Vehicle Automation: Overview of Challenges

Bart van Arem
Director TU Delft Transport Institute

A first drive with fully automated vehicle...
Vehicle Automation: Overview of Challenges

High Expectations

- Efficient travel
- Safety
- Energy, emissions
- Economy
- Comfort, quality of life
**Summary of SAE International’s Draft Levels of Automation for On-Road Vehicles (July 2013)**

SAE’s draft levels of automation are descriptive rather than normative and technical rather than legal. Elements indicate minimum rather than maximum capabilities for each level. “System” refers to the driver assistance system, combination of driver assistance systems, or automated driving system, as appropriate. NHTSA’s levels of automation are provided to indicate approximate correspondence.

<table>
<thead>
<tr>
<th>NHTSA level</th>
<th>SAE level</th>
<th>SAE name</th>
<th>SAE narrative definition</th>
<th>Execution of steering and acceleration/ deceleration</th>
<th>Monitoring of driving environment</th>
<th>Backup performance of dynamic driving task</th>
<th>System capability (driving modes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human driver monitors the driving environment</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 0</td>
<td>Non-Automated</td>
<td>the full-time performance by the human driver of all aspects of the dynamic driving task, even when enhanced by warning or intervention systems</td>
<td>Human driver</td>
<td>Human driver</td>
<td>Human driver</td>
<td>n/a</td>
<td></td>
</tr>
<tr>
<td>1 1</td>
<td>Assisted</td>
<td>the driving mode-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the human driver perform all remaining aspects of the dynamic driving task</td>
<td>Human driver and system</td>
<td>Human driver</td>
<td>Human driver</td>
<td>Some driving modes</td>
<td></td>
</tr>
<tr>
<td>2 2</td>
<td>Partial Automation</td>
<td>the driving mode-specific execution by one or more driver assistance systems of both steering and acceleration/deceleration using information about the driving environment and with the expectation that the human driver perform all remaining aspects of the dynamic driving task</td>
<td>System</td>
<td>Human driver</td>
<td>Human driver</td>
<td>Some driving modes</td>
<td></td>
</tr>
<tr>
<td>Automated driving system (“system”) monitors the driving environment</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 3</td>
<td>Conditional Automation</td>
<td>the driving mode-specific performance by an automated driving system of all aspects of the dynamic driving task with the expectation that the human driver will respond appropriately to a request to intervene</td>
<td>System</td>
<td>System</td>
<td>Human driver</td>
<td>Some driving modes</td>
<td></td>
</tr>
<tr>
<td>4 4</td>
<td>High Automation</td>
<td>the driving mode-specific performance by an automated driving system of all aspects of the dynamic driving task, even if a human driver does not respond appropriately to a request to intervene</td>
<td>System</td>
<td>System</td>
<td>System</td>
<td>Some driving modes</td>
<td></td>
</tr>
<tr>
<td>5 5</td>
<td>Full Automation</td>
<td>the full-time performance by an automated driving system of all aspects of the dynamic driving task under all roadway and environmental conditions that can be managed by a human driver</td>
<td>System</td>
<td>System</td>
<td>System</td>
<td>All driving modes</td>
<td></td>
</tr>
</tbody>
</table>

Automated, autonomous, cooperative?

- **Automated**
  - Level 5: Full Automation
  - Level 4: High Automation
  - Level 3: Conditional Automation
  - Level 2: Partial Automation
  - Level 1: Drive Assistance

- **Autonomous**
- **Cooperative**

- **Manual**

Vehicle Automation: Overview of Challenges
Vehicle Automation: Overview of Challenges

Two paths for deployment

- Functional
  - Partial automation
    - Driver support
    - Dedicated roads
  - Full automation
    - High/full automation
    - Mixed traffic
    - Operational speed

- Spatial
  - High/full automation

Fundamental changes in driving behaviour

- Driver in control
- Vehicle in control
- Driver supervision

Workload, driving performance, attention, situation awareness, risk compensation, Driver Vehicle Interface, acceptance, mode transition, purchase and use
Potential impacts on traffic

- Solve traffic jams by increased outflow
- Prevent traffic jams by better stability
- Better distribution of traffic over network
- Decreased throughput by larger headways
- Decreased stability by lack of anticipation

Less congestion delay
Increased risk of congestion

Non connected Large penetration

Car driving more attractive!

- Partial automation: Better comfort, Less accidents, Less congestion
- High automation: Travel time can partially be used for other purpose
- Full automation: Travel time can fully be used for other purposes
Spatial implications

- Geometric redesign of roads and junctions
- Increasing sprawl residential and employment locations
- Concentration activities by better accessibility
- Redesign of urban, commercial, touristic areas
- No on street parking
- Combinations with car sharing, electric driving

Huge investments in technology

- Sensing
- Communication
- Positioning
- Data fusion
- Situation awareness
- Trajectory predication
- Cooperative control
- Traffic management
- Driver monitoring

- Performance
- Complexity
- Security
- Privacy
- Liability
- Failure modes
- Weather conditions
- Energy
- Cost
Challenges for Vehicle Automation

- Maaike Snelder: Traffic impacts
- Gonçalo Correia: Mobility impacts

Break

- Dimitris Milakis: Land use impacts
- Joost de Winter: Technology and Human factors