<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>
<th>...</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 5: Full Automation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Level 4: High Automation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Level 3: Conditional Automation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Level 2: Partial Automation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Level 1: Driver Assistance</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Level 0: No Driving Automation, support beyond human capability to act</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **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

**Use Cases**

- **Auto Pilot**
- **Chauffeur**
- **Driving Assistance**
- **Advanced Driver Assistance Systems (ADAS)**
- **Warning or Support by active safety systems**
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>
<th>...</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 5: Full Automation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Fully Automated Passenger Cars</td>
</tr>
<tr>
<td>Level 4: High Automation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Urban and Sub-Urban Pilot</td>
<td></td>
</tr>
<tr>
<td>Level 3: Conditional Automation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Highway Autopilot including Highway Convoy</td>
<td></td>
</tr>
<tr>
<td>Level 2: Partial Automation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Traffic Jam Chauffeur</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Level 1: Driver Assistance</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Traffic Jam Assist Parking Assist</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Level 0: No Driving Automation, support beyond human capability to act</td>
<td></td>
<td></td>
<td></td>
<td>Adaptive Cruise Control Stop &amp;Go Lane Keeping Assist Lane Change Assist Parking assist</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Level 0: No Driving Automation, support beyond human capability to act</td>
<td></td>
<td></td>
<td></td>
<td>Lane Departure Warning Blind-spot Warning Forward Collision Warning ABS, ESC Emergency Brake</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Passenger Cars: M1 category
Highway Autopilot L4

First-Introduction-Approach:
Further development of a Maximum-Customer-Benefit Highway Chauffeur (L3) with slight updates
In the case of a non-takeover by the driver, not always safe and permanent parking is possible.
→ Driver is still necessary.

Maximum-Customer-Benefit--Approach:
New development of extended fail-operational-System (energy and data availability), sensors und algorithms
Usage for driving and parking on parking spaces as well as on rest areas.
→ Driverless operation will be possible, no driver necessary.

Customer function and benefits:
Driving on multilane roads with a constructional separation. In case of very rare system boundaries during a journey, the driver takes over (awake or waked up), unless the car parks on a highway parking bay or after the motorway exit at the roadside (extremely uncommon).

In a first-introduction-approach, the car could in extreme single cases also rest on the hard shoulder or traffic lane with activated hazard lights. The probability of the occurrence of a fault or unforeseeable system boundaries will be significantly reduced in comparison to the highway chauffeur. The customer’s take-over time due to sideline activities or sleeping will be infinite, including further extensions of the alarm cascade.
Highway Chauffeur and AutoPilot build on the same technologies.

Perception, Planning and Driving can include different levels of Artificial Intelligence (Deep Neural Net, Bayes-Net, …). Validation is based on Scenario Databases and Simulation Technologies.
Highway Chauffeur

- System relieves driver and potentially enhances safety in annoying traffic jam scenarios.
- Driver must deliberately activate system and can override/switch off the system at any time.
- Longitudinal and lateral control are accomplished by the system during the use case scenario.

Traffic Jam Chauffeur
- 0 to 60 km/h in traffic jam scenarios
- System can be activated if traffic jam scenario is present, meaning that slow driving vehicles must be detected in front.

Motorway Chauffeur
- 0 to 130 km/h on each lane of a highway from entrance to exit.
- Overtaking of slower vehicles
- Handle roads with complex course including junctions, tunnel, toll station, construction sites, accident scenes
- compliance with traffic rules incl. comfortable keeping to all speed limits, cooperative behavior at motorway entrance
## Automated Freight Vehicle 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>
<th>...</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Level 5:</strong> Full Automation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Level 4:</strong> High Automation</td>
<td></td>
<td></td>
<td></td>
<td>Highly Automated Vehicles on Dedicated Roads</td>
<td>Highly Automated Vehicles on Open Roads</td>
<td>Highway Pilot Platooning</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Level 3:</strong> Conditional Automation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Level 2:</strong> Partial Automation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Level 1:</strong> Driver Assistance</td>
<td></td>
<td>Adaptive Cruise Control Stop &amp; Go</td>
<td>Lane Keeping Assist</td>
<td>Lane Change Assist</td>
<td>C-ACC Truck Platooning</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Level 0:</strong> No Driving Automation, support beyond human capability to act</td>
<td></td>
<td>Lane Departure Warning</td>
<td>Blind-spot Warning</td>
<td>Forward Collision Warning</td>
<td>ABS, ESC</td>
<td>Emergency Brake</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Highly Automated Vehicles on Open Roads**

**Highway Chauffeur**

**Traffic Jam Chauffeur**

**Automated Truck Platooning**

**Traffic Jam Assist**

**C-ACC Truck Platooning**

**Lane Departure Warning**

**Blind-spot Warning**

**Forward Collision Warning**

**ABS, ESC**

**Emergency Brake**

---

Truck: Freight vehicle > 3.5 tonnes categorie N2 or N3
### ERTRAC Long-Distance Freight Transport

**Strategic roadmap by market application**

**Prioritized operational targets**

<table>
<thead>
<tr>
<th>CONFINED AREAS</th>
<th>HUB-TO-HUB</th>
<th>OPEN ROADS</th>
<th>URBAN ENVIRONMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increased transshipment efficiency by 30%*</td>
<td>Increase Load factor by 30%*</td>
<td>More than 3% CO2 reduction per year TTW</td>
<td>Urban commercial vehicles offering zero emission driving with suitable range and payload</td>
</tr>
<tr>
<td>Increased automation up to level 4: Easy to maneuver and high security levels</td>
<td>Increased automation up to level 4: New solutions to enable a fast exchange of loading units</td>
<td></td>
<td>Noise reduction</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Increase Load factor by 30%*</td>
</tr>
</tbody>
</table>

* For logistics efficiency - There is no baseline and no measurement as of today. Looking further into measurements and targets for logistics efficiency (in particular for transshipment efficiency and load factor) should be a forthcoming research topic as such.
ERTRAC Long-Distance Freight Transport
Strategic roadmap by market application

Adaptable Transport solutions by application domain

- Different needs by usage of vehicle: mixed situation with progressive extension of high-technologies to different use cases, from ‘simple’ environments to more and more complex environments

- Definition
  - Confined Area: ports and terminals $\rightarrow$ simple environment: repetitive tasks, private area, fully controlled traffic management
  - Hub-To-Hub: from factories to ports or terminals $\rightarrow$ relatively simple environment: repetitive tasks, partly public road, partly controlled traffic management
  - Open roads: highways, roads $\rightarrow$ complex environment: tailored tasks, public roads, no controlled traffic management
  - Urban Environment: cities $\rightarrow$ very complex environment: made-to-order tasks, public roads, non-adapted infrastructure in dense cities, no controlled traffic management

- The different application domains are intermixed. To get this connected is a key challenge for long-distance freight. We need to have priorities for long distance freight along the routes connecting the interurban corridors and roads to ports or terminals.
ERTRAC Long-Distance Freight Transport
Strategic roadmap
Prioritization of research activities
ERTRAC Long-Distance Freight Transport Strategic roadmap

Prioritization of research activities

Scope and objectives

Implementation barriers

Strategic roadmap

Research & Innovation activities

Prioritized Research Topics

<table>
<thead>
<tr>
<th>Legal Framework</th>
<th>Hub-to-Hub</th>
<th>Performance based regulation vs weight and dimensions</th>
<th>Ethics &amp; privacy in the supply chain</th>
<th>New driver/operator role</th>
<th>Acceptability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labor Environment</td>
<td>Cross-modal interchange infrastructures for automated logistics</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Infrastructure</td>
<td>Planning of dedicated lanes / infrastructures</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Services</td>
<td>Connectivity supporting traffic and space management</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vehicle</td>
<td>C-ACC Truck platooning Traffic Jam Chauffeur</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Highly automated vehicle on dedicated roads</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fully automated freight vehicles</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lightweighting; Tires; Aerodynamics</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>HCV and new vehicle concepts</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Highly efficient ICE PWT (increasing share of alt. fuels)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hybrids; Plug-in hybrids; Electrified road systems; BEV</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>High-voltage architecture</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

TODAY 2020-23 2024-27 2027-30+
Highway chauffeur based hub2hub heavy freight vehicles - examples

- Highly automated, un-manned but connected to a control and supply-chain management center
- For repetitive transport involving high precision between hubs
- Slow speed on dedicated roads with infrastructure support

VERA by Volvo Trucks

- Highly automated trucks on open roads in mixed traffic
- For flexible transport assignments with automated and manual operation
- Integrated with supply chain
- Multi-brand-truck platooning enabled

ENSEMBLE – Multi-brand truck platooning
### Automated Urban Mobility Vehicle 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>
<th>...</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 5:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Full Automation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Level 4:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High Automation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Level 3:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conditional</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Automation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Level 2:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Partial Automation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Level 1:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Driver Assistance</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Level 0:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No Driving</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Automation, support beyond human capability to act</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Use Case**
- **Automated PRT/Shuttles on Dedicated Roads**
- **Automated Buses on Dedicated Roads**
- **Automated PRT/Shuttles in Mixed Traffic**
- **Automated Buses in Mixed Traffic**
- **Automated Urban Bus 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**

PRT (Personal Rapid Transit) incl. Urban Shuttle
City Bus/Coach: M2 < 5 tonnes < M3
Urban Automated Shuttles for Individual and Collective Use
Urban Mobility and Automation

Autonomous vehicles will only help to meet public policy goals if they come as shared fleets integrated with public transport.

Shared fleet of vehicles

- Strong reduction in number of cars (reduced car ownership, effective use of cars as they operate most of the day)
- Drastically improved mobility for people that do not own a car

Privately owned cars

- No effect on car ownership
- No effect on number of parked cars (cars unused most of the day)
- No effects on costs/km
- No effects on mobility for people that do not own a car
- Even more car traffic (as it is even more comfortable and attractive to go by car)

Fleet cars COMPETING with traditional public transport services

- More traffic (more increase in Vehicle Miles Traveled (VMT))
- Inefficiency (small vehicles replacing buses and trains)
- Passenger loss for traditional public transport walking and cycling

Fleet cars INTEGRATED with traditional public transport services

- Large scale street reclaiming
- Highly improved access to public transport
- Highly improved mobility for people that do not own a car
- Strong decrease in VMT
- High gain of efficiency (large and small vehicles perfectly mixed)
- Low costs/km

> Unsustainable, even more car traffic
> Better mobility, less efficiency
> Sustainable, better mobility and equity

Urban Mobility and Automation

**In Focus:**
**Personal Rapid Transit (PRT) including Urban Shuttles** for smaller urban mobility vehicles primarily for transport of **people**, for last-mile use, but potentially also for longer distances, on confined, dedicated and **open roads**.

**Both considered:** Models of operation of **collective** and **individual** (”taxi”) character.

<table>
<thead>
<tr>
<th>category</th>
<th>features</th>
</tr>
</thead>
<tbody>
<tr>
<td>ODD characteristics</td>
<td>Mixed traffic – same speed as other traffic</td>
</tr>
<tr>
<td>ecosystem</td>
<td>integrated into smart seamlessly connected ecosystem by mobility services (booking, sharing, networking, parking, charging); (SW-) solutions for management and maintenance of vehicles</td>
</tr>
<tr>
<td>enablers (selection)</td>
<td>map-based localization (down to few centimeters), security solutions considering level 4 automation, keyless access, data connectivity to outside world, SW-updates</td>
</tr>
</tbody>
</table>
Individual Use

**User Insight:** “I want to get from A to B in the city fast and convenient, but taxis are so expensive. If I drive myself I can’t use the time and need to be alert”

**User Benefit:** Mobile phone app allows ordering convenient point-to-point transportation in a defined urban area, at a lower price point than current taxis

**UAT Features**

- Automated driving in complex urban areas
- SAE Level 4: no passenger intervention in driving task
- Focus on safety & time-to-market
- Operation initially limited to certain areas & weather conditions
- High-end sensor set, high on-board computing power
- Tele-operation of vehicle
- Backend connectivity
Collective Use

Features

- Automation level 4: no driver and no passenger intervention required
- Travelling on-demand on pre-defined driving corridors
- Ego speed: low (urban highway not to be considered initially)
- Driving in mixed traffic under released conditions
- Overtaking within ego lane
- Safety concept: Safe stop
- Transport of people and goods possible
- Operating initially on private areas, stepwise release to low-complexity public areas

Services

- Backend services to seamlessly integrate into existing public mobility solutions
- Vehicle Control and Occupant Monitoring Center
- Offering mobility services to businesses and end-customers

© Robert Bosch GmbH