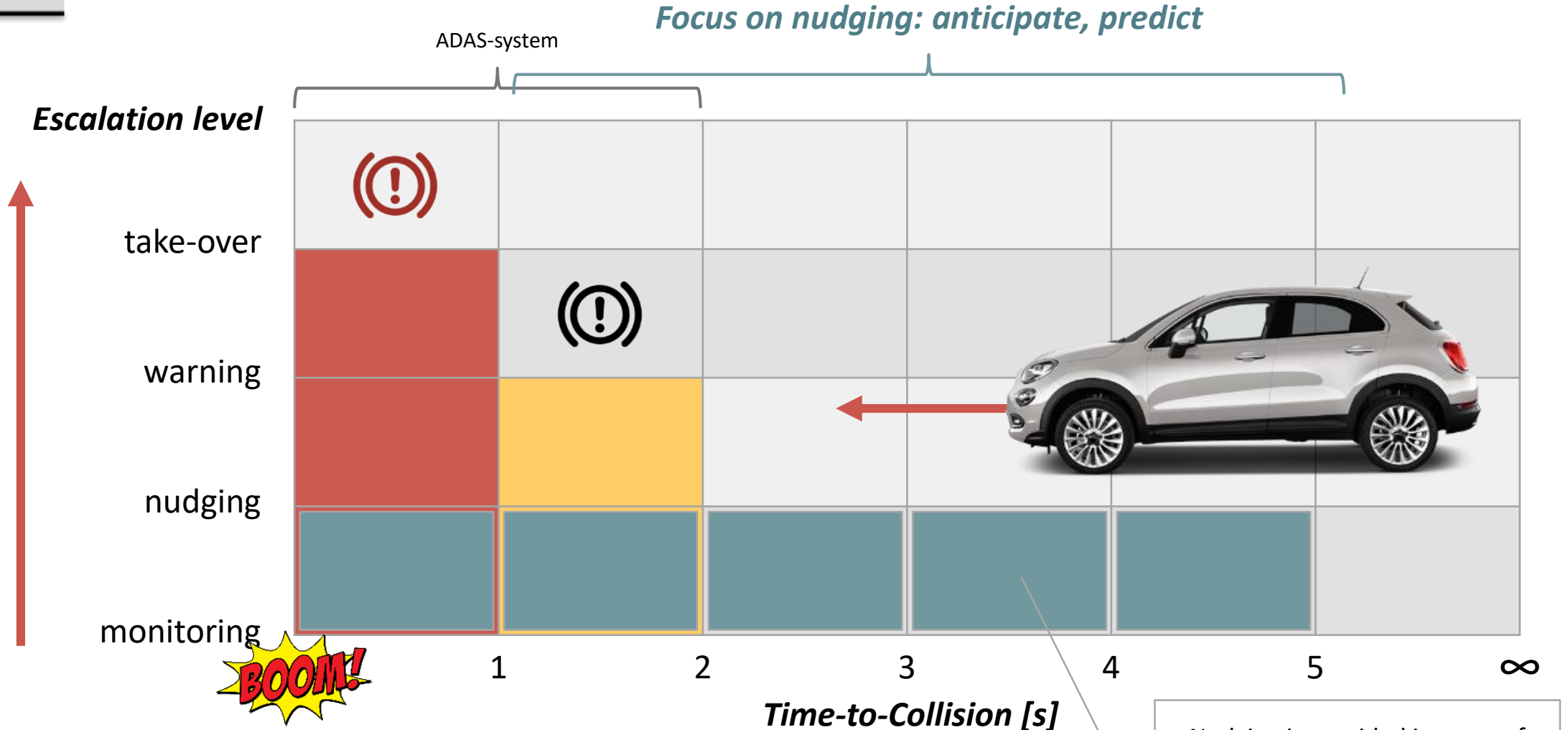




  - Autonomous Emergency Braking

Nudging versus AEB/FCW





HISTORIC TRENDS IN TRAFFIC CASUALTIES

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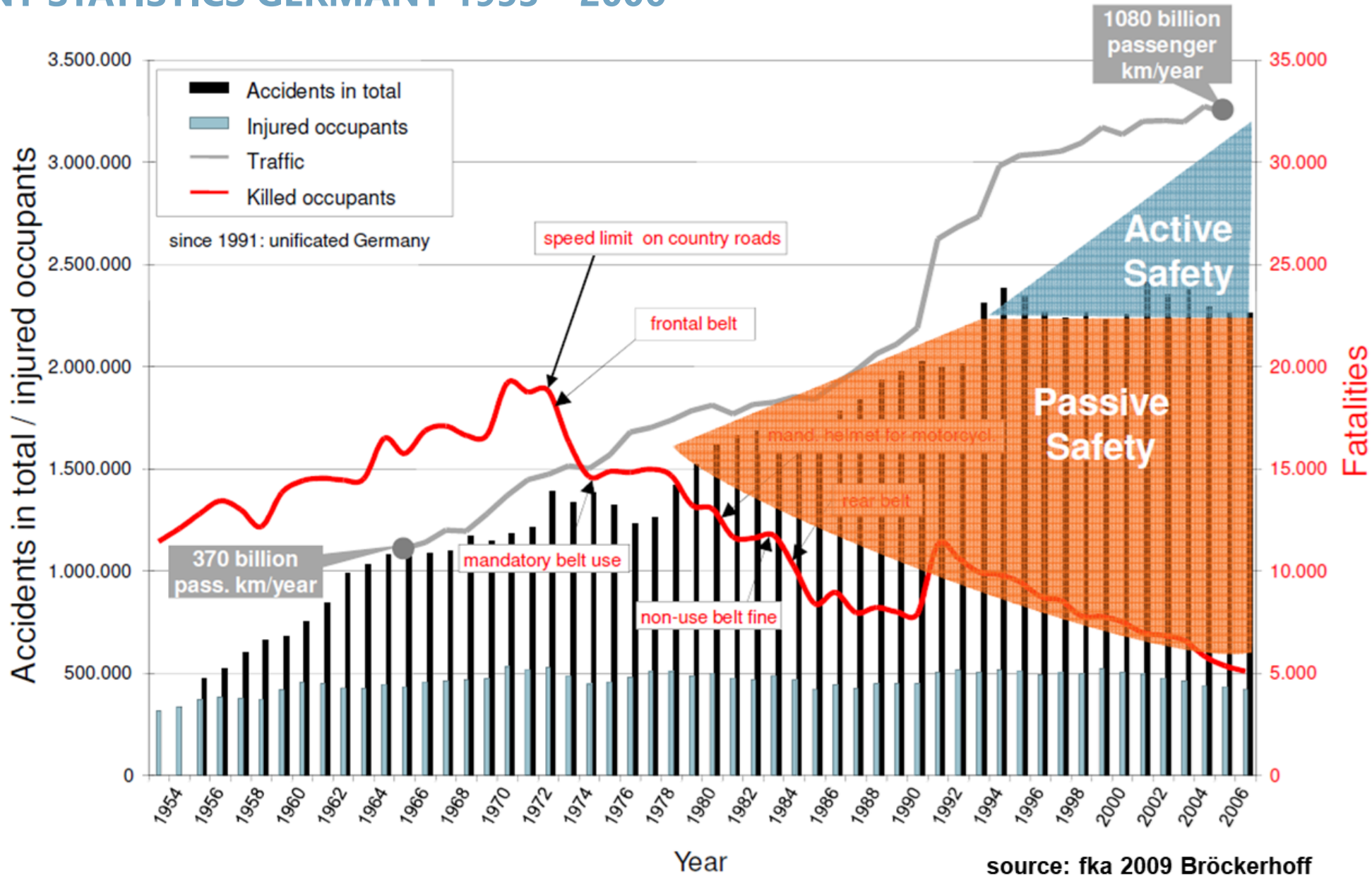
ACCIDENT STATISTICS GERMANY 1953 – 2006



source: fka 2009 Bröckerhoff

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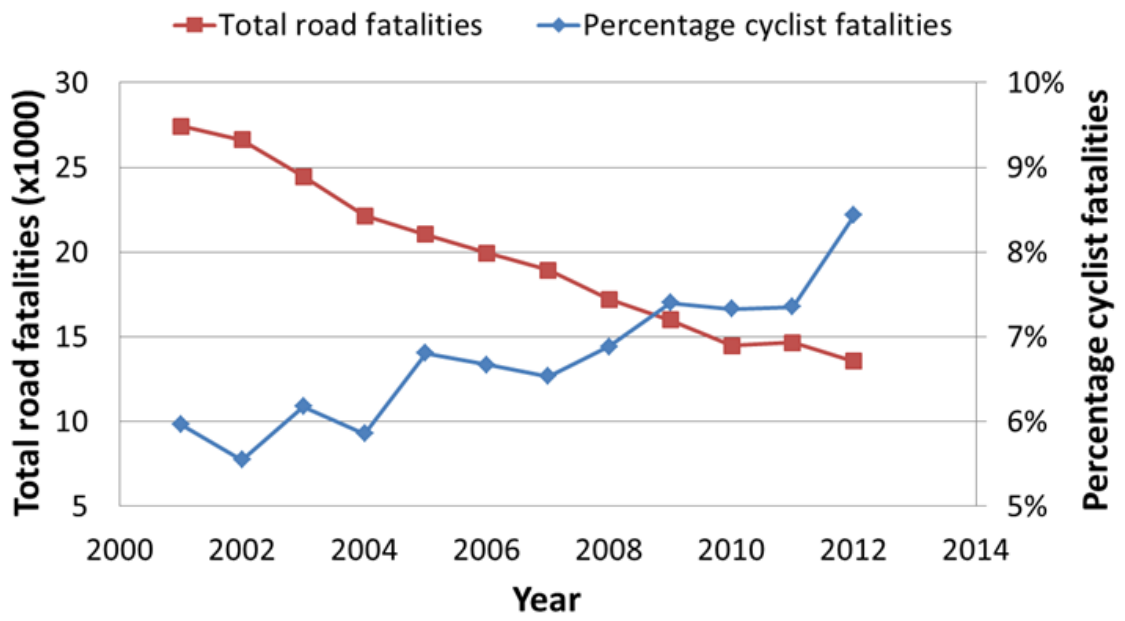
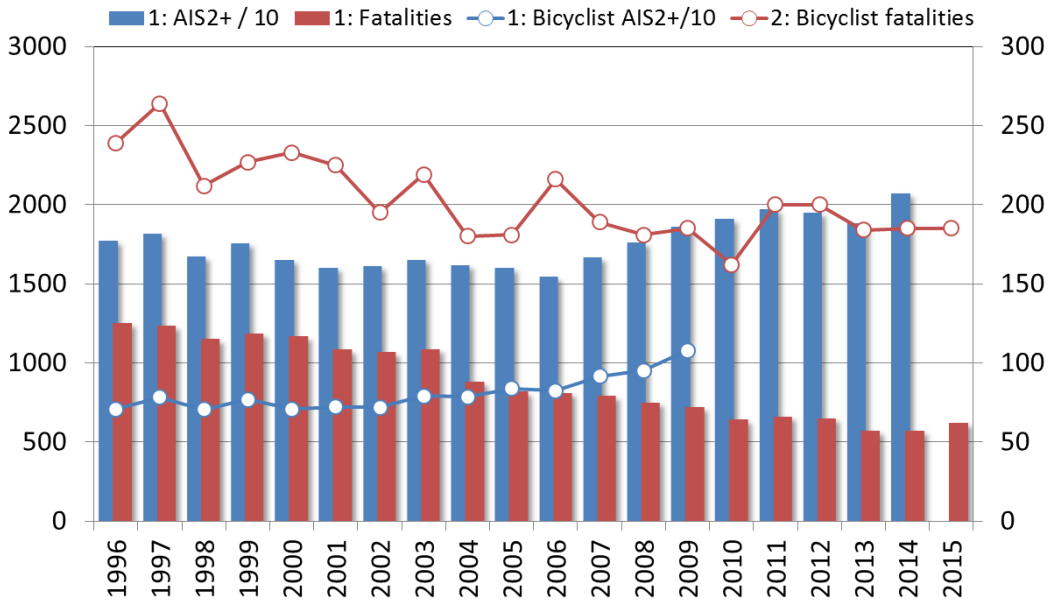
ACCIDENT TRENDS FOR CYCLISTS (EUROPE, NL)



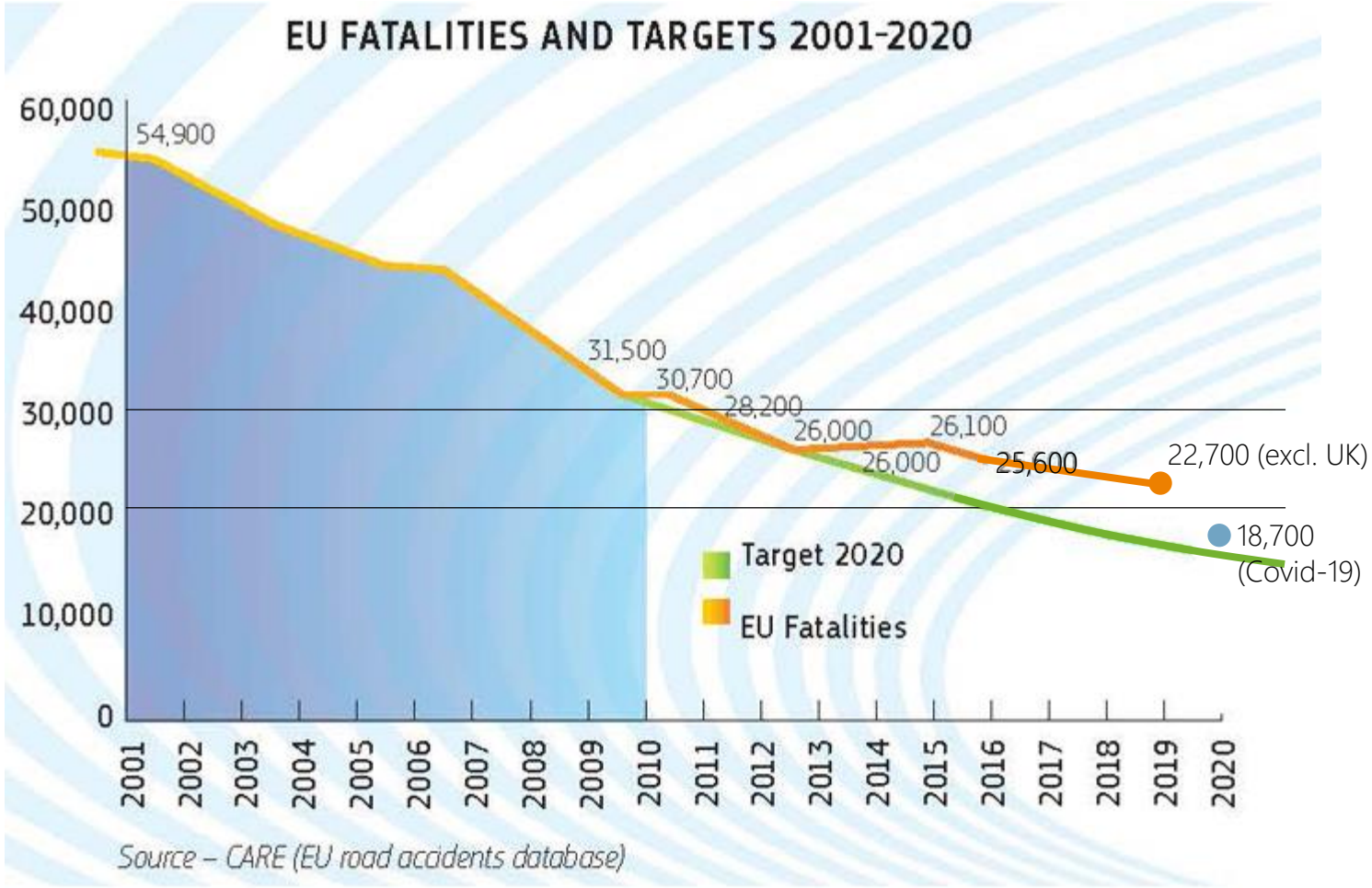
Trends of total road fatalities and cyclist fatalities for France, Germany, Italy, the Netherlands, Sweden plus the UK over the period of 2001 to 2012 according to CARE community road accident database as collected by the EU Member States.

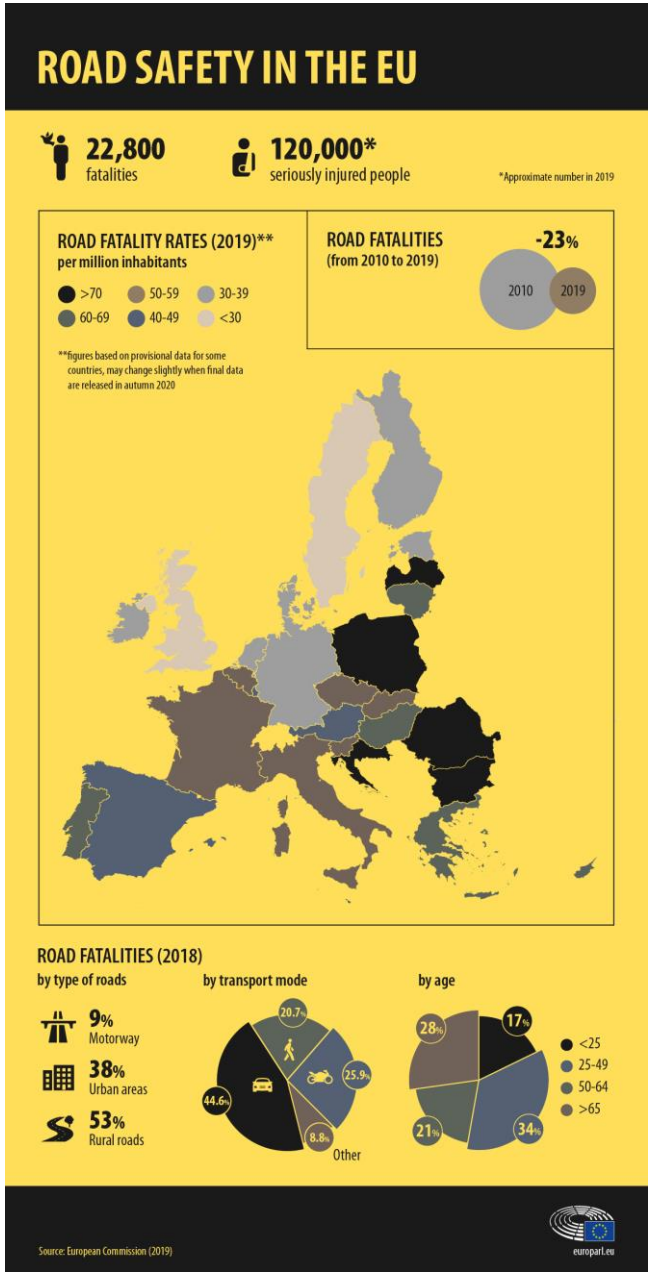


Trends for fatalities and seriously injured (total and bicyclists) for the Netherlands from 1996 to 2015.
30% of fatalities are bicyclists - 10% are pedestrians (2015)

- Trends show a need for enhanced cyclist protection in car-2-cyclist accidents

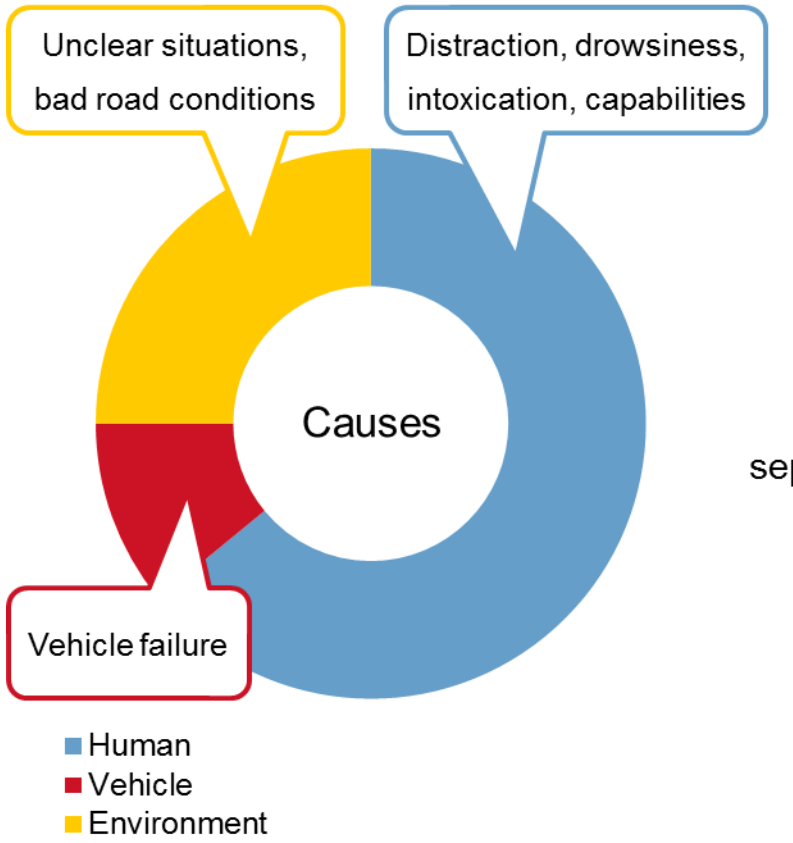
ACCIDENT TREND FOR EU



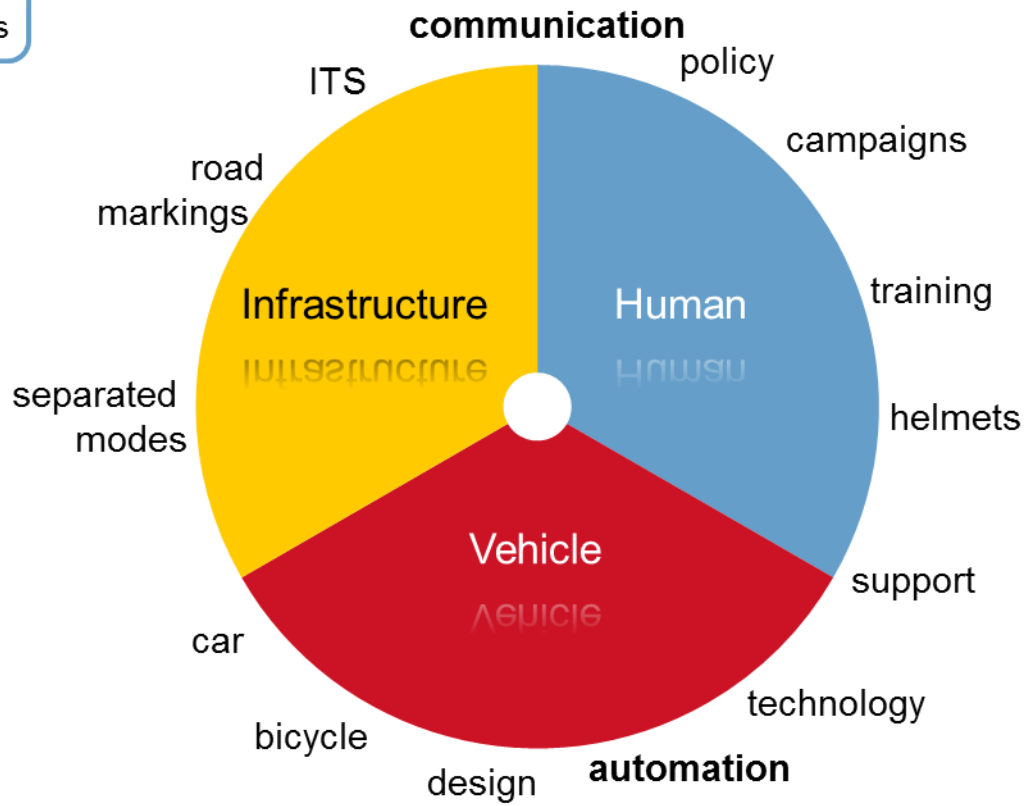


CAUSES OF ACCIDENTS AND SOLUTIONS

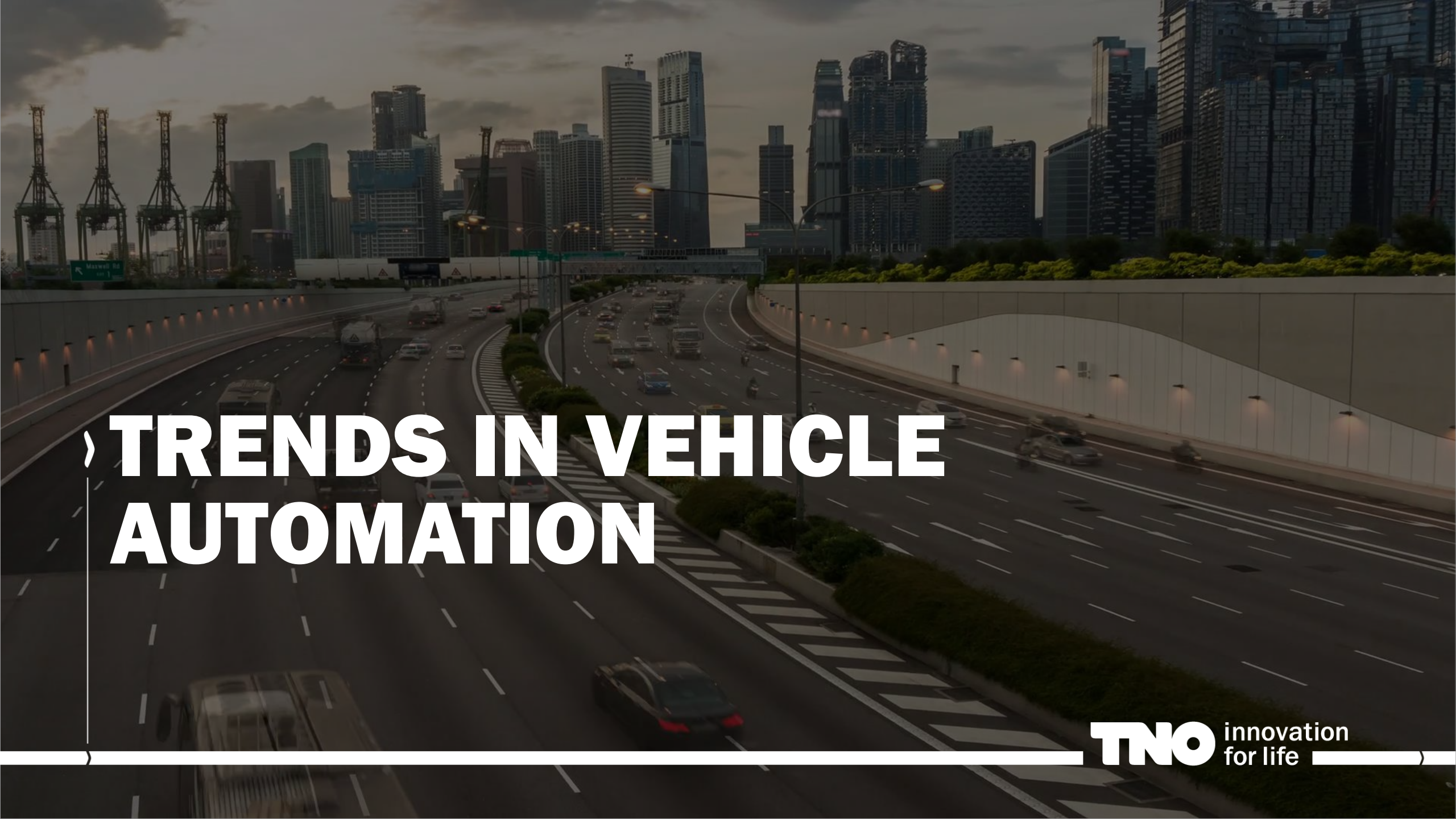
Causes of accidents:



Solutions:



source: Volvo Car Corporation



TRENDS IN VEHICLE AUTOMATION

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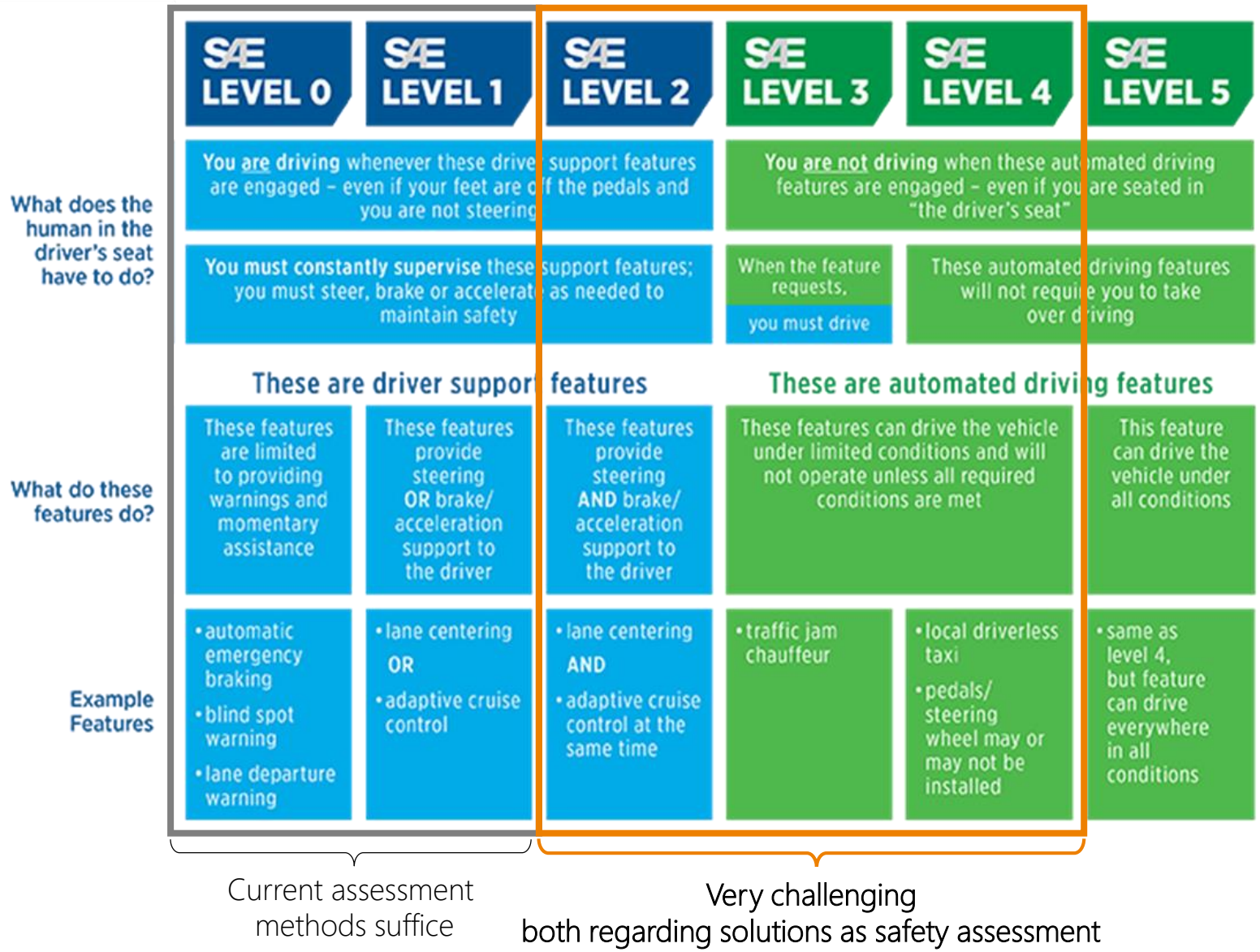
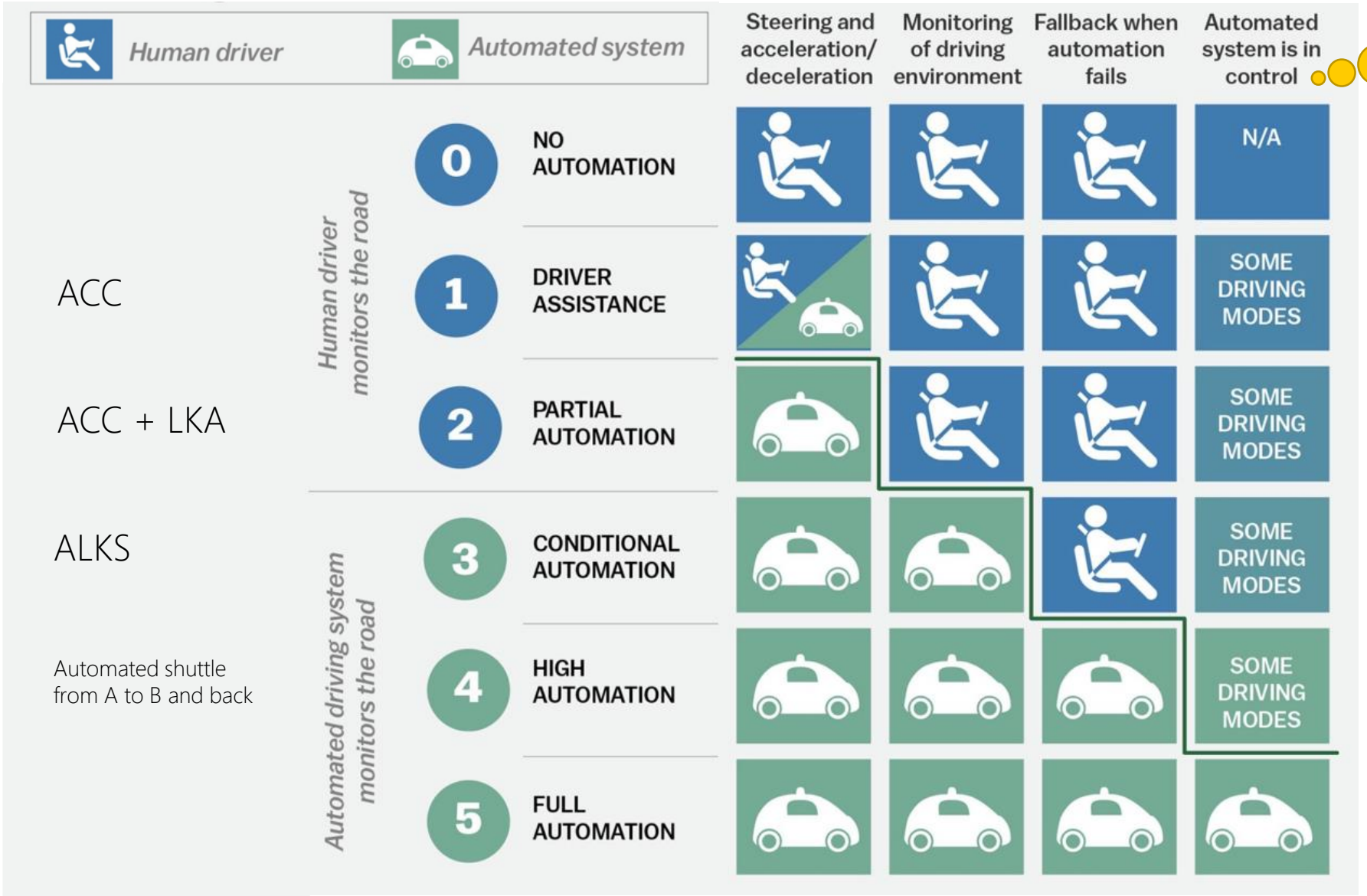
AUTOMATION LEVELS ACCORDING TO SAE J3016



AUTOMATION LEVELS ACCORDING TO SAE J3016



ACC

ACC + LKA

ALKS

Automated shuttle from A to B and back

Operational Design Domain (ODD)

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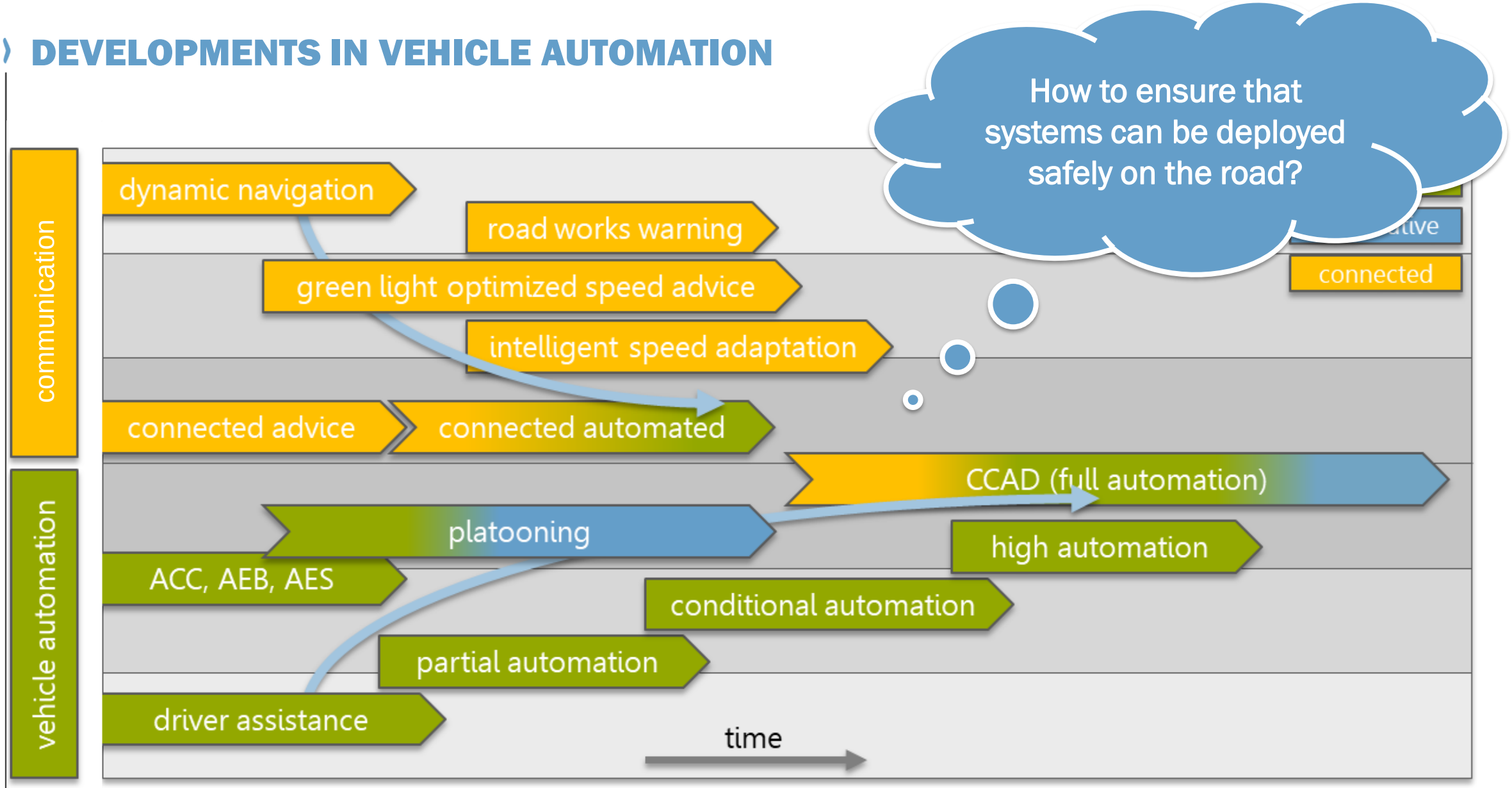
DEVELOPMENTS IN VEHICLE AUTOMATION



SAFETY ASSESSMENT, CHALLENGES AND NEEDS

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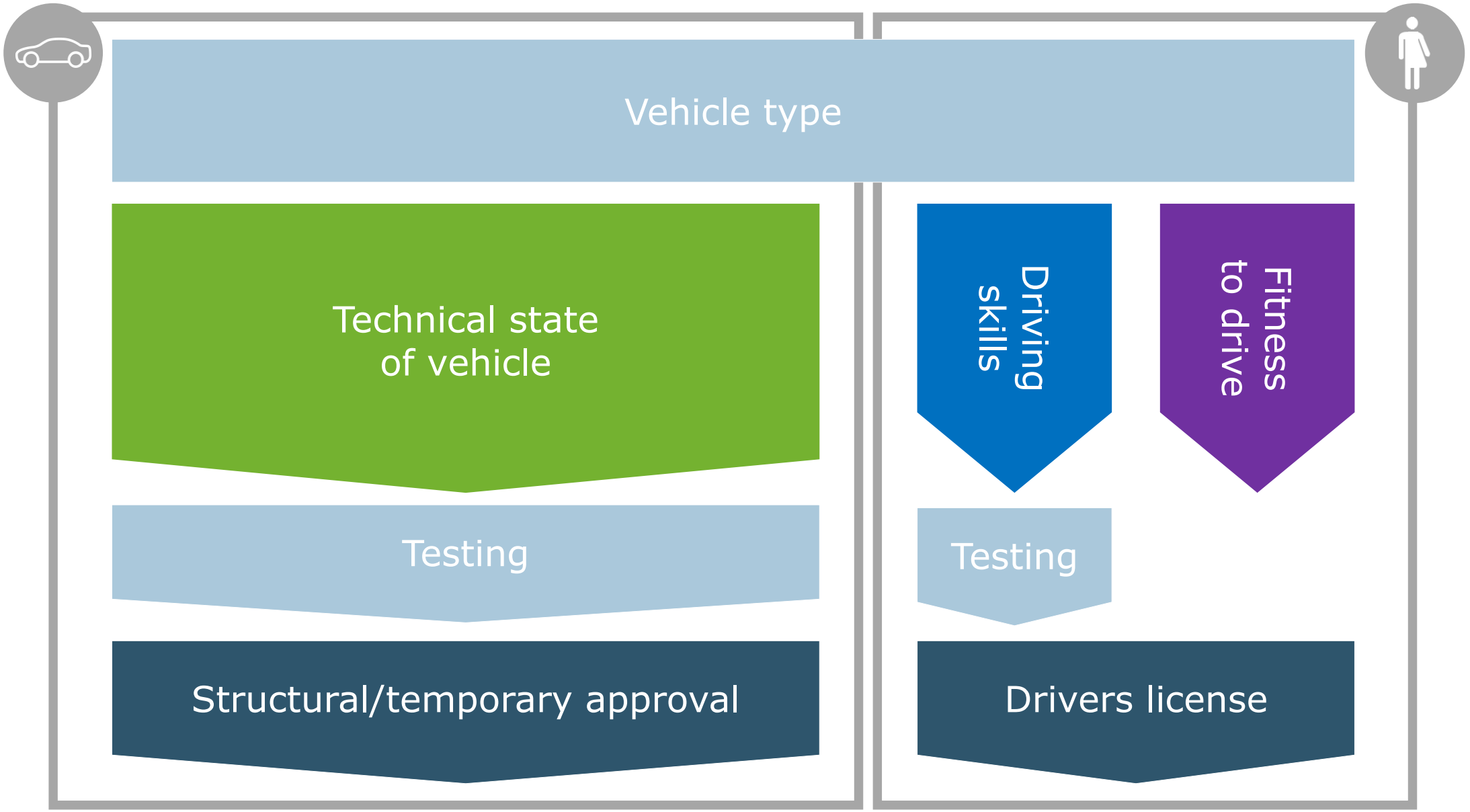
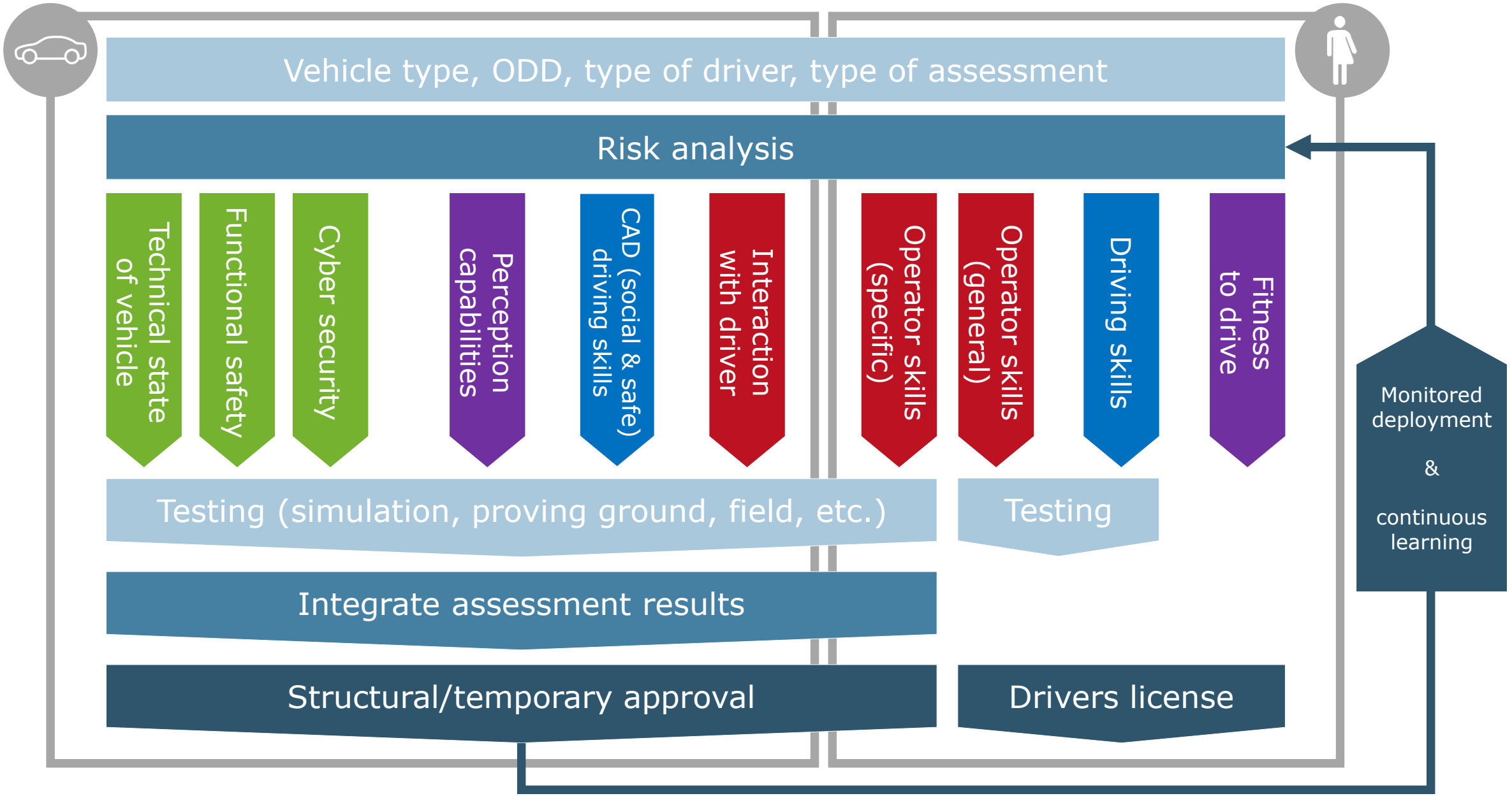
TRADITIONAL APPROACH FOR ALLOWING VEHICLES AND DRIVERS ONTO THE ROAD



TYPE APPROVAL FOR AUTOMATED DRIVING SYSTEMS AND THE ROLE OF THE DRIVER

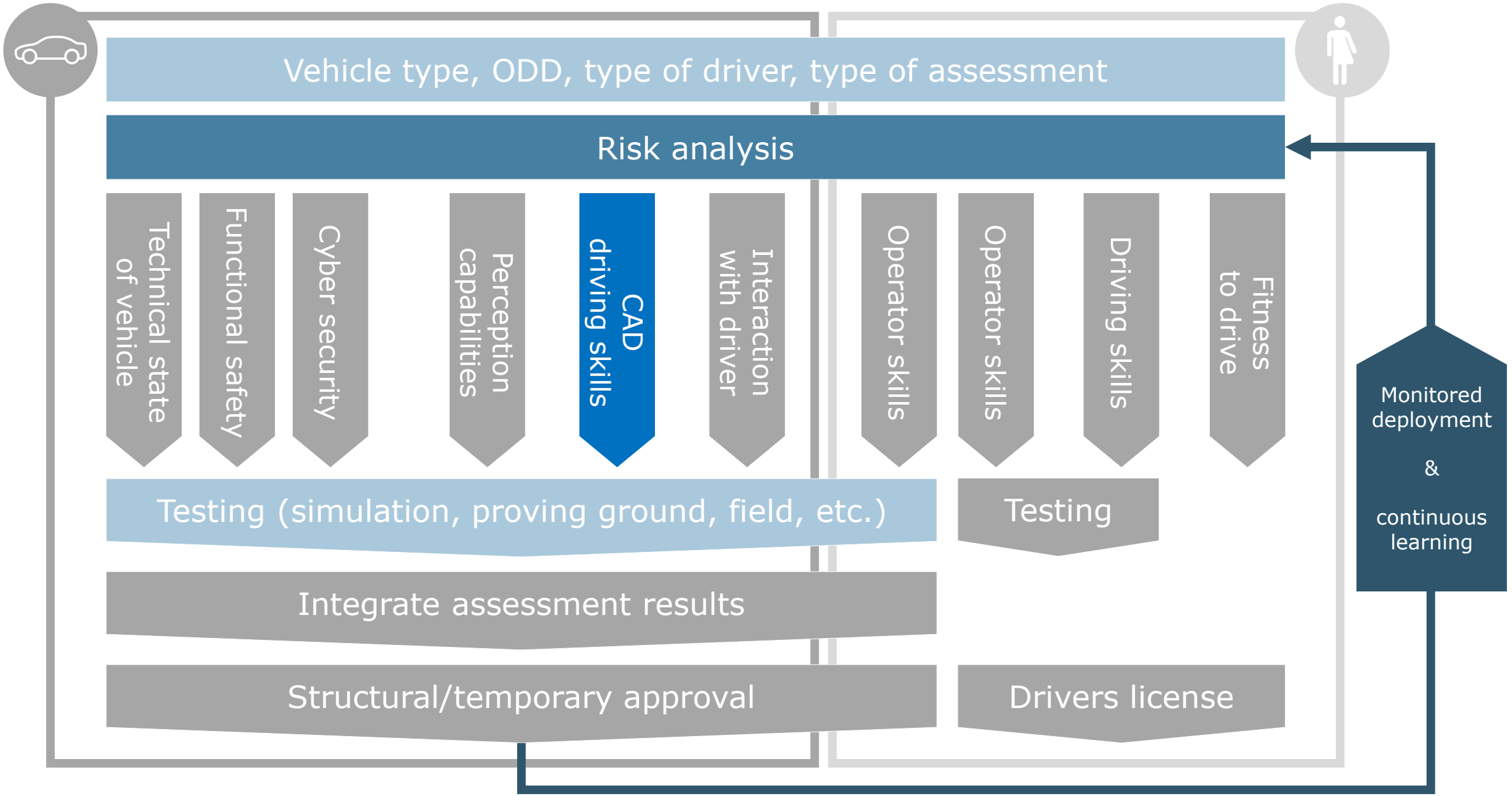



Ready for *all* road situations, in different countries?
Have we tested enough?
How to handle the test explosion? 100 million km?
I can no longer test AD functions independently
How do vehicles behave around our vehicle?
How to convince road authorities?

REQUIREMENTS TO SAFETY ASSESSMENT FRAMEWORKS

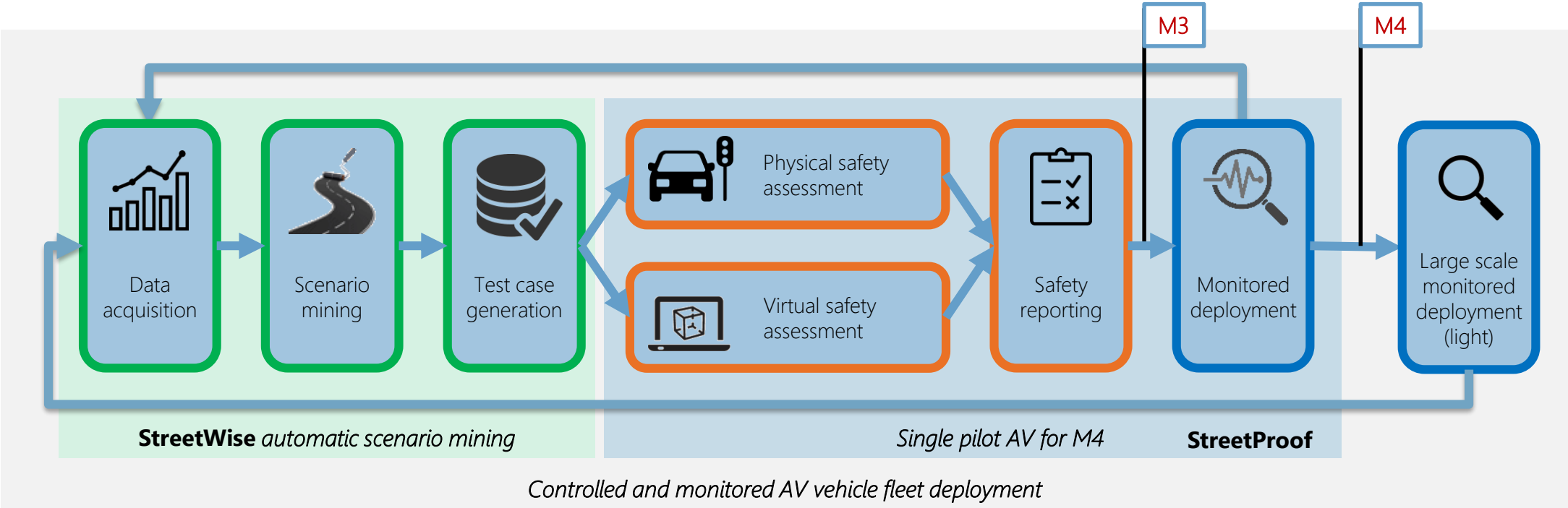
- **SPECIFIC** – "good" systems should pass the assessment, "bad" systems should fail
- **FAIR** – method for assessment should be the same for all, not same tests, but same method
- **ROBUST** – should be able to handle different automation levels, different Operational Design Domains
- **UNDERSTANDABLE/EXPLAINABLE** – should be understood (agreed) by all stakeholders, should be explainable to the general public (acceptance)
- **EFFICIENT** – should be able to deal with the shear infinite number of possible tests (Euro NCAP > 440 tests!)
- **SUSTAINABLE** – method should be able to consider the new technologies that are entering the market over the next decade

TYPE APPROVAL FOR AUTOMATED DRIVING SYSTEMS AND THE ROLE OF THE DRIVER



PROPOSED SAFETY ASSESSMENT FRAMEWORK

- Safety assessment, milestone stepwise approach
  - Milestone M1 Safety driver take-over test
  - Milestone M2a Emergency response test
  - Milestone M2b Basic navigation tests
  - Milestone M3 incl. vehicle driving license, and monitored deployment mandatory (requirements for reporting)
  - Milestone M4 incl. vehicle driving license, and (light) monitored deployment mandatory (requirement for reporting)



Controlled and monitored AV vehicle fleet deployment

TNO STREETWISE

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STREETWISE SOLUTION

What is StreetWise?

- **Automated identification and classification of scenarios from 'object-level' data collected in driving many kilometres in relevant traffic situations.**
- Methodology to generate test cases for the assessment of a system- or function-under-test based on the relevant scenarios in the StreetWise database
- Scenarios are shared between partners in the automotive industry, collected for different regions, countries, and continents
- Provides statistics (distributions) for the parameters describing the occurrence of a scenario, which is indispensable information to quantify completeness, exposure, and risk

Objectives

- Worldwide harmonization of data-driven scenario-based safety assessment for connected cooperative automated driving systems.
- Common understanding of scenarios and assessment methods leads to:
  - Understanding & acceptance of assessment results
  - True comparison in performance of different systems
- Sharing the effort of data collection, scenario identification and test case generation

REAL-WORLD SCENARIOS

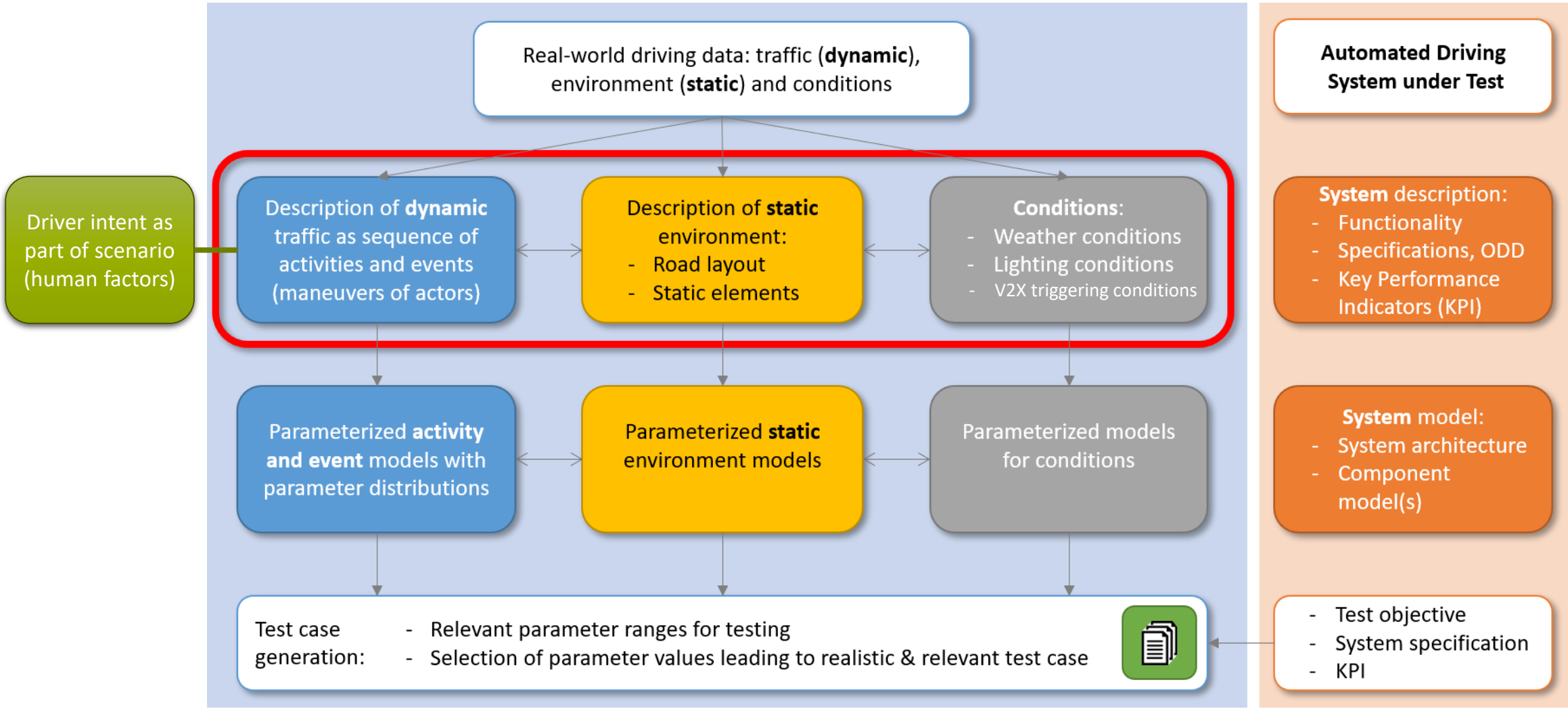
- An overview of real-world scenarios (and variations) to which a subject vehicle needs to respond, is required for:
  - Development & testing (industry internal validation)
  - Safety assessment (type approval – for authorities – or consumer testing – for consumer organizations)

- A scenario describes any situation on the road including the intent of the subject vehicle, the behavior of road users, the road layout, and weather & lighting conditions. A drive on the road is considered a continuous sequence of scenarios – which might overlap.

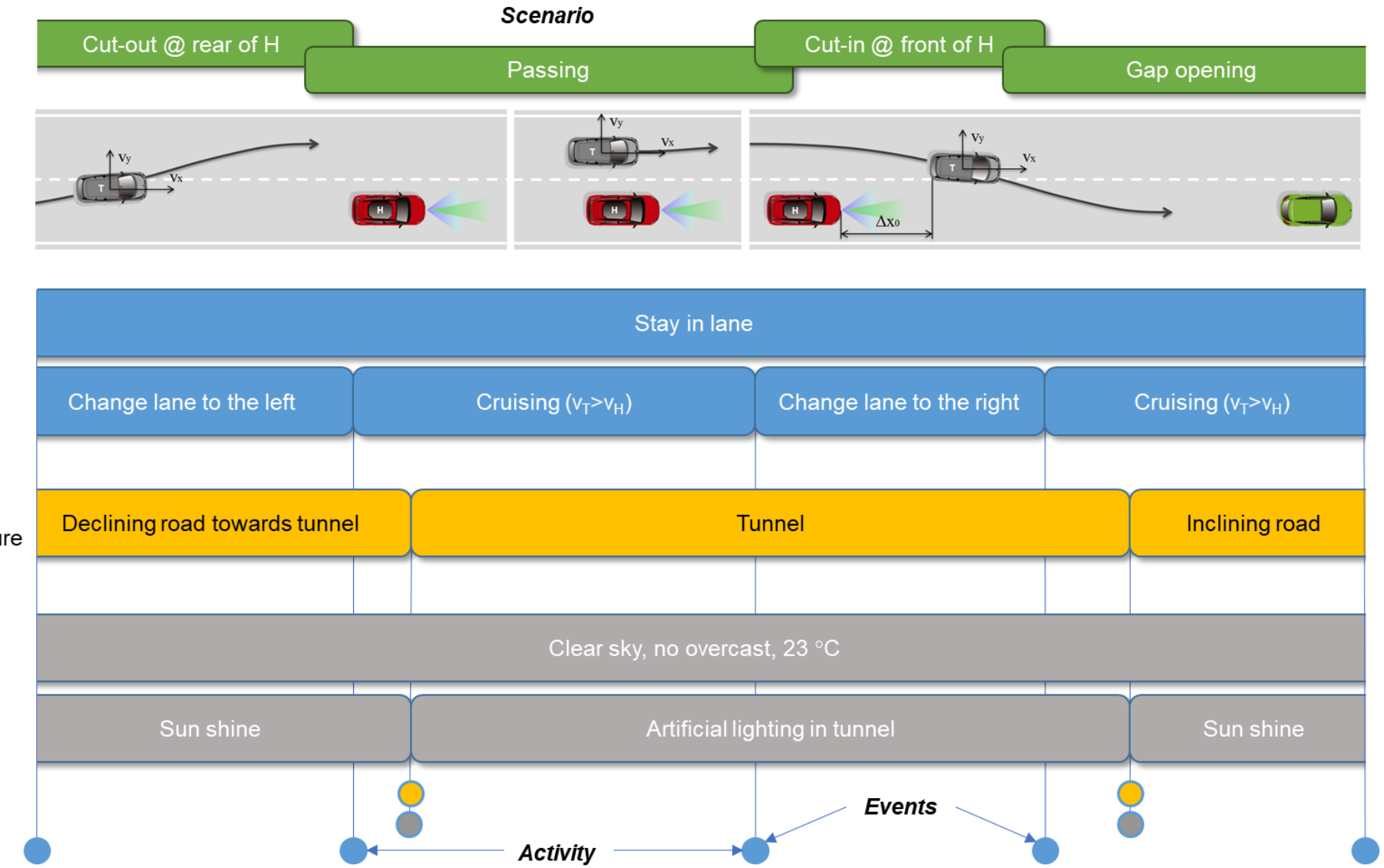
- Scenarios are essential to generate test cases for the assessment of system performance in the subject vehicle. Assessment concerns:
  - Perception and identification performance of the subject vehicle's sensor set (also in adverse conditions). This includes sensor fusion;
  - Interaction, decision & control logic: performance regarding interpretation of the world-model, the potential interaction with other road users (e.g. through communication) and decision on an appropriate response;
  - Dynamic vehicle response: what is the delay in controlling the actuators, and how well does the vehicle respond to the actuation under different conditions;
  - Driver response tests (human-machine interaction in relation to human capabilities, transition-of-control).

- Scenarios are also important for setting up system specifications for a vehicle's ADAS or CADS in the development stage: the vehicle's operational design domain (ODD) as well as the dynamic driving task (DDT)

DEFINITIONS: SCENARIO, TEST CASE, ODD (OPERATIONAL DESIGN DOMAIN)



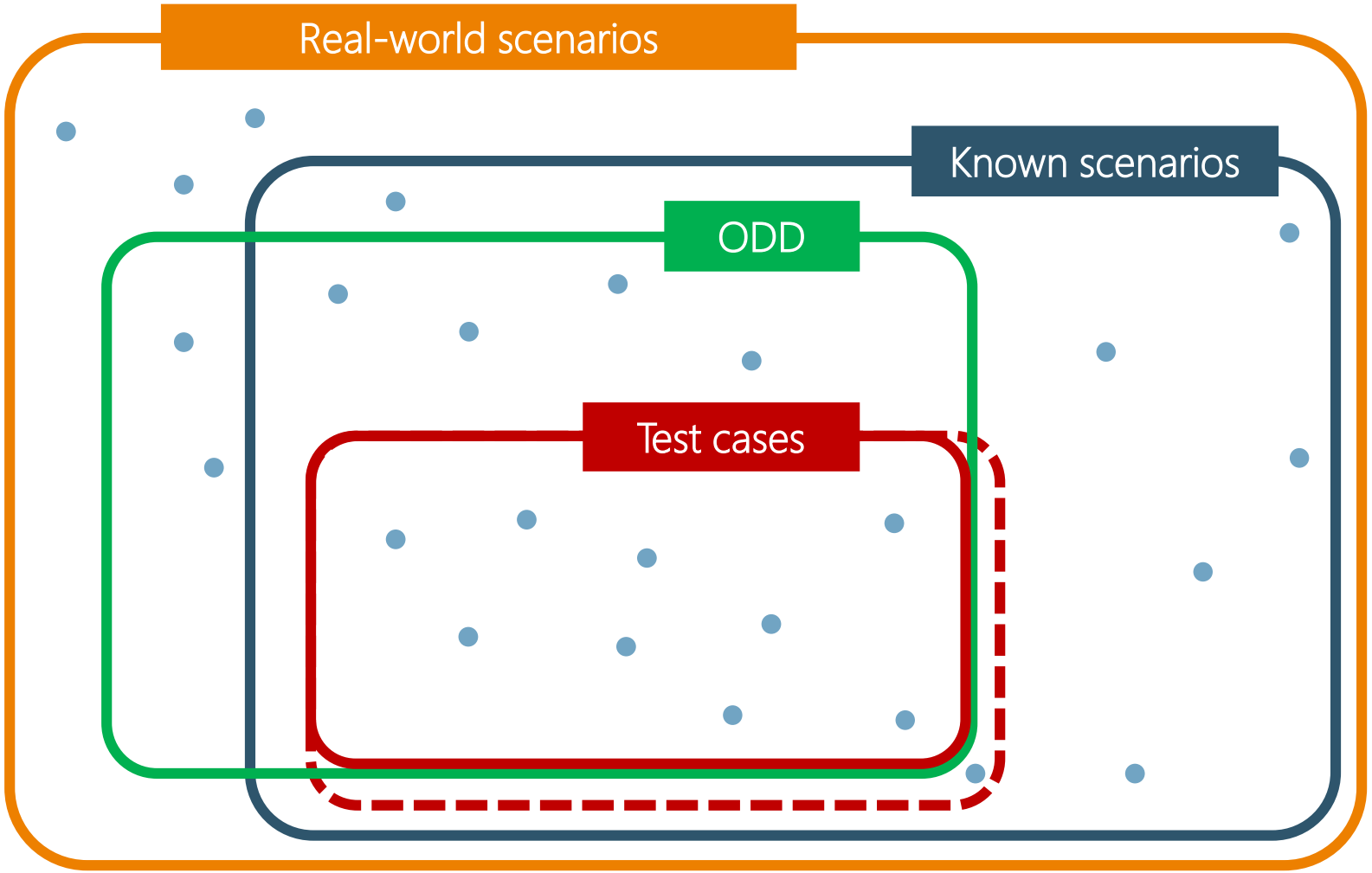
SCENARIO EXAMPLE



DEFINITIONS: SCENARIO, TEST CASE, ODD (OPERATIONAL DESIGN DOMAIN)

ASAM Association for Standardization of Automation and Measuring Systems

Adapted from: E. de Gelder, O. Op den Camp, and N. de Boer, "Scenario Categories for the Assessment of Automated Vehicles." Available at: https://cetran.sg/publications/, 2020.



- Specific scenario
- Set of all possible scenarios
- Set of identified/known/ recorded scenarios
- Set of scenarios within the ODD
- Set of test cases

- Completeness
- Coverage
- ODD / Operation Domain

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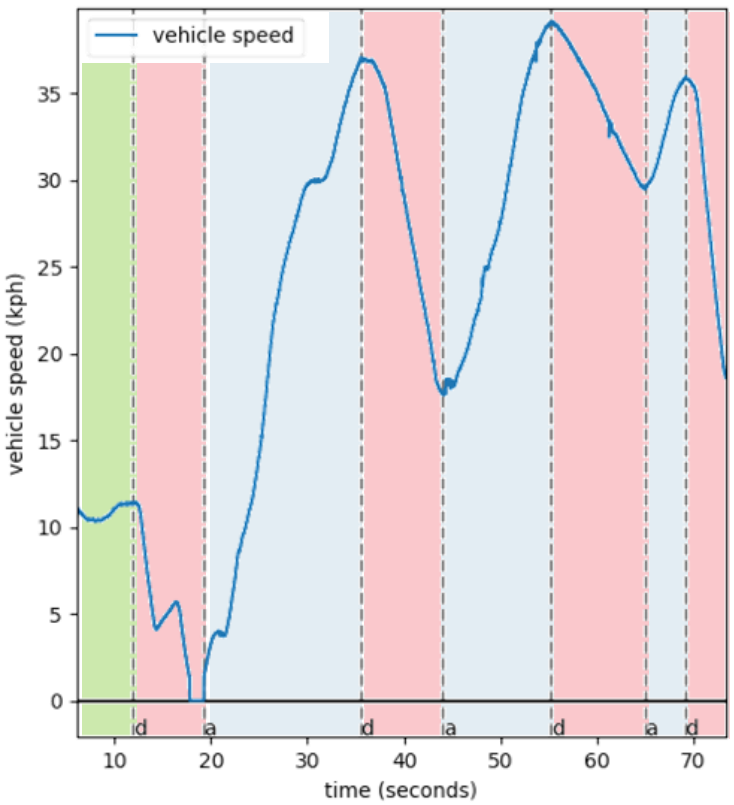
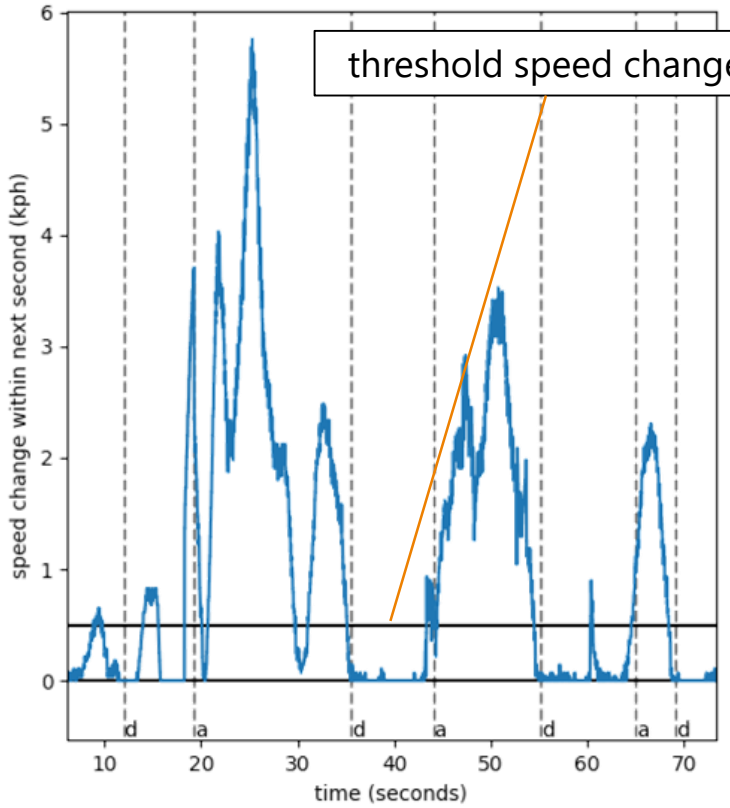
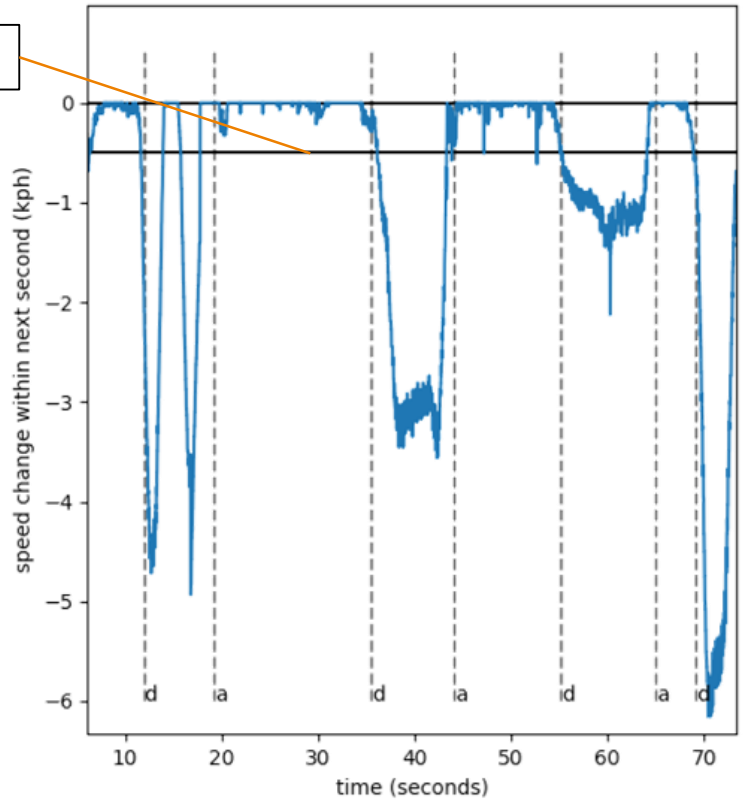
ACTIVITY DETECTION – LONGITUDINAL

- Longitudinal activities: accelerating, cruising, decelerating
- Target speed: vertical dashed lines represent events separating activities.

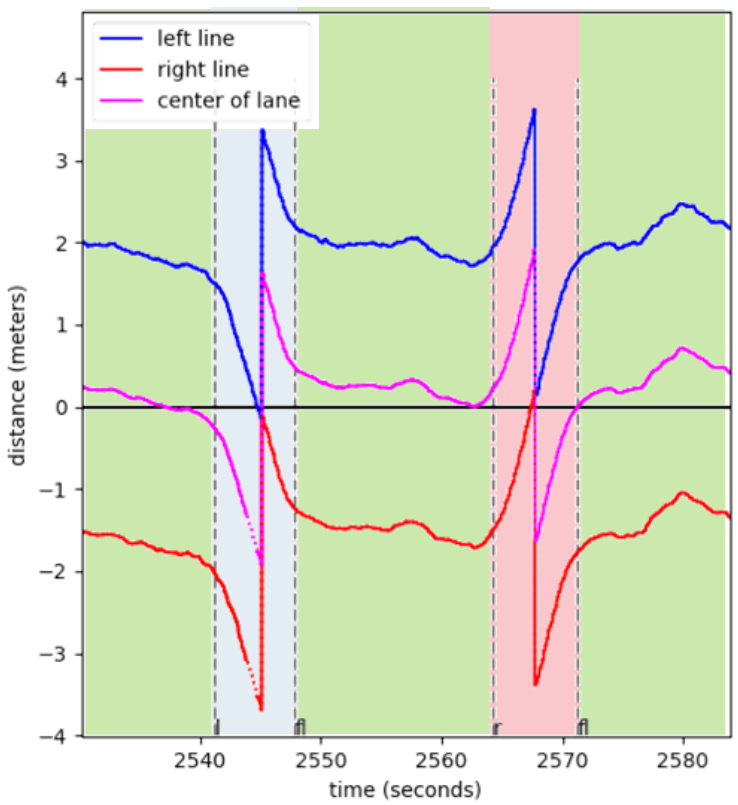


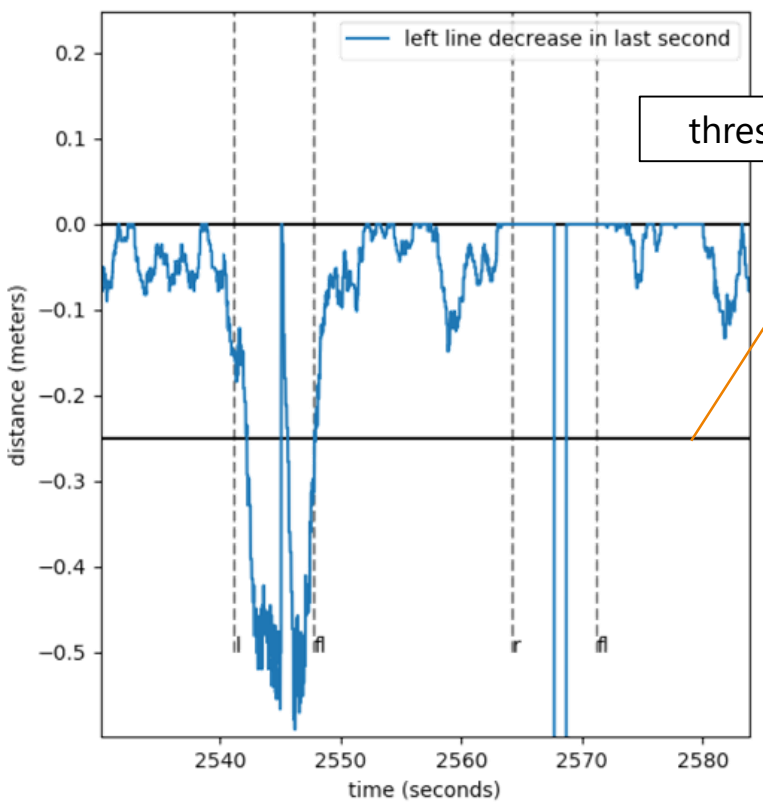


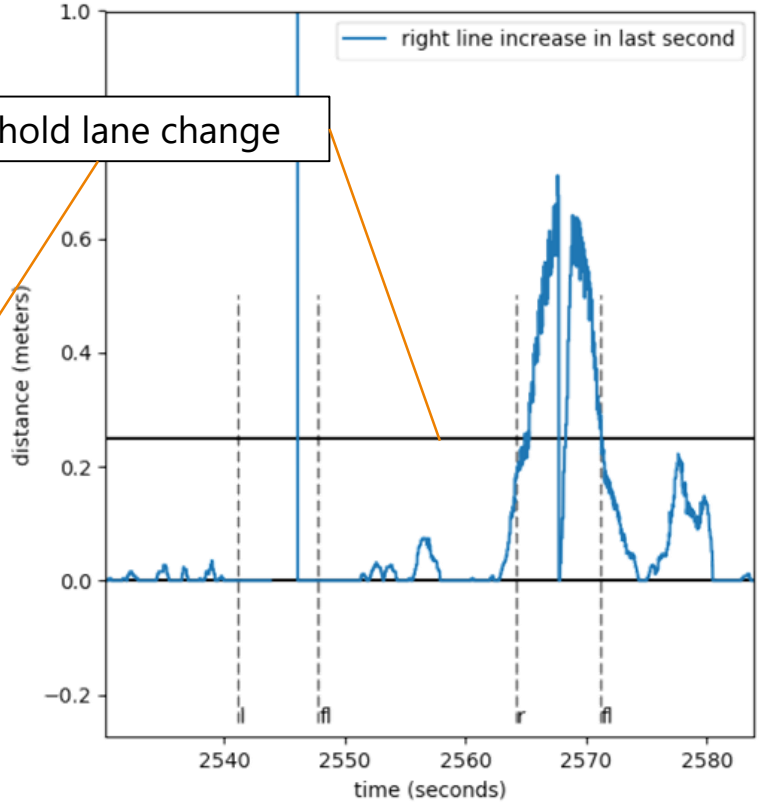


ACTIVITY DETECTION – LATERAL

- Lateral activities: lane change to the left, lane change to the right, lane following
- Distance to lane marker: vertical dashed lines represent events separating activities.

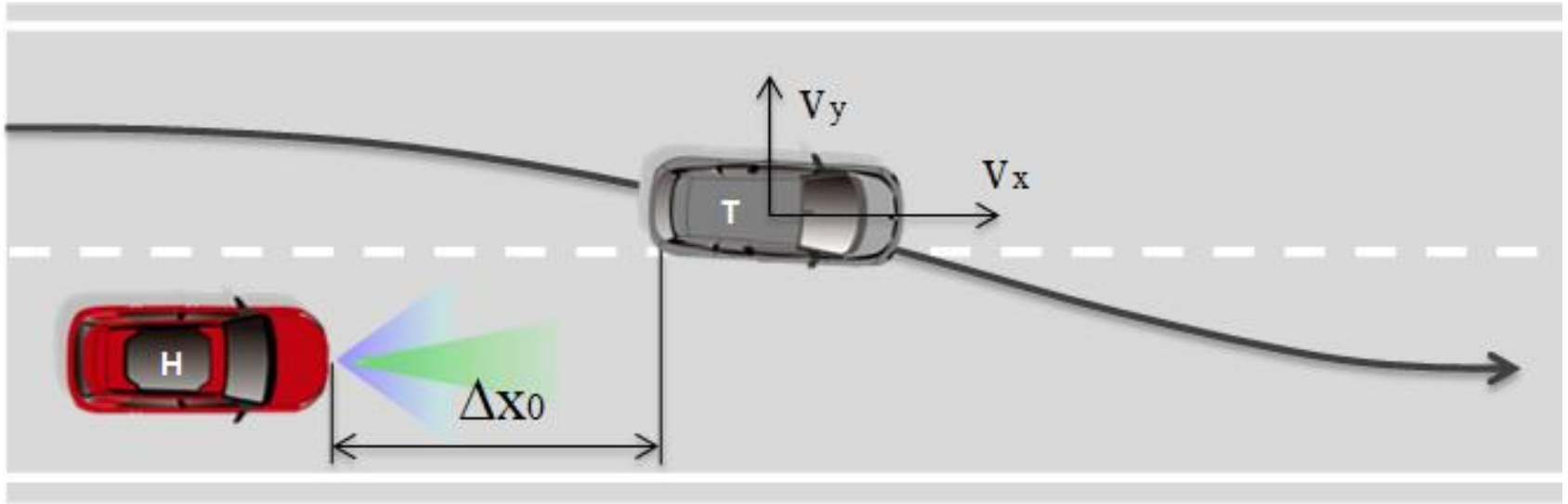






SCENARIO PARAMETRISATION

Cut-in of target vehicle (T) onto the ego-vehicle (H)



V_x^H : ego initial longitudinal velocity [m/s]

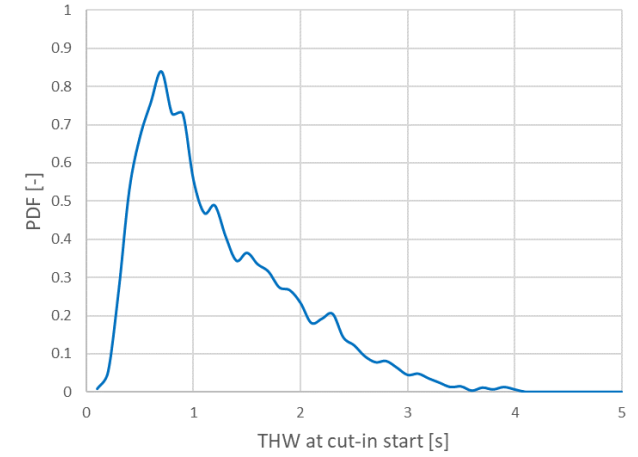
ΔV_x^T : target initial relative longitudinal velocity with respect to ego [m/s]

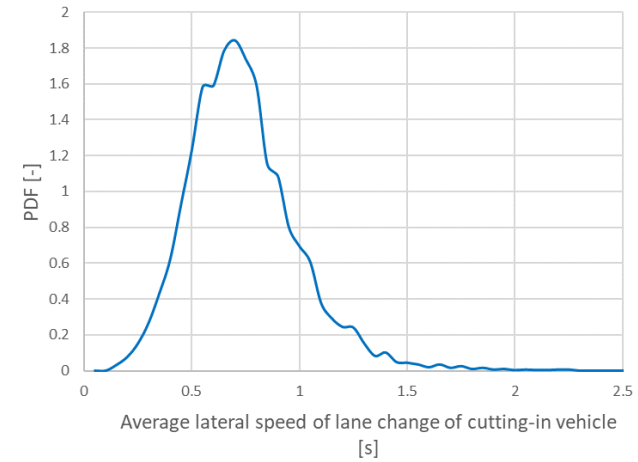
$\overline{V_y^T}$: target average lateral velocity relative to lane over the duration of the lane change [m/s]

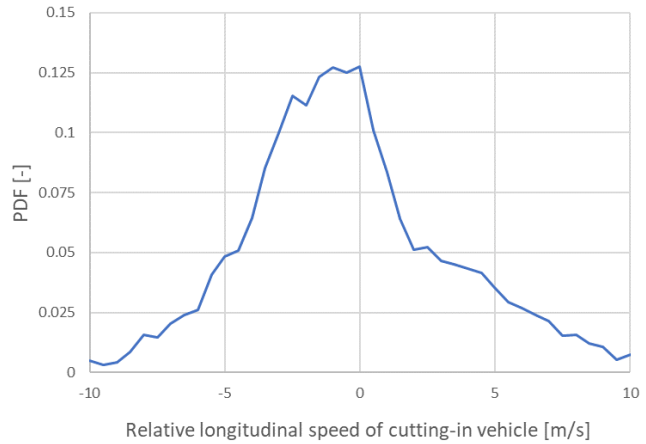
sign V_y : target lane change direction [-1: from left to right, 1: from right to left]

THW_{LC} : time headway at start of lane change [s] $= \Delta x_0 / V_x^H$

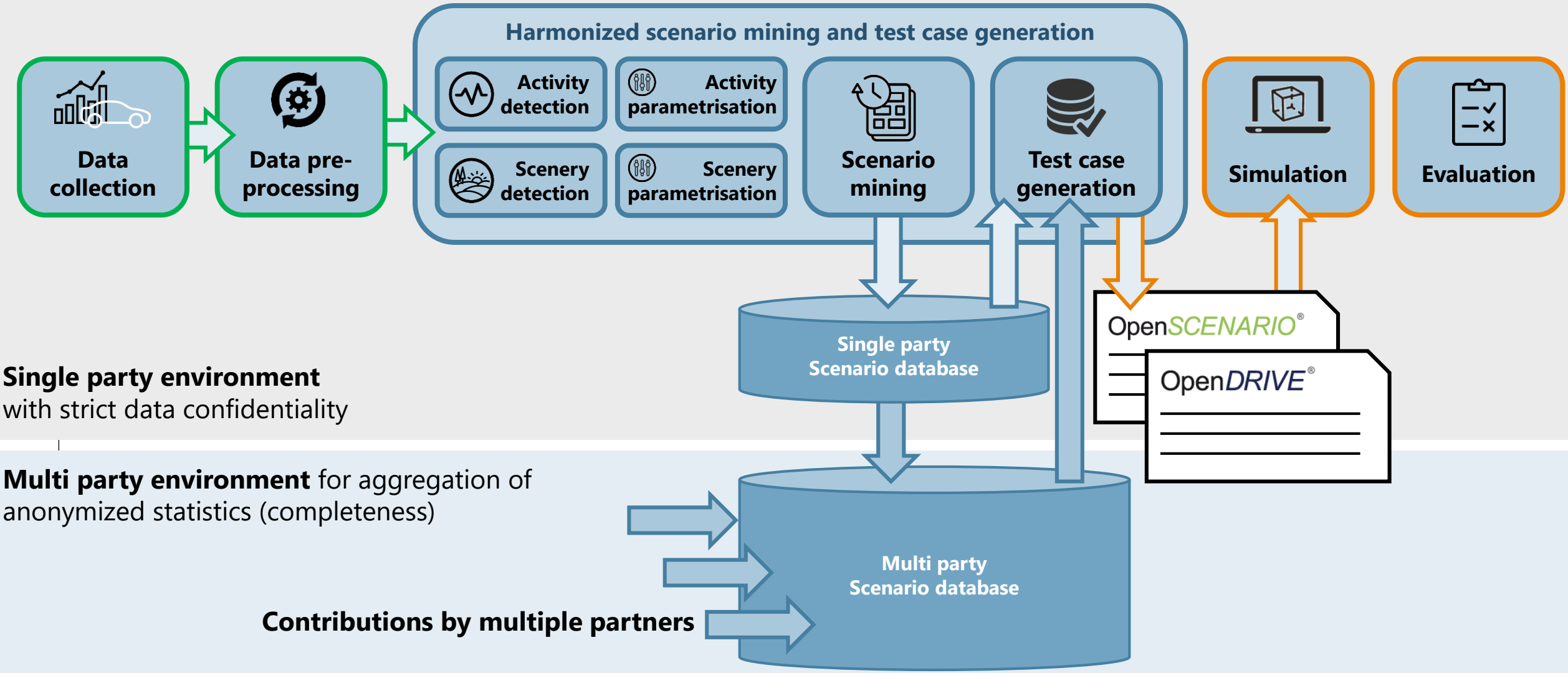
Δx_0 : distance between target and ego vehicle when target starts crossing the lane marking







STREETWISE TOOL CHAIN



Single party environment
with strict data confidentiality

Multi party environment for aggregation of anonymized statistics (completeness)

STREETWISE TEST CASE SELECTION

LOGGED IN AS: OLAF OP DEN CAMP (OLAF.OPDENCAMP@TNO.NL)

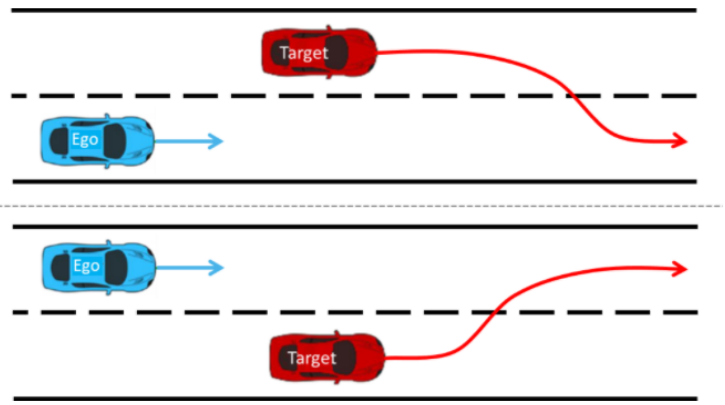
LOGOUT

SCENARIO CATEGORY

Name	Exposure (n/h)	Observations
☐ Lead vehicle decelerating	8.4	8166
☐ Vehicle overtaking ego vehicle	0.7	715
☑ Cut-in in front of ego vehicle	3.2	3084
☐ Ego vehicle performing lane change with vehicle behind	1.3	1307
☐ Lead vehicle cruising	7.0	6826
☐ Ego vehicle approaching slower lead vehicle	2.5	2445
☐ Ego vehicle driving in lane without lead vehicle	13.2	12896
☐ Cut-out in front of ego vehicle	3.9	3760
☐ Lead vehicle accelerating	8.1	7878
☐ Ego merging into an occupied lane	0.4	375

SCENARIO DETAILS

Cut-in in front of ego vehicle



DESCRIPTION

Dynamic actors:

Ego: Driving in lane.
Driving forward.

Target: Driving in lane adjacent to ego lane, performs cut-in in front of ego.
Driving forward.

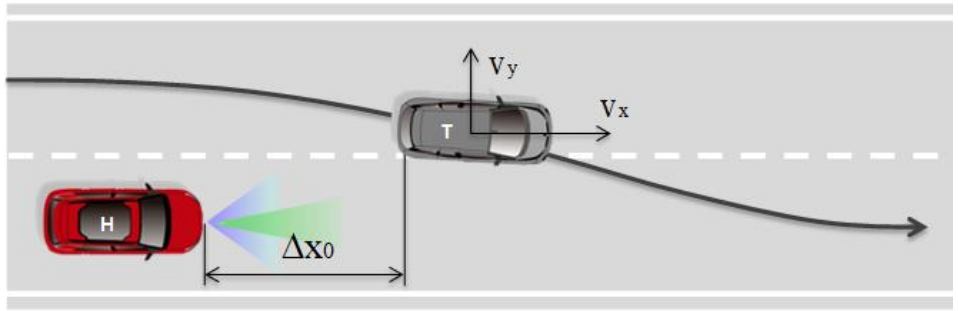
Static environment:

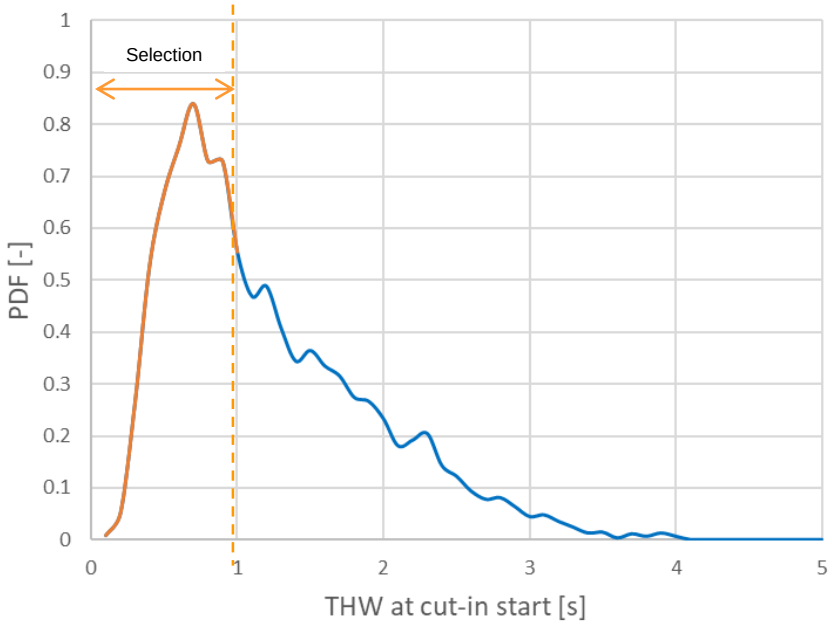
Main environment: Motorway, at least 2 lanes
Infrastructure: Not specified
Region: EU west central

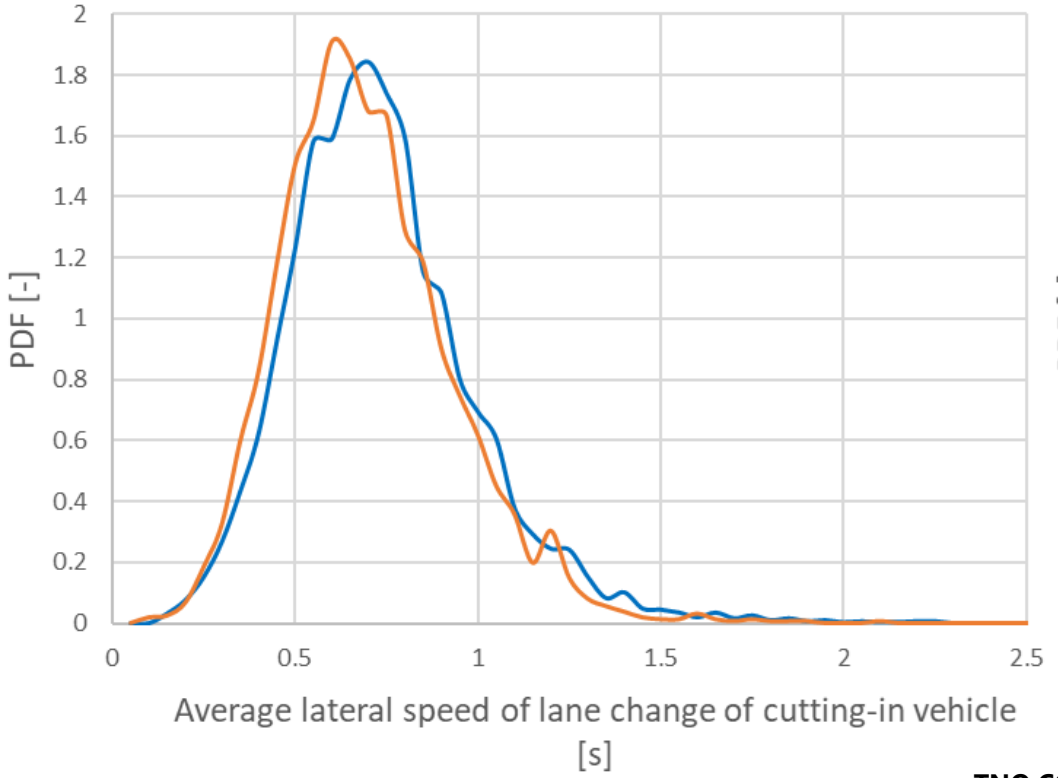
Environmental conditions:

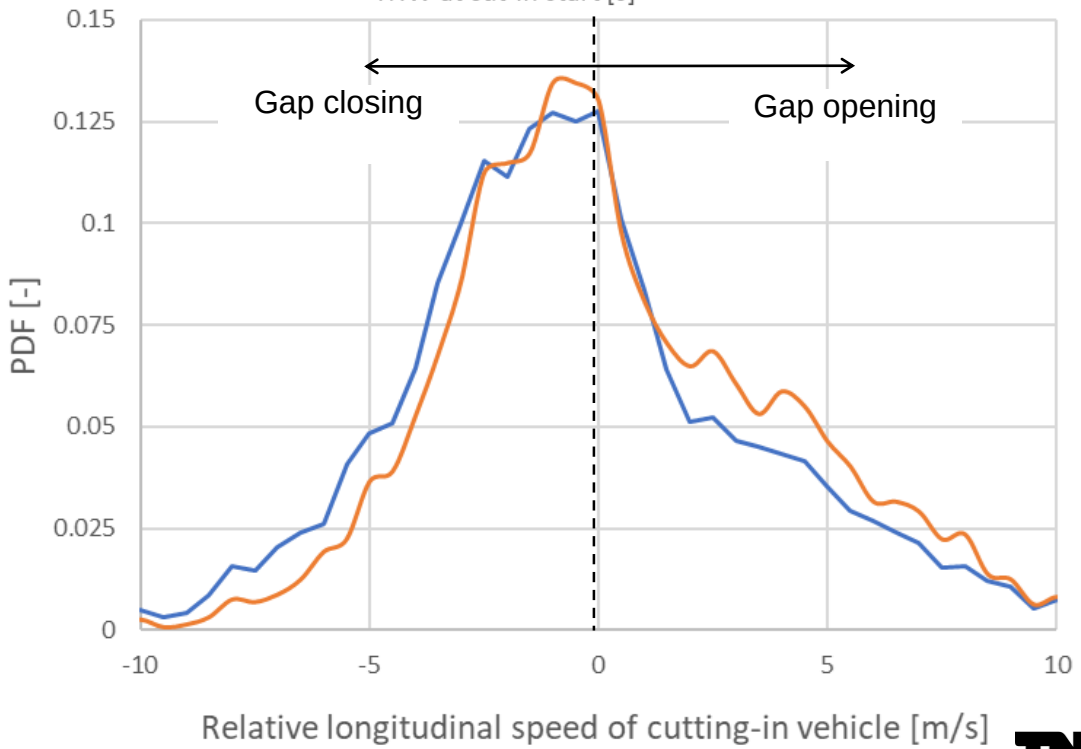
Light: Not specified
Weather: Not specified

SCENARIO PARAMETRISATION










How to deal with systems that use Artificial Intelligence?
We focus on safety, but how can we guarantee cyber security?
How to test the increasingly complex human-vehicle interaction?
How to handle the danger of mode-confusion?
How can we cover the increased role of communication?
How to explain the complexity and how to involve road and vehicle authorities?

CONCLUSION

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WHAT IS THE IMPACT OF VEHICLE AUTOMATION ON TRAFFIC SAFETY?

CERTAINLY

- Advanced driver assistance systems are becoming a standard in new vehicles
- The level of automation and digitalization in vehicles is increasing drastically
- All these systems aim at supporting the driver, and taking over dull tasks, and tasks that are difficult to handle by humans (emergency situations)
- In this way Connected Cooperative Automated Mobility adds to traffic safety

HOWEVER

- There is a huge challenge to proof safety of vehicles with high levels of automation that have many interactions with human drivers:
  - Mode confusion (system in control vs. human driver in control; large variety of human responses to system inputs – different people respond differently)
  - Differences in solutions introduced by automotive industry
  - Decreasing driver skills
- We need to keep paying attention to driver training and to forgiving roads (safe infrastructure)

AND …

SOCIALIZATION OF AUTOMATED VEHICLES (ARTURO TEJADA) IS A KEY ELEMENT OF CONTINUOUS SAFETY ASSESSMENT

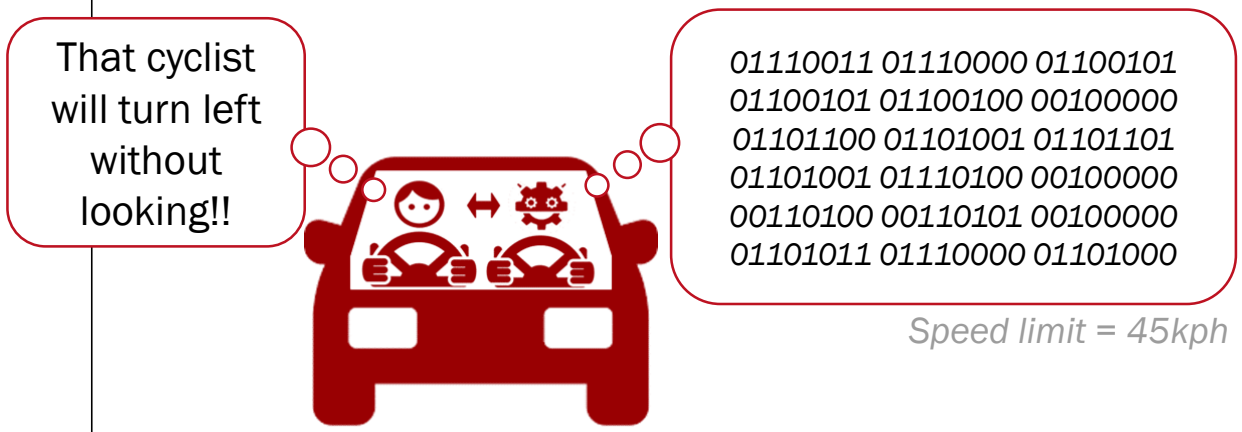
- To live with humans, dogs need to learn **how to act in a way that humans want.**
- How to play, eat and **behave the way we expect.**
- This is called **“socialization”.**

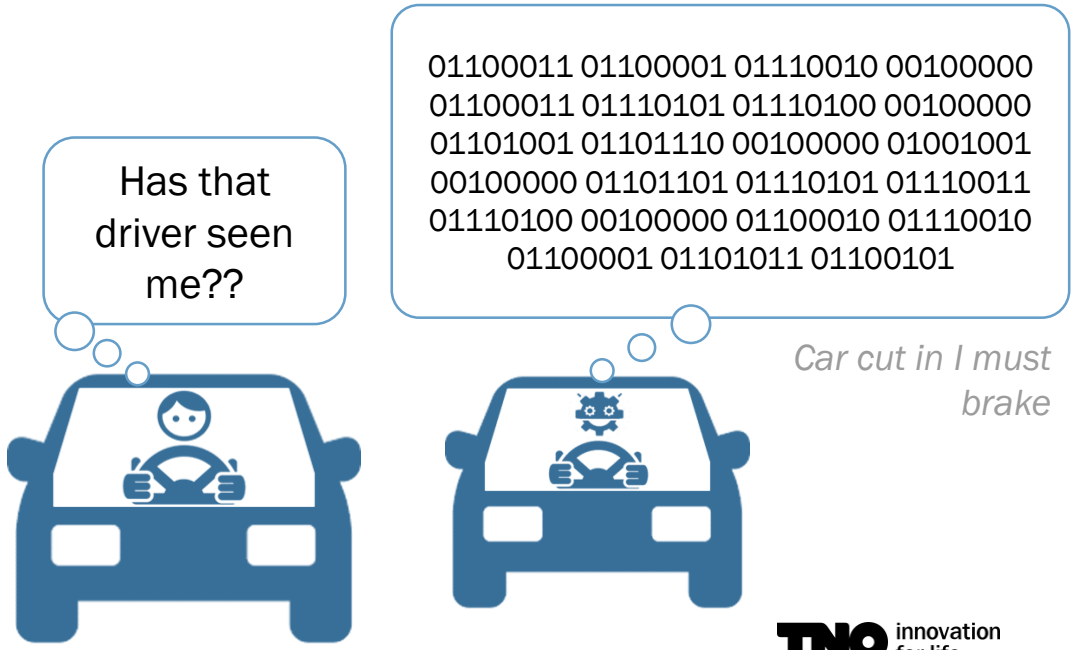
- To interact with humans, cars need to learn how behave **in a way that humans want.**
- **AVs need to learn how to drive and behave in traffic** the way humans expect.
- **AVs need to be socialized.**

- Through **Streetproof** TNO wants to socialize automated vehicles.
- TNO is developing **knowledge** and **technology** to **make AVs safe & social.**
- **To make AVs behave in a way that humans expect and want.**

CONTINUOUS SAFETY ASSESSMENT ENSURES AVs WILL KEEP DRIVING SAFELY & SOCIALLY IN MIXED TRAFFIC

- When normal and low-automated vehicles (L0, L1 and L2), higher levels of AV (L3 and L4), motorcycles and cyclists will be driving on the road together we call this mixed traffic.
- Mixed traffic is expected to exist for several decades.
- **Mixed Traffic can create problems for traffic safety.**
  - **Traffic is** a **social** thing.
  - **Automated Vehicles are** a **technological** thing.






THANK YOU FOR YOUR ATTENTION
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