Connected Automated Driving Roadmap – 2019 update

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Co-Chair CAD Working Group ERTRAC
CAD Roadmap version 8.0 – now available!

- Increased scope to better cover Connected Automated Driving, including cooperative and connected vehicles.
- Strengthen the link to the Infrastructure, through CEDR.
- Deeper dive into three use cases including requirements on ’connected & infrastructure’:
  - Automated Passenger Cars Path
  - Automated Freight Vehicles Path
  - Urban Mobility Vehicles
- Connect to the CARTRE (CSA) results and the ARCADE (CSA) project and provide a EU wide overview (and beyond).
- Incorporate the STRIA CAD actions (2018) via Key Challenges and Objectives.
1. Scope and Objectives

2. Common Definitions
   2.1 Levels of Automation
   2.2 Operational Design Domain
   2.3 Vehicle and infrastructure interaction
   2.4 Regulatory and standardisation framework for Automation
   2.5 Connectivity as a requirement for vehicle-infrastructure interaction

3. Development paths
   3.1 Automated Passenger Cars Path
   3.2 Automated Freight Vehicles Path
   3.3 Urban Mobility Vehicles

4. EU and international initiatives
   4.1 European research projects
   4.2 European initiatives
   4.3 EU Member States initiatives
   4.4 Initiatives around the world

5. Key Challenges and Objectives
   5.1 User awareness, users and societal acceptance and ethics, driver training
   5.2 Human Factors
   5.3 Policy and regulatory needs, European harmonisation
   5.4 Socio-economic assessment and sustainability
   5.5 Safety validation and roadworthiness testing
   5.6 New mobility services, shared economy and business models
   5.7 Big data, artificial intelligence and their applications
   5.8 Physical and Digital infrastructure (PDI) including Connectivity
   5.9 In-vehicle technology enablers
   5.10 Deployment

6. Annex: definitions of systems – Levels 0 to 2 + Parking
   6.1 Current and future vehicle systems – Level 0
   6.2 Current systems – Level 1
   6.3 Automated Driving Assistance - Level 2
   6.4 Automated Parking Assistance
Newest update on SAE Levels

<table>
<thead>
<tr>
<th>Level</th>
<th>Name</th>
<th>Narrative definition</th>
<th>DDT</th>
<th>OEDR</th>
<th>DDT fallback</th>
<th>ODD</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No Driving Automation</td>
<td>The performance by the driver of the entire DDT, even when enhanced by active safety systems.</td>
<td>Driver</td>
<td>Driver</td>
<td>Driver</td>
<td>n/a</td>
</tr>
<tr>
<td>1</td>
<td>Driver Assistance</td>
<td>The sustained and ODD-specific execution by a driving automation system of either the lateral or the longitudinal vehicle motion control subtask of the DDT (but not both simultaneously) with the expectation that the driver performs the remainder of the DDT.</td>
<td>Driver and System</td>
<td>Driver</td>
<td>Driver</td>
<td>Limited</td>
</tr>
<tr>
<td>2</td>
<td>Partial Driving Automation</td>
<td>The sustained and ODD-specific execution by a driving automation system of both the lateral and longitudinal vehicle motion control subtasks of the DDT with the expectation that the driver completes the OEDR subtask and supervises the driving automation system.</td>
<td>System</td>
<td>Driver</td>
<td>Driver</td>
<td>Limited</td>
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<tr>
<td></td>
<td>ADS (&quot;System&quot;) performs the entire DDT (while engaged)</td>
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<td>3</td>
<td>Conditional Driving Automation</td>
<td>The sustained and ODD-specific performance by an ADS of the entire DDT with the expectation that the DDT fallback-ready user is receptive to ADS-issued requests to intervene, as well as to DDT performance-relevant system failures in other vehicle systems, and will respond appropriately.</td>
<td>System</td>
<td>System</td>
<td>System</td>
<td>Limited</td>
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<td>4</td>
<td>High Driving Automation</td>
<td>The sustained and ODD-specific performance by an ADS of the entire DDT and DDT fallback without any expectation that a user will respond to a request to intervene.</td>
<td>System</td>
<td>System</td>
<td>System</td>
<td>Limited</td>
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<tr>
<td>5</td>
<td>Full Driving Automation</td>
<td>The sustained and unconditional (i.e., not ODD-specific) performance by an ADS of the entire DDT and DDT fallback without any expectation that a user will respond to a request to intervene.</td>
<td>System</td>
<td>System</td>
<td>System</td>
<td>Unlimited</td>
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</table>
Traffic regulations, Homologation Framework ODD and ISAD

- Explanation and information on ODD
- Vehicle and Infrastructure Interaction
- Regulatory and Standardisation framework for Automation
- Connectivity as a requirement for vehicle-infrastructure interaction
ODD – Operational Design Domain

• ODD := A description of the specific operating conditions in which the automated driving system is designed to properly operate, including but not limited to roadway types, speed range, environmental conditions (weather, daytime/nighttime, etc.), prevailing traffic law and regulations, and other domain constraints (SAE J3016 June 2018)

• Long term vision is to align infrastructure data with automotive safety integrity level.

• Visualize automated driving quality and availability, driving/travel experience from a user perspective

• To further provide input from CEDR CAD: What are the prerequisites towards the infrastructure from vehicle side?
ODD – Operational Design Domain Example #1

- **ODD**: Operational Design Domain
- **Manual driving**: A stage before automated driving
- **Automated driving**: A stage after manual driving
- **Everywhere**: Coverage of various environments
- **Always & all conditions**: Unconditional coverage
- **Origin**: Starting point
- **Destination**: End point

Diagram illustrates the transition from manual to automated driving across different domains and conditions.
ODD – Operational Design Domain Example #2

Transition of control

Always & all conditions

Origin

Destination

Manual driving

Automated driving

merging

raining
Input - How the infrastructure can (and should) support CAD

- Road infrastructure can provide additional information for on-board decisions of CAVs
- A classification of infrastructure support is needed:
  - Common understanding between OEMs, automotive industry and road operators is to be established
  - More use-cases have to be defined to understand the potential of ISAD in mixed traffic
  - Long transition period with mixed traffic is expected
- The workgroups’ feedback was incorporated in the approach and classification of this infrastructure support levels, please find the related information on the next slides.
**Infrastructure Support levels for Automated Driving (ISAD)**

*Elaborated in cooperation with INFRAMIX, see also ITS World Congress 2018 paper by AAE & ASFINAG*

<table>
<thead>
<tr>
<th>Level</th>
<th>Name</th>
<th>Description</th>
<th>Digital information provided to AVs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td>Cooperative driving</td>
<td>Based on the real-time information on vehicle movements, the infrastructure is able to guide AVs (groups of vehicles or single vehicles) in order to optimize the overall traffic flow.</td>
</tr>
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<td></td>
<td>B</td>
<td>Cooperative perception</td>
<td>Infrastructure is capable of perceiving microscopic traffic situations and providing this data to AVs in real-time.</td>
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<td></td>
<td>C</td>
<td>Dynamic digital information</td>
<td>All dynamic and static infrastructure information is available in digital form and can be provided to AVs.</td>
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<td></td>
<td>D</td>
<td>Static digital information / Map support</td>
<td>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.</td>
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<tr>
<td></td>
<td>E</td>
<td>Conventional infrastructure / no AV support</td>
<td>Conventional infrastructure without digital information. AVs need to recognise road geometry and road signs.</td>
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</table>
Infrastructure Support levels for Automated Driving (ISAD)

- Based on the ISAD Level of information and services different on-board vehicle decisions can be supported.
- CAVs will have to be able to drive on E-level, but the additional possibilities provided by A-level sections enable a much higher customer satisfaction as well as support road safety and capacity management related goals.
Connectivity as a requirement for vehicle-infrastructure interaction

Option 1: Metadata & data via NAP

Option 2: only Metadata via NAP
The three development path use cases

- CEDR & ERTRAC Chair meeting Vienna August 2018 provided many useful insights and new ideas on the development paths to focus on:
  - NRAs can provide valuable support through infrastructure and data provision -> this requires the NRAs to form an unified, viable approach.
  - One use case per deployment path has been deemed especially beneficial to be researched (-> green boxes), and they align well with the CEDR research project MANTRA’s targeted use cases

- The use case selection was then further adapted to best fit our current focus points and still align well with other activities.
- All chapters in the roadmap include requirements on ‘connected & infrastructure’
## Automated Passenger Car Development Paths

<table>
<thead>
<tr>
<th>Automation Level</th>
<th>Established</th>
<th>2018</th>
<th>2020</th>
<th>2022</th>
<th>2024</th>
<th>2026</th>
<th>2028</th>
<th>2030</th>
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<tbody>
<tr>
<td>Level 5: Full Automation</td>
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<td>Level 4: High Automation</td>
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<td>Level 3: Conditional Automation</td>
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<td>Level 2: Partial Automation</td>
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<td>Level 1: Driver Assistance</td>
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<td>Level 0: No Driving</td>
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### Development Paths

- **Highway Autopilot (Level 4)**
  - Highway Chauffeur
  - Highway Autopilot including Highway Convoy

- **Highway Convoy (Level 4)**
  - Urban and Sub-Urban Pilot

- **Urban and Suburban Pilot (Level 4)**
  - Traffic Jam Chauffeur

### Features
- Lane Departure Warning
- Blind-spot Warning
- Forward Collision Warning
- ABS, ESC
- Emergency Brake
- Adaptive Cruise Control
  - Stop & Go
- Lane Keeping Assist
- Lane Change Assist
- Parking assist
- Traffic Jam Assist
- Parking Assist
- Traffic Jam Assist
- Urban and Sub-Urban Pilot

*Indicative development paths TRL 7-9*
Level 4 for passenger cars – use cases

**Highway Autopilot (Level 4)**
- up to 130 km/h on motorways or motorway similar roads
- from entrance to exit, on all lanes, including lane change
- sleeping is allowed
- when average human driver would try to end the journey or simply stop at the motorway (e.g. extreme weather) and the driver does not take over, the system can leave the motorway and park the vehicle safely

**Highway Convoy (Level 4)**
- electronically linked vehicles of all types on motorways or similar roads in the same lane with minimum distance between each other
- if V2V communication is available with realtime performance
- reduce safety distances far below today’s manually driven distances
- in large urban areas, highway traffic could develop to be much more efficient (traffic space per person, energy consumption per vehicle)

**Urban and Suburban Pilot (Level 4)**
- Highly Automated Driving up to limitation speed
- The system can be activated by the driver in all traffic conditions
- The driver can override or switch off the system at all time
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<td>Level 4: High Automation</td>
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<tr>
<td>Level 0: No Driving Automation, support beyond human capability to act</td>
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**Automated Freight Vehicle Development Paths**

- **Highly Automated Vehicles in Confined Areas**
- **Highly Automated Vehicles on Dedicated Roads**
- **Highly Automated Vehicles on Open Roads**

**Key Technologies**

- Lane Departure Warning
- Blind-spot Warning
- Forward Collision Warning
- ABS, ESC
- Emergency Brake
- Adaptive Cruise Control
- Stop & Go
- Lane Keeping Assist
- Lane Change Assist
- Traffic Jam Assist
- Traffic Jam Chauffeur
- Automated Truck Platooning
- C-ACC Truck Platooning
- Highway Pilot Platooning
- Highway Chauffeur
- Traffic Jam Chauffeur
- Fully Automated Freight Vehicles

**Unmanned vehicles, confined and hub-to-hub**

**Highway chauffeur, open roads**

**Truck: Freight vehicle > 3.5 tonnes categorie N2 or N3**
Highway chauffeur for hub2hub and open-roads, Heavy Freight Vehicles - examples

- Highly automated, un-manned connected to control and supply-chain management center
- For repetitive transport between hubs. Slow speed for energy optimized electrified operation
- Dedicated roads/lanes with infrastructure/charging support

- Highly automated trucks on open roads in mixed traffic
- For flexible transport assignments with automated/manual operation
- Integrated with logistics supply chain
- Cooperative automation
Automated Urban Mobility Vehicle Development Paths

Automation Level

- **Level 5:** Full Automation
- **Level 4:** High Automation
- **Level 3:** Conditional Automation
- **Level 2:** Partial Automation
- **Level 1:** Driver Assistance
- **Level 0:** No Driving Automation, support beyond human capability to act

Established and Future Development Paths (2018-2030)

- **Automated PRT/Shuttles on Dedicated Roads**
- **Automated Buses on Dedicated Roads**
- **Automated Urban Chaffeur**
- **Urban Bus Assist**
- **Traffic Jam Assist**
- **Parking Assist**
- **Adaptive Cruise Control**
  - Stop &Go
  - Lane Keeping Assist
  - Lane Change Assist
  - Parking assist
- **Lane Departure Warning**
- **Blind-spot Warning**
- **Forward Collision Warning**
- **ABS, ESC**
- **Emergency Brake**

*Indicative development paths TRL 7-9*

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Overview of EU funded projects that support the development of automated driving
Key Challenge Areas

**VEHICLES & TECHNOLOGIES**
- New mobility services, shared economy and business models
- Big data, artificial intelligence and their applications
- In-vehicle technology enablers
- Digital and physical infrastructure, including Connectivity
- Deployment
- Human Factors

**SYSTEM & SERVICES**
- Safety validation and roadworthiness testing
- Policy and regulatory needs, European harmonisation
- Socio-economic assessment and sustainability

**USERS & SOCIETY**
- User awareness, users and societal acceptance and ethics, driver training
- Big data, artificial intelligence and their applications
- Safety validation and roadworthiness testing
- Policy and regulatory needs, European harmonisation
- Socio-economic assessment and sustainability

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21.10.2019

Driving the Future of Mobility

IBTTA: YVILLE. WONG SMARTER
Thank you for your work and support in updating the roadmap!