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Agenda item 5 (a)

OICA

Future Certification of Automated/Autonomous Driving Systems

2019/01/28 - 2019/02/01, GRVA-02

Submitted by the experts of OICA

Introduction

Introduction

- With the introduction of automated driving systems complexity and thereby the number of software-based functions will continue to increase.
- Compared to conventional vehicles, the potentially affected safety-areas and variances of scenarios will increase and cannot fully be assessed with a limited number of tests that are performed on a test track or test bench
- The aim of this presentation is to propose a new innovative certification scheme allowing to demonstrate the level of safety and reliability which allows for safe market introduction of automated/autonomous vehicles
- The concept and building blocks for a future certification of automated/autonomous driving systems that are discussed in this presentation could be applied both under a type approval or self-certification regime
- Application of a regulation under a self-certification regime requires precise descriptions of the procedures and tests to be applied by the manufacturer
- This presentation is based on several documents that OICA submitted under the activities of WP.29 IWG ITS/AD, the former TF AutoVeh including its subgroups 1 and 2 and under the current IWG VMAD

General Challenges/Premises for a suitable Approach to Regulate Automated Driving

- It is important to consider that WP.29 GRVA is aiming at regulating new technologies of which the majority is not available on the market yet

  → lack of experience should not be neglected and tackled with reasonable strategies (e.g. generic safety-approaches/requirements) in order to guarantee the highest possible level of safety.
- It will be difficult to regulate each and every topic in detail from the early beginning

  → need to prioritize the different topics

  → start with a first set of requirements and develop further as the experience and data on new technologies grow
- Technology for Automated/Autonomous Driving Systems will continue to evolve rapidly over the next years

  → need flexible structures that can be applied to the different kinds of L3-L5 systems instead of limiting the variation/innovation of different kinds of systems by design restrictive requirements

  → Regulating "function by function" would require frequent updates/ upgrades of regulations and would therefore not be practical. Furthermore, it could easily become highly design restrictive
- Need to find a pragmatic way for industry and authorities that on the one hand leaves "controlled" flexibility and on the other hand defines reasonable requirements/principles to allow evolution of the new technology within the agreed safety principles over the next years

  → structure should allow to add output of research initiatives and lessons learned at a later stage

Comparison of published Safety Principles

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	Safety Principles	USA (NHTSA FAVP 3.0)	Japan (MLIT-Guideline)	Canada (Transport Canada)	Europe (EC Guidance)
			Vision: "0" accidents with injury or fatality by ADV Ensure Safety : Within ODD ADV shall not cause rationally foreseeable & preventable accidents		
1	Safe Function (Redundancy)	1) System Safety 9) Post Crash Behavior	ii) System safety by redundancy	6) Safety systems (and appropriate redundancies)	7) Safety assessment – redundancy; safety concept
2	Safety Layer	3) (OEDR)	ii) Automatic stop in situations outside ODD iii) Compliance with safety regulation iii) Compliance with standards recommended vii) for unmanned services: camera link & notification to service center	4) International standards and best practices	2) Driver/operator/ passenger interaction - takeover delay; camera & voice link for driverless systems
3	Operational Design Domain	2) Operational Design Domain	i) Setting of ODD	2) Operational design domain	1) System performance in automated mode – description 2) Driver/operator/ passenger interaction – boundary detection
4	Behavior in Traffic	3) OEDR 12) Federal, State and local Laws		3) OEDR	1) System performance in automated mode – behavior 4) MRM – traffic rules; information
5	Driver's Responsibilities		iv) HMI – driver monitoring for conditional automation	1) Level of automation and intended use 7) HMI and access of controls – accidental misuse	2) Driver/operator/ passenger interaction – information; driver monitoring
6	Vehicle Initiated Take-Over	4) Fallback (MRC) 6) HMI	ii) Automatic stop in situations outside ODD iv) HMI – inform about planned automatic stop		3) Transition of driving task – lead time; MRM; HMI 4) MRM
7	Driver Initiated Transfer	6) HMI		7) HMI and Accessibility of Controls	1) System performance in automated mode - takeover
8	Effects of Automation			7) HMI and Accessibility of Controls – unsafe misuse	
9	Safety Certificate		viii) Safety evaluation via simulation, track & real world testing ix) In-use safety - inspection	5) Testing and validation 11) After market repairs / modifications	7) Safety assessment – product; processes; risk assessment; standards
10	Data Recording	10) Data Recording	v) Installation of data recording devices	12) User privacy 13) Collaboration with government agencies & law enforcement	5) Data storage system
11	Security	7) Vehicle Cybersecurity	vi) Cybersecurity – safety by design ix) In-use safety – software update	10) Cyber security 11) System update	6) Cyber security
12	Passive Safety	8) Crashworthiness		9) User protection during collision & system failure	
13	Driver's training	11) Consumer Education/Training	x) Information provision to users	8) Public education and awareness	8) information provision to users

Conclusions:

→ **General safety-frameworks are available. They are not design-restrictive and could be further explored for regulatory use at UNECE**

→ **Internationally harmonized safety principles endeavored by OICA**

“Classical” Certification Approach

“Classical” Certification Approach

Example: Tires UN-R 30 and 54; UN-R 117

- Tire tests (“classical approach”):
  - ➢ Mechanical strength: Load/speed performance tests
  - ➢ Rolling sound emission values in relation to nominal section width and category of use
  - ➢ Adhesion on wet surfaces (wet and snow grip index)
  - ➢ Rolling resistance

→The “classical certification approach” typically defines a limited number of performance criteria and physical certification tests to set-up the necessary safety-level as a prerequisite for market entrance

→Such tests are performed on test tracks or on a test bench, requirements were refined over years

→Approach is well suited for systems with limited complexity, limited interactions with other systems and clearly defined system boundaries (typical for mechanical systems/components)

Existing Extension of the "Classical" Certification Approach

Example: Performance of a braking system (UN-R 13-H)

- Braking Tests ("classical approach"):
  - Min. deceleration: 6,43 m/s^2 and 2,44 m/s^2 for the fallback secondary braking system
  - Stopping distance in relation to initial speed: 60 m for 100 km/h
  - Parking brake to hold the laden vehicle stationary on a 20% up or down gradient

→ When ABS, ESP and Brake-Assist were regulated, it was realized that the "classical approach" was not able to address all safety-relevant areas of electric/electronic systems due to the high number of potential failures/scenarios:

- This led to the introduction of the process- and functional safety oriented audits: Annex 8 for safety of complex electronic vehicle control systems
- Introduction of simulation as acceptable simulation-approach for ESP

→ It should also be noted that at the time UN-R 13-H was updated regarding electronic control systems like ABS and ESP, such technologies were already deployed for some years and technically standardized (long-term-experience was available)

Further Extension of the "Classical" Certification Approach

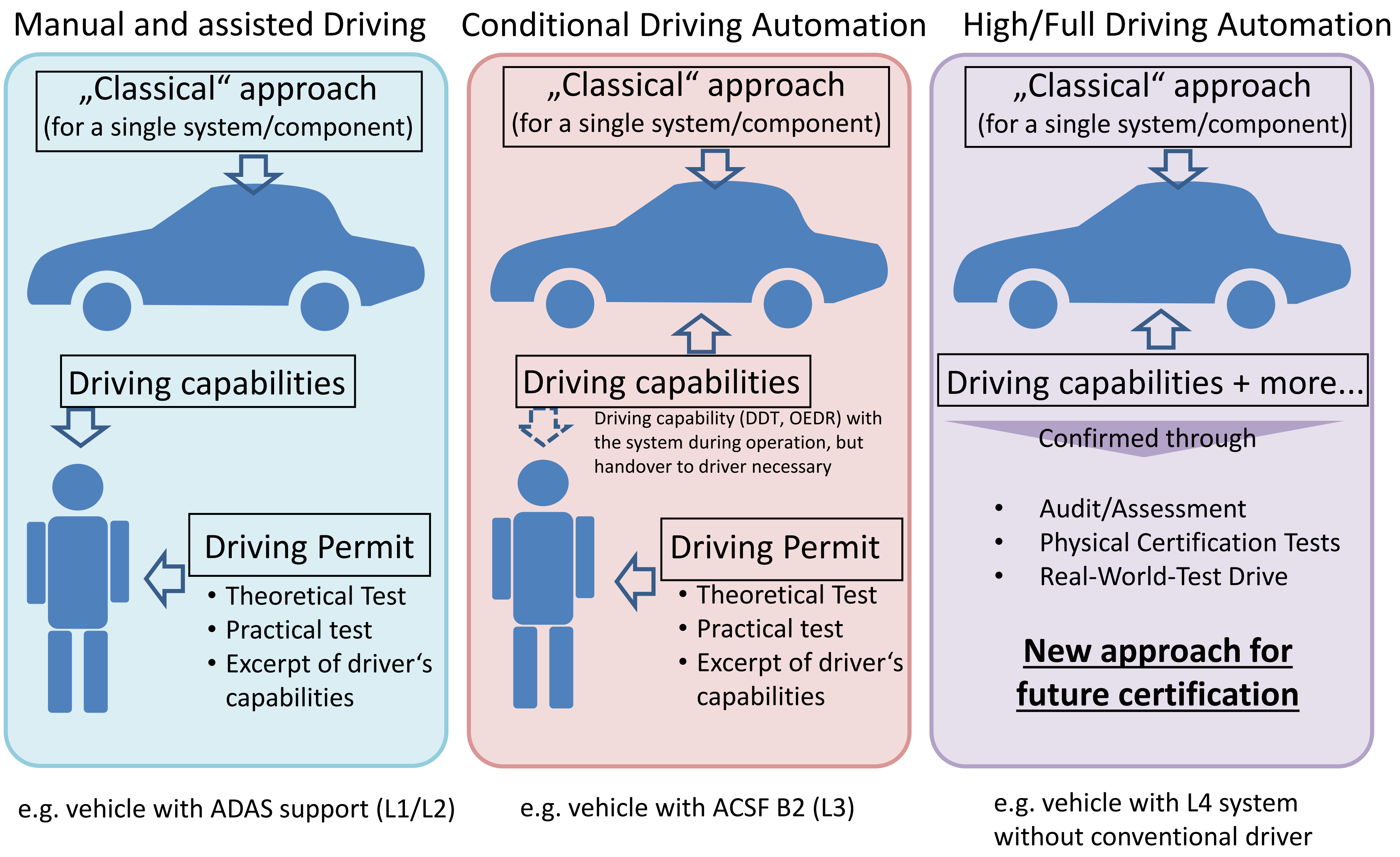
Why the testing of the automated driving systems requires new elements:

- The system complexity and thereby the number of software-based functions will continue to increase with automated driving systems. Compared to the complex electronic control systems, the potentially affected safety-areas and variances of scenarios will further increase and cannot fully be assessed with a limited number of tests that are performed on a test track or test bench.
- The existing audit-approach used for electronic control systems both in safety systems (e.g. ABS, ESP) and driver assistance systems (L1, L2) should be further extended and upgraded to tackle L3-L5 systems.

Why elements of the "classical" approach are still necessary:

- Testing of existing conventional safety-regulations should continue with the "classical approach" also for vehicles that are equipped with automated driving systems.
- Furthermore, classical certification elements (track testing) are an essential part of the three-pillar approach (see from slide 14). Additions are needed to appropriately cover the software related aspects – they will augment and not replace the classical certification approach.

Paradigm shift - new approach required



Overview: Concept for ADS Certification

Concept for certification – the three pillars

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Real-World-Test Drive

- Overall impression of system behavior on public roads
- Assessment of system‘s ability to cope with real world traffic situations with a **standardized checklist**
- **„Driving license test“** for automated driving system
- Guidance through given set of situations which shall be passed

Physical Certification Tests

- Matching of audit/assessment results with real world behavior
- Assessment of system behavior in fixed set of challenging cases, which either aren‘t testable on public roads or cannot be guaranteed to occur during the real world test drive.
- Reproducibility of situations is given

Audit and Assessment

Simulation

- Audit of development process (methods, standards)
- Assessment of safety concept (functional safety, safety of use) and measures taken
- Check of integration of general safety requirements and traffic rules
- Use of simulation results (high mileage approval, capability to cope with critical situations, which aren‘t testable on proving grounds or in public)
- Assessment of development data/field testing, OEM-self-declarations

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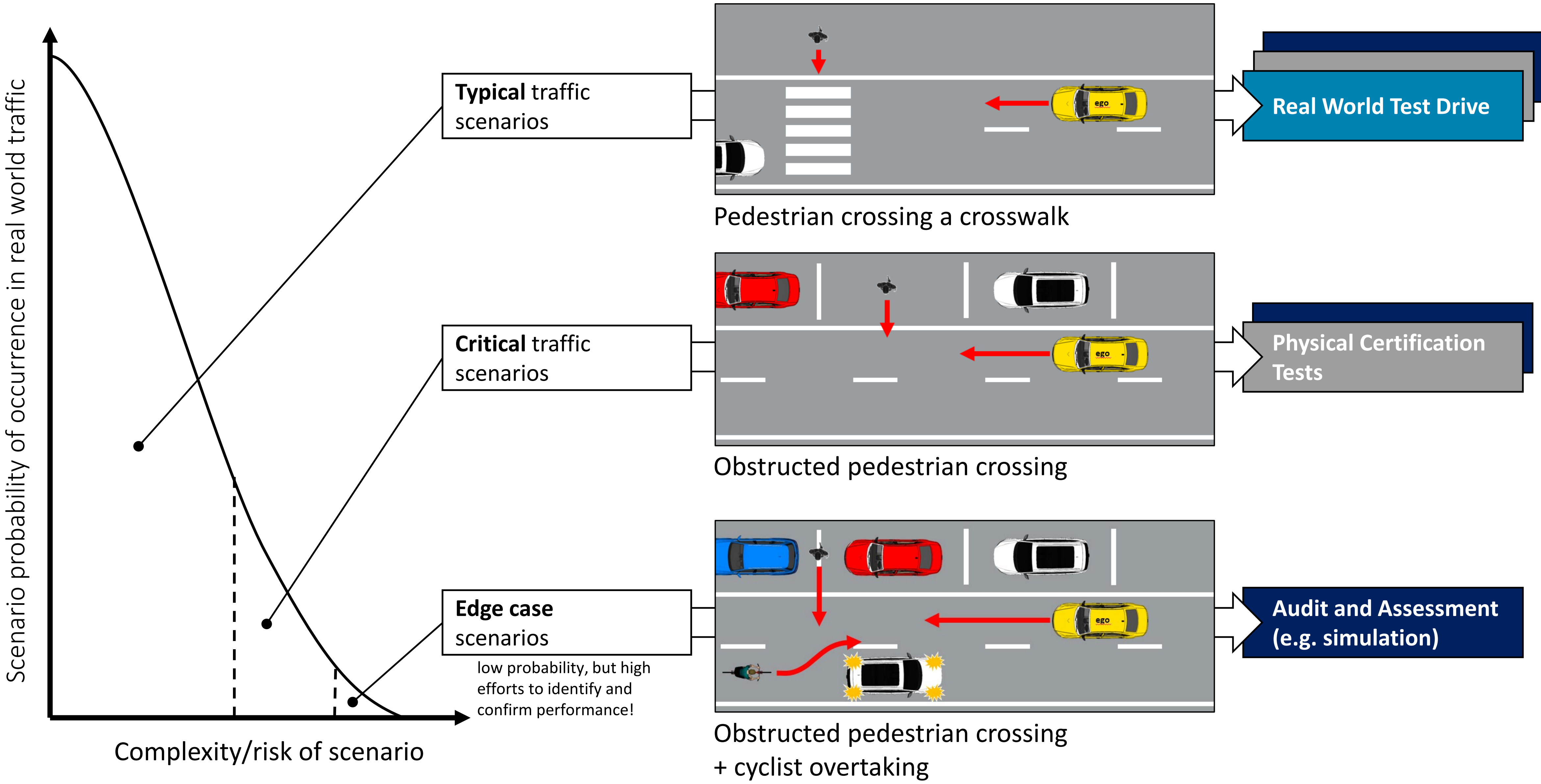
- Certification depends on all three pillars – partial assessment doesn‘t have significance
- Scope of work should reduce with every step (audit/assessment: largest scope – real world test drive: final confirmation)
- Safety for test witnesses and other road users – no endangering tests on public roads

Example of the different pillars' functions



Concept for certification – the three pillars and their individual purpose

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Audit/Assessment **Simulation**

- Understand the system to be certified
- Assess that the applied processes and design/test methods for the overall system development (HW and SW) are effective, complete and consistent
- Assess system’s strategies/rest performance to address (multiple) fault-conditions and disturbances due to deteriorating external influences; vehicle behavior in variations of critical scenarios
- Simulation: Test parameter variations (e.g. distances, speeds) of scenarios and edge-cases that are difficult to test entirely on a test track

Physical Certification Tests

- Assess critical scenarios that are technically difficult for the system to cope with, have a high injury severity (in case the system would not cope with such a scenario) and are representative for real traffic
- Compare with critical test cases derived from simulation and validate simulation tools

Real World Test Drive

- Assess the overall system capabilities and behavior in non-simulated traffic on public roads and show that the system has not been optimized on specific test scenarios
- Assess system safety requirements like e.g. HMI and ODD
- Assess that the system achieves a performance comparable to an experienced driver

Concept for certification of automated driving systems Level 3-5

Why the new approach can generate an equivalent/higher safety-level compared to the "classical" approach:

- The new approach recognizes established process and functional safety oriented audits for certification of complex electronic vehicle control systems as a foundation.
- Consequently, the new approach requires manufacturers to give evidence that their system has been designed and tested in a way that complies with established safety principles, different traffic rules, and ensures safe performance both under fault-conditions and arbitrary external influences.
- Furthermore, the new approach evaluates specific complex situations on a test track.
- To complement the assessment, the new approach includes a real-world-drive test in real world traffic (non-simulated).

Mapping of Safety Principles and the Pillars

Comparison of published Safety Principles

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Conclusions:

→ General safety-frameworks are available. They are not design-restrictive and could be further explored for regulatory use at UNECE

→ Internationally harmonized safety principles endeavored by OICA

Coverage of safety principles by the pillars

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X = OICA views on how some requirements could be reasonably addressed		Audit/ Assessment	Track Testing	Real-World-Test-Drive	
Safety Principles					
1	Safe Function (e.g. failure strategy, redundancy concepts, etc.)	X			
2	Safety Layer (OEDR, Emergency Maneuvers)	X	X	X	
3	Operational Design Domain (definition, recognition of the limits)	X		X	
4	Behavior in Traffic (OEDR, compliance with traffic laws)	X		X	
5	Driver‘s Responsibilities (HMI, Driver Monitoring)	X	X	X	
6	Vehicle Initiated Take-Over (Minimum Risk Maneuver, transition scenario, HMI, etc.)	X	X	X	
7	Driver Initiated Transfer (e.g. activation, deactivation, override)	X	X	X	
8	Effects of Automation (Driver Monitoring, System Design, driver' support)	X			
9	Safety Certificate (in-use-safety, testing and validation, etc.)	X	X	X	
10	Data Recording	X			may be by conventional regulation
11	Security	X			may be by conventional regulation
12	Passive Safety Testing of existing conventional safety-regulations continues with the “classical approach” (update of such regulations will be necessary)				
13	Driver‘s training	X			

Back-Up

References

This presentation is based on several documents that OICA submitted under the activities of WP.29 IWG ITS/AD and under the former TF AutoVeh including its subgroups 1 and 2:

- ITS_AD-12-11
- ITS_AD-13-05-Rev1
- ITS_AD-14-07
- TFAV-02-05
- TFAV-SG1-01-02
- TFAV-SG1-01-03
- TFAV-SG1-01-04
- TFAV-SG1-01-05
- TFAV-SG2-01-02
- TFAV-SG1-02-08
- TFAV-SG2-02-07

-SG1-03-10

Overview: Concept for ADS Certification

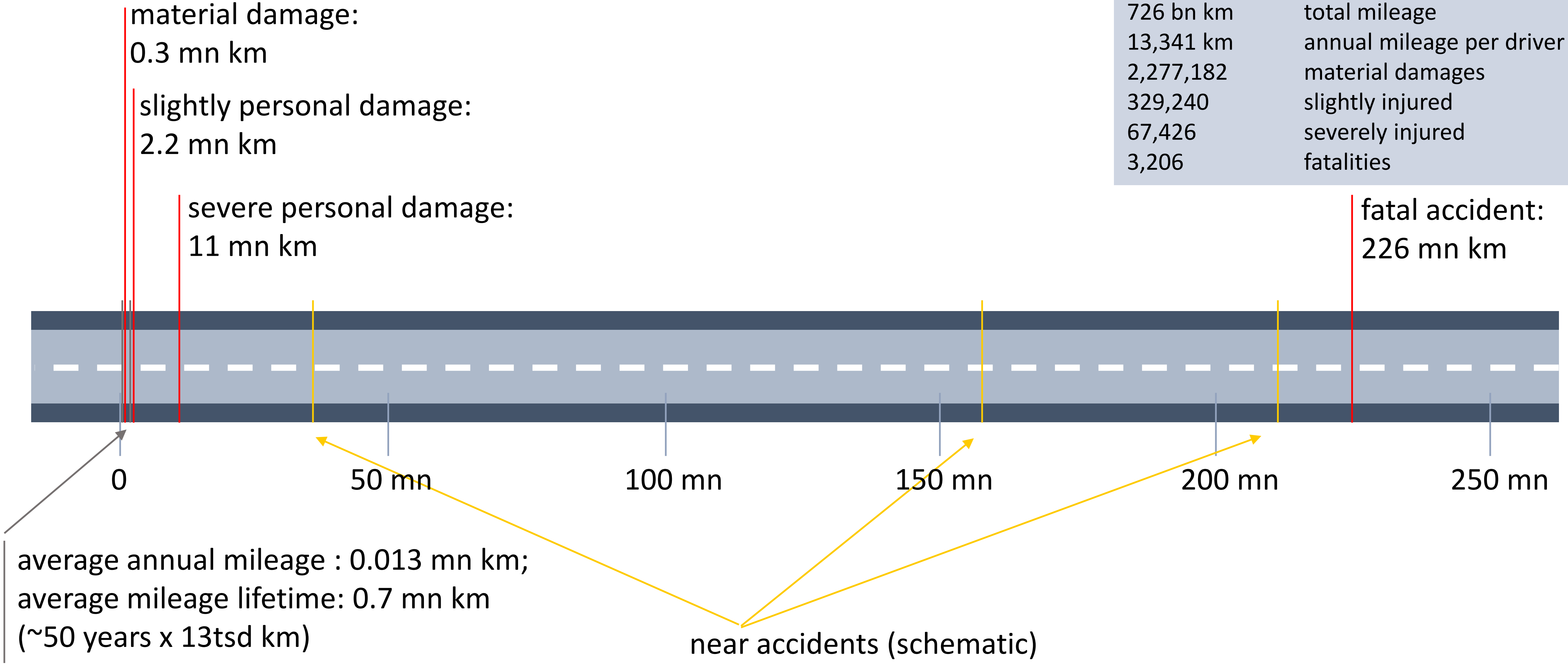
Academia views on why a different approach is needed

- Autonomous vehicles would have to be driven hundreds of millions of miles and sometimes **hundreds of billions of miles to demonstrate their reliability in terms of fatalities and injuries — an impossible proposition** if the aim is to demonstrate their performance prior to releasing them on the roads for consumer use and even then, this would not ensure that all safety-relevant situations occurred. (see e.g. also next slide based on German accident data base)
- Developers of this technology and third-party testers will need to develop **innovative methods of demonstrating safety and reliability**.
- In parallel to developing new testing methods, it is imperative to develop **adaptive regulations that are designed from the outset to evolve with the technology** so that society can better harness the benefits and manage the risks of these rapidly evolving and potentially transformative technologies.

Source: See e.g. research conducted by Prof. Dr. Hermann Winner (Technical University Darmstadt) and publication by RAND Corporation, 2016

Challenge of validation.
Statistics Mileage and Accidents

Accident Statistics Germany (Destatis 2016):	
726 bn km	total mileage
13,341 km	annual mileage per driver
2,277,182	material damages
329,240	slightly injured
67,426	severely injured
3,206	fatalities



Definitions: „use-case“ vs. „test scenario“

“Use cases” for automated driving in the sense of the proposed certification concept are areas of application in relevant traffic environments:

- “**Highway/motorway traffic**” means a traffic environment in which traffic flows on multilane highways often with high maximum allowed speeds. Characteristic is that the lanes with traffic flow in opposite direction are separated from each other. Also there are typically no intersections and no traffic lights (except some tunnels or bridges).
- “**Urban traffic**” means an environment (typically in a city) where maximum speed is limited to [e.g. 50-60 kph].
- “**Interurban traffic**” means a traffic environment in which traffic flows does not necessarily flow on multilane highways, however high maximum speeds are allowed. Besides, lanes with traffic flow in opposite direction are not fully separated from each other. Also there may be intersections and traffic lights.

“Test scenarios” for automated driving in the sense of the proposed certification concept are challenging maneuvers that are physically tested on test tracks (e.g. an obstructed pedestrian crossing the street or an emergency braking maneuver before the tail end of a traffic jam)

Overall driving capabilities for the use-case „motorway/highway traffic“

- Depending on the foreseen use-case, an autonomous driving system shall be capable of handling the following typical traffic scenarios representative of motorway/highway driving or in case of an automated driving system may request the driver to take-over with sufficient lead time (requirements concerning transition scenario apply)
  - Normal traffic flow: lane keeping, distance keeping, road speed compliance, lane changes (including motorbikes on adjacent lanes in the rear), merging, road signs
  - Entering and exiting highway: exit, gas station, recreational parking site
  - Passing slower vehicles
  - Ending lanes
  - Construction sites
  - Scenarios involving emergency vehicles (police, ambulance, fire brigade)
  - Objects/obstacles on the road (e.g. lost cargo)
  - Policeman or roadman directing traffic

If the manufacturer can provide evidence that certain requirements are not relevant due to the foreseen use-case (e.g. no automatic lane change foreseen), the respective requirements are not applicable.

Overall driving capabilities for the use-case „urban traffic“

- Depending on the foreseen use-case, an autonomous driving system shall be capable of handling the following typical traffic scenarios representative of urban traffic:
    - Normal traffic flow: lane keeping, distance keeping, road speed compliance, lane changes (including 2-wheelers on adjacent lanes in the rear), merging, signs
    - Intersection scenarios: traffic lights, signs, right of way rules, protected and unprotected turning
    - Roundabout scenario
    - Scenarios involving pedestrians and cyclists: walkway, turning left/right
    - Scenarios involving emergency vehicles (police, ambulance, fire brigade)
    - Objects/obstacles on the road (e.g. lost cargo)
    - Policeman or roadman directing traffic
    - Bus stations (school bus)
    - Tram way / Cable cars crossing vehicle road; parallel to vehicle road

If the manufacturer can provide evidence that certain requirements are not relevant due to the foreseen use-case (e.g. the autonomous driving system can only be activated on a dedicated geo-fenced city-route where traffic lights are not existent), the respective requirements are not applicable.

Concept for certification – the three pillars – their individual strengths (+) and weaknesses (-)

Use-Cases: Urban, Highway, Interurban, [Parking] for automation levels 3, 4 and 5
Requirements address vehicle behavior in road traffic and further general safety requirements

Audit/Assessment **Simulation**

OEM provides e.g.:
Safety concept / functional safety strategy; simulation and development data to verify vehicle behavior in edge cases; manufacturer's self declarations etc.

+ Limited testing efforts for certification
– Requires highly skilled and qualified test house/certification agency to appropriately assess data/ documents/ systems, possibly subjective judgements

Physical Certification Tests

Dedicated, reproducible challenging tests under worst-case vehicle configurations for specific scenarios that cannot be guaranteed to occur in real world test drives

+ Objective performance criteria
– Significant testing efforts
– Transfer of requirements into reproducible tests technically difficult or likely to result in remarkable functional restrictions

Real World Test Drive

Test drive to assess the vehicle's standard behavior in public road traffic, compliance with traffic laws and maneuvers according to defined checklist

+ Limited testing efforts/duration
+ Many situations may occur → vehicle must be capable to handle
– Requires highly skilled and qualified test house/certification agency to appropriately assess systems behavior, possibly subjective judgements

A proper combination of all 3 pillars allows for compensation of the weaknesses of each single method

What’s behind the three pillars

Audit & Assessment

Overview of complete certification structure

Certification
of Automated Driving Systems (L3-L5)
Objective: System is safe and technical compliant

Audit and Assessment

Highway/ Motorway | Inter-urban/ rural | Urban

- Audit: Development processes and methods (use-case independent)
  - Pass/fail criteria: *tbd* (e.g. criteria of existing technical standards like ISO 26262)
  - Implementation and change management regarding traffic laws and rules
  - Safety-relevant areas: Assess that the applied processes and design/test methods for overall system development (HW and SW) are effective, complete and consistent
- Assessment: Safety concept to address fault/non-fault conditions
  - General system safety requirements
  - Traffic rules
  - Safety-relevant areas: Assess system's strategies/rest performance to address (multiple) fault-conditions and disturbances due to deteriorating external influences; vehicle behavior in variations of critical scenarios

Physical Certification Tests

Highway/ Motorway | Urban | Inter-urban/ rural

- Test scenarios (use-case-specific)
  - Pass/fail criteria: Defined performance requirements and test procedures under dry/normal conditions
  - Safety-relevant areas: Assess critical scenarios that are technically difficult for the system to cope with, have a high injury severity (in case the system would not cope with such a scenario) and are likely to occur in real traffic

Real-world-test-drive

Highway/ Motorway | Urban | Inter-urban/ rural

- Test drive under real conditions (use-case-specific)
  - Pass/fail criteria: Individual qualitative checklist
  - Safety-relevant areas: Assess the overall system capabilities in typical traffic scenarios; general system safety requirements like HMI; behavior in some fault-conditions?

Audit structure: Processes and documentation

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Certification
of Automated Driving Systems (L3-L5)
Objective: System is safe and technical compliant

Audit → Focus: Processes and Documentation

Documentation of the system → Purpose: Understand the system to be audited and assessed →

- System layout/architecture and schematics
- Description of the components and functions
- Identification of relevant HW and SW
- List of all input and sensed variables
- Description of the ODD (boundaries of functional operation)
- List of all output variable controlled by the system
- Signal flow chart and priorities

Processes and methods (use-case independent) → Purpose: Assess that the applied processes and design/test methods for overall system development (HW and SW) are effective, complete and consistent →

- Safety analysis → Safety plans of the system and of relevant components/ECUs
- Development process incl. Specifications management, Testing, Failure Tracking Requirements' implementation → Development process plans and quality management plans; Validation and change/ release management plans
- Implementation and change management regarding traffic laws and rules → Validation and change/ release management plans

→ <u>Pass/fail criteria:</u> *<u>tbd</u>* (e.g. criteria of existing technical standards like ISO 26262)

OEM to provide for inspection

OEM to submit to technical service

Assessment Structure: Safety Concept and Validation

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Certification
of Automated Driving Systems (L3-L5)
Objective: System is safe and technical compliant

Assessment → Focus Safety Concept and Validation

Safety concept to address fault- and non-fault conditions →

Purpose: Assess the system's strategies/rest performance to address (multiple) fault-conditions and disturbances due to deteriorating external influences; vehicle behavior in variations of critical scenarios

*Safety-relevant: Behavior that results in unintended leaving of the ego-lane or in a collision

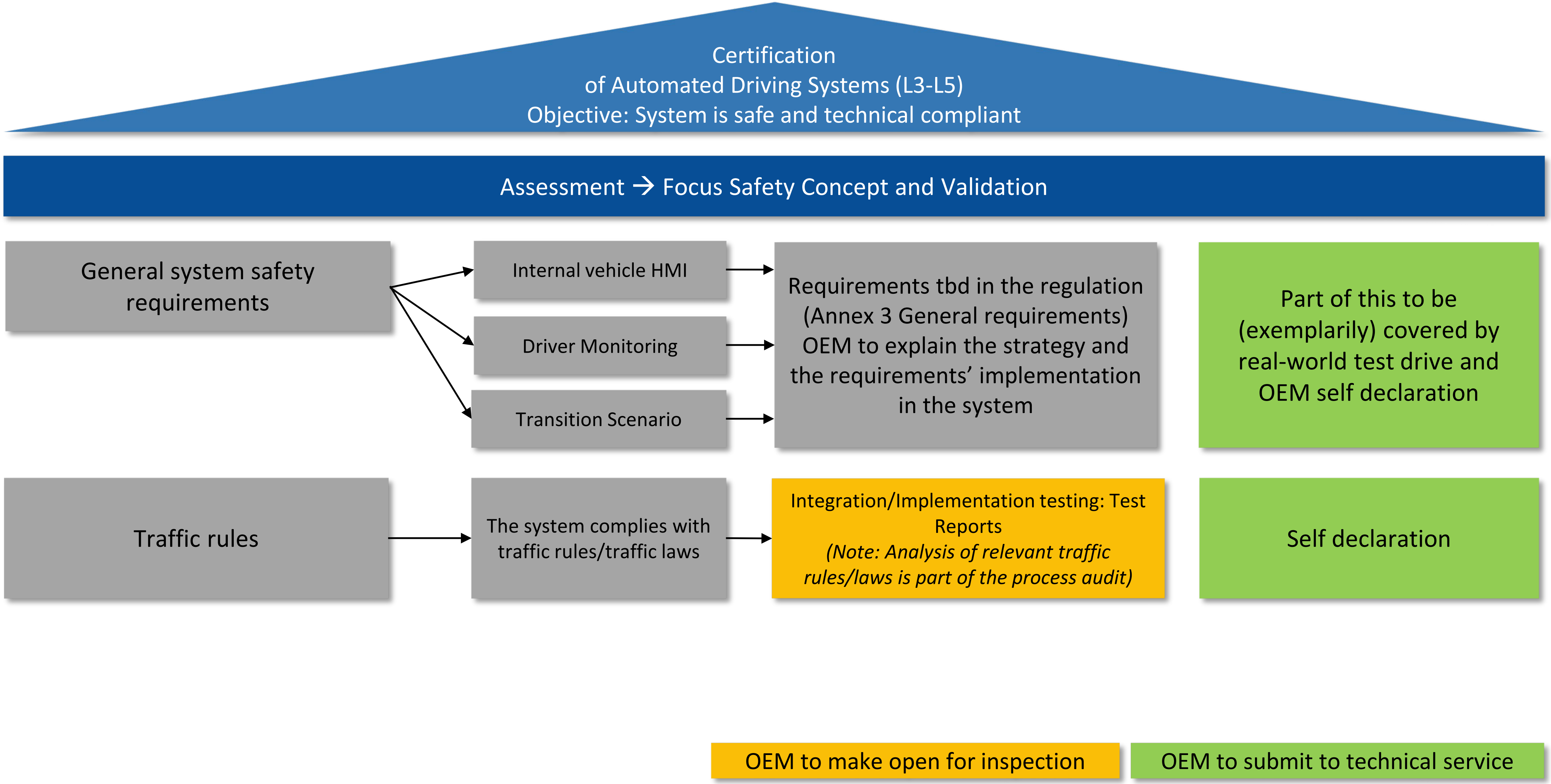
Safety Goals Hazard Analysis and Risks Assessment (HARA)	Purpose: Identify all safety relevant* hazards and risks
Functional Safety Concept Assessment Reports	Purpose: confirmation of the process
Failure Mode and Effects Analysis (FMEA) Fault Tree Analysis (FTA)	Purpose: Analyze failure modes, occurrence probabilities, severity/effects and detection capabilities
Matrix of all failures, failure simulation and strategy, safe state/minimal risk condition	Purpose: Analyze failure modes, occurrence probabilities, severity/effects and detection capabilities
Safety of the Intended Functionality (SOTIF)	Purpose: Identify all non-fault conditions (e.g. disturbances/environmental constraints) that lead to a safety-relevant*/traffic-compliance-relevant system behavior
System/component specifications	Purpose: Consistent requirements management
Integration/Implementation testing: Testing and Safety Assessment Reports	Purpose: Verification that the safety requirements are effectively implemented
Safety-Case	Purpose: Gives evidence (collects work products) in a consistent/structured way that the system is acceptably safe
Manufacturers' statement/self-declaration	

<u>Pass/fail criteria:</u>
-The system is fail-operational;
-The system can cope with all relevant external/environmental conditions;
-The system can cope with all relevant traffic scenarios;
-The system does not endanger under fault- and non-fault conditions other traffic participants

OEM to make open for inspection (orange)

OEM to submit to technical service (green)

Assessment Structure: Safety Concept and Validation



Physical Certification Tests on Proving Grounds

Relevant test scenarios on proving grounds for the urban use-case – OICA views

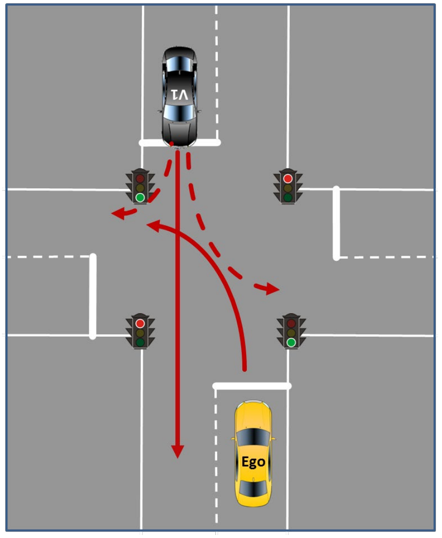
Introduction/basis for discussion

- The next slides are based on the concept document "Structure of a future Regulation of autonomous vehicles" that OICA provided to the TF AutoVeh at the meeting in Den Haag
  → Special requirements for the use-case urban traffic: See Annex 5, paragraph 2: "Physical tests required for type approval/certification"
- The intention of this presentation is to start the discussion and explain a proposal on four critical test scenarios for the urban use-case that are suitable for testing on proving grounds. There may be additional scenarios to be added
- These four critical test scenarios for the urban-use-case were presented at the 1st meeting of the subgroup physical testing and audit in Den Haag (TFAV-SG1-01-02) and were supported by the group as a starting point. OICA was asked to continue the work for specifying reproducible tests (i.e. define parameters like e.g. speed and distances, infrastructure, targets, pass/fail criteria, test equipment etc.).
- This updated presentation is based on TFAV-SG1-01-02 and adds a first collection of parameters that need to be defined when developing the test procedures. There may be additional parameters to be specified.
- It should be noted that defined tests on proving grounds (test tracks) are only one single element in the overall concept of the system certification/assessment. Additional scenarios are addressed by other means e.g. during the real-world-driving test and the audit/assessment.

Scenario Justification

- In a first step, the proposed test scenarios were identified and evaluated with an "engineering judgement approach" based on two criteria:
  - Criteria 1: Performance based technical difficulty/complexity for the system to detect/manage the particular situation
  - Criteria 2: Injury/crash severity
- Remark: It was qualitatively considered that the scenarios should have a significant relevance /occurrence probability in traffic
- Outlook: Additional statistics/external sources could be added in mid- and long-term to complete the justification on a scientific basis

Proposal Test Track Scenarios „Urban“



2.1 Unprotected „left turn“ (in case of right hand traffic)

Situation: The vehicle approaches an intersection in autonomous mode with the intention to perform a left turn. Other Dynamic Objects are present.

Expected Behavior: The vehicle should automatically activate the left direction indicator when slowing down. Then, the vehicle yields considering the traffic rules from the corresponding country and turns left.

Initial Condition: The vehicle follows the ego-lane and is heading an intersection that is controlled by a traffic light without green arrows as status, by a yield sign or without any traffic elements at all.

Final Condition: The vehicle has applied the left turn indicators and turned left according to the traffic rules without endangering oncoming traffic. The vehicle drives on at the new lane.

Justification:

Criteria 1: Technical difficulty/complexity for the system to detect/manage the situation

- Path of other vehicles is difficult to predict/sense; high differential speeds

Criteria 2: Injury/crash severity

- High severity due to side impact and high speeds of involved vehicles

Excerpt Parameters Test Procedure

INITIAL CONDITIONS:

Infrastructure: Crossing (dimensions, lane markings, design and position of traffic lights) → *see e.g. EU-Project PROSPECT*, design and position of speed sign on ego lane before the crossing, area before crossing to allow smooth acceleration of Ego to reach initial speed

Environment: Ambient temperature, track temperature, wind speed, ambient illumination etc.

Ego-Vehicle: Initial speed/speed range to approach the crossing

TEST MANEUVER:

Vehicles V1: Speed/speed range, differential position/trajectory to Ego

Options: Number and dimension of gaps between vehicles V1, trajectory of V1 (drive straight or left/right turn)

EU Project PROSPECT* – Standard Intersection Layout

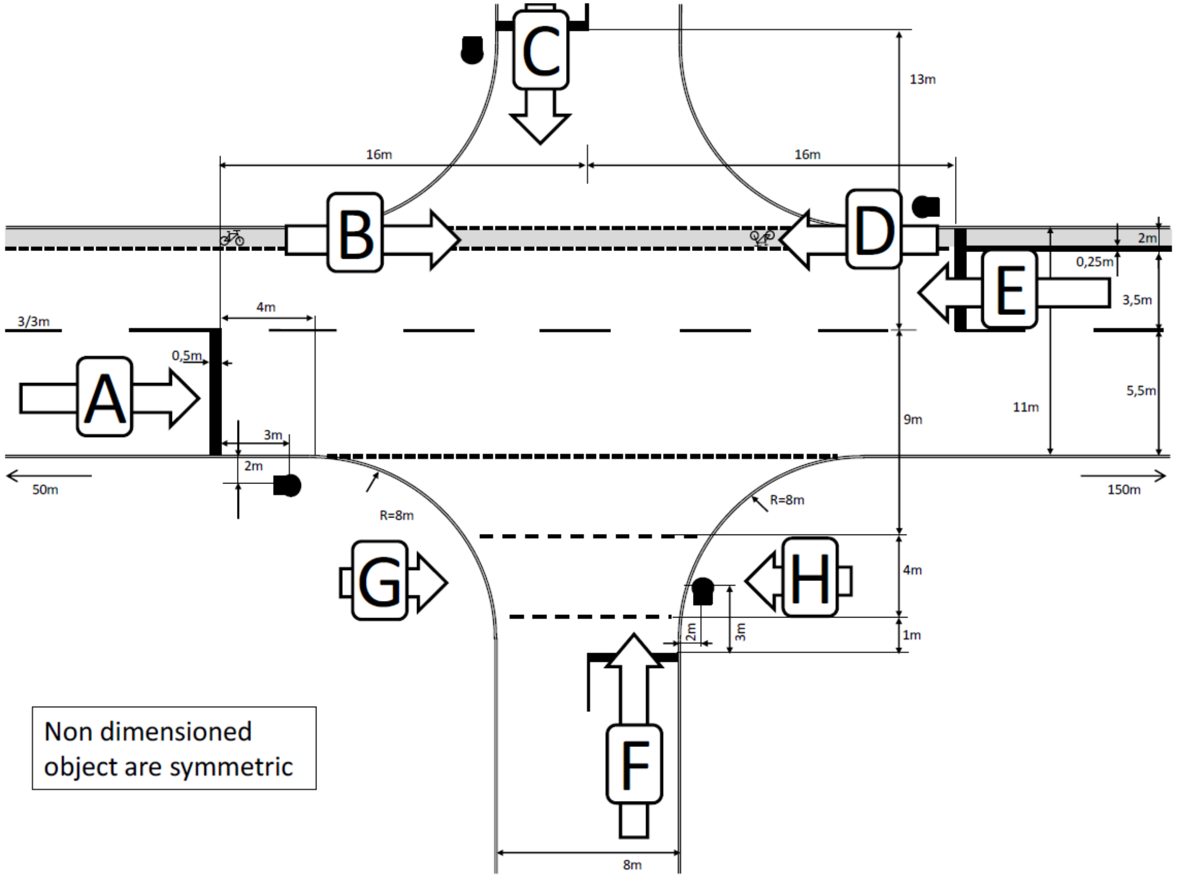
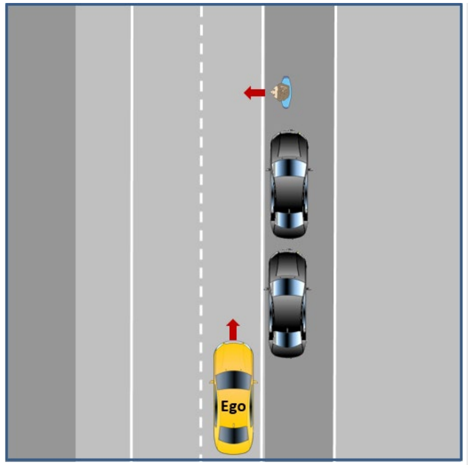


Figure 2: Versatile intersection to be implemented on test tracks

* Source: Proactive Safety for Pedestrians and Cyclists, European Commission, Eigth Framework Programme, Horizon 2020, GA No. 634149; Deliverable D7.4

- EU-Project PROSPECT issued a draft proposal for standard intersection layout : *“Deliverable D7.4 proposes an intersection geometry that allows the conduction of all intersection test cases with no need to manipulate the lane markings in-between tests: only tracks for Vehicle-Under-Test and VRU Dummy need to be reprogrammed, object positions need to be shifted and implemented.”*
- OICA proposes to consider this intersection geometry proposal for test scenario 2.1 and 2.3
- Open point: Different intersection layouts needed for other countries like USA/CAN, China, etc.?

Proposal Test Track Scenarios „Urban“



2.2 Obstructed Pedestrian crossing (without traffic lights, without pedestrian walkway)

Situation: The vehicle follows in autonomous mode the ego-lane and approaches a gap after parked vehicles, where an obstructed pedestrian passes the street.

Expected Behavior: The vehicle shall stop in a safe manner in order to avoid the collision. The vehicle can continue the drive, when the driving path is clear.

Initial Condition: The vehicle follows the ego-lane and is heading towards an obstructed pedestrian behind parked vehicles.

Final Condition: The vehicle continues its drive without violating traffic rules as well as safety and comfort criteria.

Justification:

Criteria 1: Technical difficulty/complexity for the system to detect/manage the situation

- Dynamic obstacle test including obstruction of the pedestrian (child) dummy by other vehicles/objects on the side of the road is difficult to predict/sense; high differential speeds

Criteria 2: Injury/crash severity

- High severity for an unprotected pedestrian if the vehicle does not safely stop

Excerpt Parameters Test Procedure

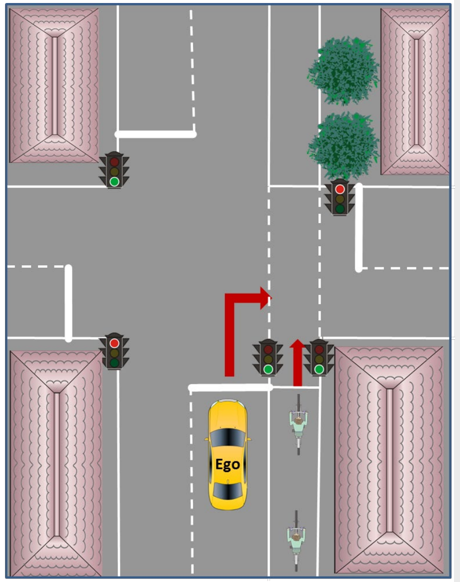
OICA proposal:

Use established EuroNCAP maneuver CPNC-50 scenario (running child from nearside from obstruction vehicles (*see Test Protocol AEB VRU systems, Version 2.0.2, November 2017*)

A test protocol with all parameters is already available. A carry-over to automated driving is possible with the only deviation that the ego vehicle speed would not be constant throughout the scenario and therefore the pedestrian target's trajectory needs to be synchronized with the Ego vehicle speed (the automated driving system can automatically reduce speed in the particular driving situation).

Child pedestrian target: Specified by NCAP, speed 5 kph, synchronized trajectory depending on Ego vehicle trajectory

Proposal Test Track Scenarios „Urban“



2.3 Cyclist test in combination with right turn

Situation: The vehicle is driving with [50 km/h] in autonomous mode on a priority road and approaches an intersection (vehicle has right of way or traffic light "green") to perform a right turn. A cyclist is driving with [15 km/h] in the same direction using a separate bicycle lane adjacent to the priority road and wants to keep straight on across the intersection. A second bicycle is following with a [20m] gap to the first, also driving with [15km/h].

Expected Behavior: The vehicle should automatically activate the right direction indicator when slowing down, first stop and let the first bicycle pass and then use the gap between the first and the second cyclist in order to turn right.

Initial Condition: The vehicle follows the ego-lane.

Final Condition: The vehicle has applied the right turn indicators and used the gap between the two cyclists for turning right. The vehicle drives on at the new lane.

Justification:

Criteria 1: Technical difficulty/complexity for the system to detect/manage the situation

- Path of the cyclist that has a certain (parallel) distance to the road is difficult to predict/detect, relatively high differential speeds

Criteria 2: Injury/crash severity

- High severity for a protected/unprotected cyclist if the vehicle does not safely stop before making the right turn

Excerpt Parameters Test Procedure

INITIAL CONDITIONS:

Infrastructure: Crossing (dimensions, lane markings for both vehicles and bicycles, design and position of traffic lights → *see e.g. PROSPECT intersection* which includes bicycle lane), design and position of speed sign on ego lane before the crossing, area before crossing to allow smooth acceleration to reach initial speed

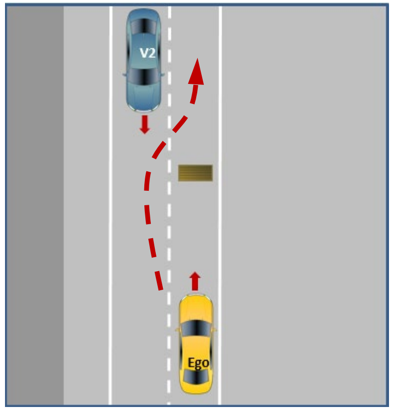
Environment: Ambient temperature, track temperature, wind speed, ambient illumination etc.

Ego-Vehicle: Initial speed/speed range to approach the crossing

TEST MANEUVER:

Bicycles: Speed, synchronized trajectory depending on Ego vehicle trajectory, dimension of gap between bicycles, target's dimension (NCAP bicycle target available)

Proposal Test Track Scenarios „Urban“



2.4 Obstacle test

Situation: The vehicle follows in autonomous mode the ego-lane and reacts on static objects located ahead of the vehicle on the driving lane while there is oncoming traffic on the neighbor lane (so that there is not at all times a possibility for evading the static object). The static object may have different sizes, but is not moved by itself.

Expected Behavior: The vehicle has to decide if the static object is traversable or not. If it is not traversable, the vehicle has to decide when it has to stop and when to evade/drive around the static object.

Initial Condition: The vehicle follows the ego-lane. The vehicle is heading a static object in lane.

Final Condition: The vehicle has just followed the ego-lane if the static object is traversable. If it is not traversable, the vehicle has safely (without endangering oncoming traffic) driven around the obstacle to follow the ego-lane.

Justification:

Criteria 1: Technical difficulty/complexity for the system to detect/manage the situation

- Detect the stationary obstacle and then drive around/evade including consideration of oncoming traffic is difficult! Note: The dynamic object that suddenly crosses the road would be covered by 2.2. and requires different technical capabilities.

Criteria 2: Injury/crash severity

- High severity for drivers/passengers due to oncoming traffic

Excerpt Parameters Test Procedure

INITIAL CONDITIONS:

Infrastructure: Lane dimensions and markings, design and position of speed sign on ego lane before stationary object, area's dimension before object to allow smooth acceleration to reach initial speed

Environment: Ambient temperature, track temperature, wind speed, ambient illumination etc.

Ego-vehicle: Initial speed/speed range to approach the stationary object

TEST MANEUVER:

Vehicle V2: Speed; synchronized trajectory depending on Ego vehicle trajectory

Stationary object: Dimension (traversable/non-traversable; extent of lane blockage), position within the lane

Options: Number of approaching vehicles V2, different differential speeds Ego to wait vs. Ego to evade immediately), additional vehicles in front of Ego

Next steps

- Agree on how to handle certain options/variants of the test scenarios in a next step to have transparency what elements the scenarios should include
- Based on this, continue working on a draft specification of reproducible tests for the scenarios 2.1 – 2.4 (i.e. define numerical values/parameters like e.g. speed and distances, road infrastructure, definition of objects, pass/fail criteria, test equipment etc.).
- OICA proposes to consider the intersection geometry proposal of the EU-Project PROSPECT for test scenario 2.1 and 2.3 and not to start a separate activity.
  → Are different intersection layouts needed for other countries like e.g. USA/CAN, China, etc.? What is the expectation of the Contracting Parties?
- Test Scenario 2.2 (Obstructed Pedestrian crossing): OICA proposes to use the existing EuroNCAP maneuver CPNC-50 scenario (running child from nearside from obstruction vehicles, *see Test Protocol AEB VRU systems, Version 2.0.2, November 2017*) with the only deviation that the ego vehicle speed would not be constant throughout the scenario (initial speed would be fixed, but the automated driving system may then automatically adapt its speed to the particular driving situation)

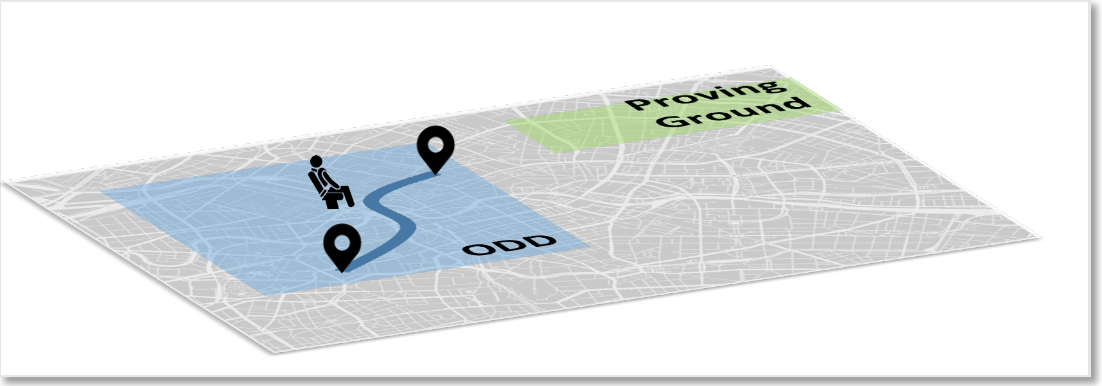
Testing of autonomous/automated driving systems on proving grounds

– The issue of “testability” –
OICA views

Testability on proving grounds - Introduction

Background:

- Especially L3-L5 features are linked to a dedicated ODD* and can only be activated and operated within this ODD*.
- This issue is a general and use-case independent, issue that even affects ACSF (e.g. CAT C, B2), but has not been resolved, yet.



Example illustration

Proving grounds:

- Are typically not part of the geographic ODD*
- Do typically not reflect other technical ODD* requirements
- Are typically not included in high definition maps

Consequence: If dedicated ODD* conditions/premises are not fulfilled, the automated driving system cannot be activated on proving grounds and therefore not be tested

**Operational Design Domain*

Testability on proving grounds - Options

Option	1	2	3	4	5
Description	Enable/adapt both proving ground infrastructure and high definition maps to allow for physical testing of ADS equipped vehicles	Test maneuvers with ADS equipped vehicles on public streets within the operational design domain	Limit physical testing of ADS equipped vehicles to OEM-specific proving grounds	Enable ADS equipped vehicles with a so called „test mode“ (that allows remote operation) for physical testing on any proving ground	Enable/adapt specific test vehicles by applying SW-modifications (e.g. activate SCN-coding) for physical testing on any proving ground
Advantages	+ Authorities/agencies can independently from OEMs conduct compliance tests with any desired ADS equipped vehicle on specific proving grounds + Testability of series systems → no modification to systems/software necessary	+ Authorities/agencies can independently from OEMs conduct compliance tests with any desired ADS equipped vehicle + Testability of series systems → no modification to systems/software necessary	+ Reduced implementation efforts for OEMs + Testability of series systems → no modification to systems/software necessary + No difficulties with OEM-specific attributes in high definition maps as considered by OEM-proving grounds	+ Authorities/agencies can independently from OEMs conduct compliance tests with any desired ADS equipped vehicle on proving grounds	+ Reduced implementation efforts for OEMs + Flexibility
Disadvantages/ Challenges	- High implementation efforts for OEMs - Handling of OEM-specific attributes (IP-issue?) in high definition maps that need to be reflected by proving grounds - Handling of new proving grounds that were not existent at the time of production (map update of proving ground) - Maintenance issues	- Road blocking may be possible in individual cases, but not realistic/practical as general solution worldwide - Safety reasons in case of on road-tests and many other things likely not easy/practical to test on public roads	- Independent execution of certification tests not possible for authorities/agencies – causes problems for rating/ compliance-Testing, CoP und market surveillance - Not realistic/practical as solution worldwide	-Risk of unauthorized access/manipulation and security threat due to external interface - No representative series systems/software	- No representative series systems/software - Independent execution of certification tests not possible for authorities/agencies – causes problems for rating/ compliance-Testing, CoP und market surveillance

OICA's conclusion: Simultaneous investigation of option 3 (short-term solution) and option 1 (long-term solution) seems to be useful and reasonable approach

Next steps

- What is the expectation of the Contracting Parties regarding testability on proving grounds?
- Can it be assumed that certification agencies/authorities etc. want to be able to independently test and assess vehicles/automated driving systems on certain proving grounds (e.g. relevant for certification-tests, in-use-compliance-tests, conformity of production, rating tests NCAP, etc.)?
- If yes, option 1 requires that proving ground infrastructure and attributes in proving ground maps fulfill certain harmonized criteria to enable testability of different kinds of systems of different manufacturers
- The discussion on standardization of such criteria/map attributes needs to start as soon as possible and is expected to take a longer time as several technical issues need to be properly resolved (e.g. handling of OEM specific attributes, handling and transferring of map data to the different kinds of systems, etc.)
- Would a combination of option 1 and 3 be an acceptable approach? E.g. Option 3 as a short- and midterm solution and option 1 as a long-term solution? → both options should be investigated and developed simultaneously

Real-World-Test-Drive

Real World Test Drive – OICA views

Introduction/basis for discussion

- The next slides are based on the document “Real world test drive” (TFAV-SG2-01-02) that OICA provided to the TF AutoVeh meeting in Den Haag.
- The intention of this presentation is to start the discussion and explain a proposal on how a real world test drive can fit into the overall concept for the certification of AVs developed by OICA.
- Several conceptual issues that were raised during the meeting. OICA was asked to further develop / clarify these items.
- This updated presentation includes these further explanations to the original document. New sections appear in blue font.

Road Test for AVs: Understanding its Role in the Certification Process

OICA

- What is the road test supposed to demonstrate? What is its role in the entire certification process?
- What is the suggested content?
- Which assessment approach is considered?
- How could the road test look like from a procedural and timing perspective?

WHAT IS THE ROAD TEST SUPPOSED TO DEMONSTRATE? WHAT IS ITS ROLE IN THE ENTIRE CERTIFICATION PROCESS (1/2)?

Hypothesis:

The road test is going to demonstrate the capability of the vehicle to adhere to traffic rules [and maneuvers according to the general expectations of other road users].

This capability is brought to the driving task currently by the experienced / approved driver.

WHAT IS THE ROAD TEST SUPPOSED TO DEMONSTRATE? WHAT IS ITS ROLE IN THE ENTIRE CERTIFICATION PROCESS (2/2)?

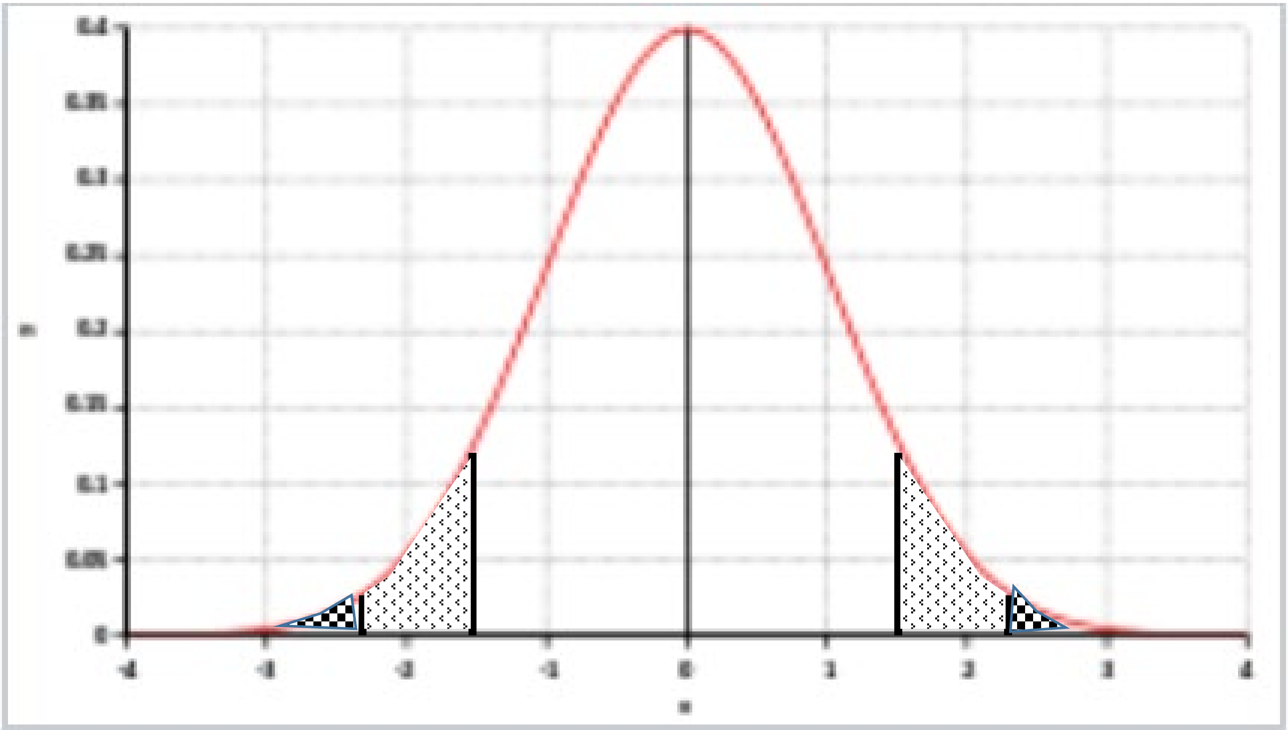
The road test is an integral building block in the assessment and certification of automated vehicles. That said it is not suggested that this is the one and only deciding criteria for certification.

The road test is going to address typical / normal traffic scenarios that a human driver is exposed to on a regular basis.

After this road test the generic „competence" of the vehicle is documented to adhere to traffic rules and the assessor has the ability to declare if it moves in traffic without becoming an obstacle.

COVERAGE OF SCENARIOS

- to be addressed according to the use case -



„Typical“ Driving – Real World Test Drive

Demanding Traffic Scenarios – Physical Tests

Edge Cases – Simulation

With the approach suggested by OICA all traffic scenarios can be addressed appropriately

DEFINITION OF “REALISTIC / TYPICAL / NORMAL” TRAFFIC CONDITIONS

- > 90 % of all road trips are „un-eventful“ because the driver does not have to deal with challenging scenarios or edge cases
- During these trips the adherence to traffic rules, showcasing a behavior that is understood by other road users and participating in the traffic without being an obstacle to other road users is the prime role of the driver, i.e. the automated system in the future.

  ➔Therefore, traffic scenarios as suggested in the „checklists“ – see below – fullfil this criteria

WHAT IS THE SUGGESTED CONTENT?

Hypothesis:

Automated/ autonomous vehicle will not operate at the beginning under all conditions and on all roads. The initial focus will be on the use cases called „highway“ and „urban“ driving.

Consequently, the content of the road test will have to be adjusted to these use casses (i.e. test scenarios of traffic situations).

Note: *the minutes of the SG2 session state that the group should „start with urban situations, while ACSF continues with highway situations.“*

WHAT IS THE SUGGESTED CONTENT?

The selected scenarios will have to be derived after assessment from various sources. Ultimate goals is to generate a data base filled with traffic scenarios with which the statistical relevance of scenarios can be assessed and changes to traffic cenarios can be document.

A vehicle can – based on the input of the vehicle manufacturer – be nominated for one or more use case related road tests.

Limitations of the automated / automonous system will be reflected, assessed and documented based on the input provided by the vehicle manufacturer. This includes weather conditions, speed restrictions, non supported roads (e.g. tunnels). For identified limitations, the HMI approach needs to be assessed during the real world test drive to ensure that an appropriate hand-over is initiated by the system and that the system can recognise the limitations.

WHICH ASSESSMENT APPROACH IS CONSIDERED?

Hypothesis:

Based on a checklist the assessor exposes the vehicle to a pre-defined number of mandatory scenarios to maintain objectivity and comparability between road tests. Additional scenarios (supplementary ones) can be tested as well according to availability.

Comments should be provided on the checklist after a scenario has been completed indicating whether it was successful or not. Additional comments – if necessary – can be provided as well.

OICA proposal for checklists as integral part of the road test

OICA

- Suggests splitting into a mandatory and a supplementary section
- All mandatory aspects need to be covered while supplementary aspects can help to refine the understanding of the vehicle performance in real traffic

Additional considerations:

- Across the markets (e.g. the EU) similar but not same traffic rules and expected behaviors apply (example: how to approach a pedestrian crossing and when to stop)
  ➔OICA suggests to not make this part of the road test but consider this for the „Audit“ pillar

Brief description of test route/location				
Date/time of test drive				
Item #	Situation	Pass		Comments (must be filled out in case of "no/unclear")
		Yes	No/ unclear	
Part A: mandatory		All lines in Part A have to be evaluated during the test drive		
HA.1	Entering the highway			
HA.2	Following other vehicle in same lane			
HA.3	Passing a slower vehicle: lane change/Passing/merging back in previous lane			
HA.4	Adapting to changing speed limits			
HA.5	Merging from an ending lane			
HA.6	Exiting the highway			
HA.7				
HA.8				
HA.9				
HA.10				

Part B: supplementary		If any of the following situations is encountered during the test drive this shall be noted in the respective line. Additional lines may be added for situations not listed which were observed.		
HB.1	Situation involving an emergency vehicle (police, ambulance, fire brigade)			
HB.2	Policeman or roadman directing traffic			
HB.3	Objects/obstacles on the road (e.g. lost cargo)			
HB.4	Driving through construction site (if possible with modified lane markings)			
HB.5	Driving through area with no/bad lane markings			
HB.6	Safely approaching end of traffic jam			
HB.7	Driving in traffic jam			
HB.8	Driving through area with bad road surface conditions			
HB.9				
HB.10				

EXAMPLES FOR A CHECKLIST – HIGHWAY DRIVING (1/2)

Brief description of test route/location				
Date/time of test drive				
Item #	Situation	Pass		Comments (must be filled out in case of “no/unclear”)
		Yes	No/ unclear	
Part A: mandatory		All lines in Part A have to be evaluated during the test drive		
HA.1	Entering the highway			
HA.2	Following other vehicle in same lane			
HA.3	Passing a slower vehicle: lane change/Passing/merging back in previous lane			
HA.4	Adapting to changing speed limits			
HA.5	Merging from an ending lane			
HA.6	Exiting the highway			
HA.7				
HA.8				
HA.9				
HA.10				

EXAMPLES FOR A CHECKLIST – HIGHWAY DRIVING (2/2)

Part B: supplementary		If any of the following situations is encountered during the test drive this shall be noted in the respective line. Additional lines may be added for situations not listed which were observed.		
HB.1	Situation involving an emergency vehicle (police, ambulance, fire brigade)			
HB.2	Policeman or roadman directing traffic			
HB.3	Objects/obstacles on the road (e.g. lost cargo)			
HB.4	Driving through construction site (if possible with modified lane markings)			
HB.5	Driving through area with no/bad lane markings			
HB.6	Safely approaching end of traffic jam			
HB.7	Driving in traffic jam			
HB.8	Driving through area with bad road surface conditions			
HB.9				
HB.10				

EXAMPLES FOR A CHECKLIST – URBAN DRIVING (1/2)

Brief description of test route/location				
Date/time of test drive				
Item #	Situation	**Pass**		Comments (must be filled out in case of “no/unclear”)
		Yes	No/ unclear	
Part A: mandatory		All lines in Part A have to be evaluated during the test drive		
UA.1	Wake/initial start of journey (with objects in close-proximity of the vehicle)			
UA.2	Pass intersection regulated by traffic light			
UA.3	Pass intersection regulated by signs			
UA.4	Pass intersection without explicit regulation concerning right of way			
UA.5	Merge lane (two flows of traffic become one)			
UA.6	Make a left turn from a priority road (in case of right hand traffic)			
UA.7	Make a turn which requires previous lane change			
UA.8	Make a turn which crosses a bicycle path / pedestrian walkway			
UA.9	Pass a roundabout			
UA.10	Pass a pedestrian walkway (with pedestrian present)			
UA.11	Park vehicle at destination			
UA.12	Adherence to speed limits			
UA.13	Adherence to stop sign			
UA.14	Adherence to other road signs			

EXAMPLES FOR A CHECKLIST – URBAN DRIVING (1/2)

Part B: supplementary		If any of the following situations is encountered during the test drive this shall be noted in the respective line. Additional lines may be added for situations not listed which were observed.		
UB.1	Situation involving an emergency vehicle (police, ambulance, fire brigade)			
UB.2	Policeman or roadman directing traffic			
UB.3	Objects/obstacles on the road (e.g. lost cargo)			
UB.4				
UB.5				
UB.6				
UB.7				
UB.8				
UB.9				
UB.10				

How could the road test look like from a procedural and time perspective?

Hypothesis:

The road test should be aligned with the existing driving test in terms of duration, acceptance and general conditions.

HOW COULD THE ROAD TEST LOOK LIKE FROM A PROCEDURAL AND TIMING PERSPECTIVE?

Process:

Duration per "use case": 30-60 Minutes in a realistic traffic environement, i.e. not in the middle of the night or during rush hour.

The assessor identifies the route to be taken and programs the route for the use case to be tested in to the navigation system.

During the road test the scenarios are being checked (not necessarily in the listed sequence) and assessed. This can include the HMI related questions in case certain limitations of the system have been declared by the OEM.

At the end an overall assessment is provided (successful: yes / no) and potentially additional comments created and recorded.