Road Vehicle Automation Levels and Safety Challenges

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Historical Context: General Motors 1939 Futurama
# SAE J3016 Definitions – Levels of Automation

<table>
<thead>
<tr>
<th>SAE Level</th>
<th>Name</th>
<th>Narrative Definition</th>
<th>Execution of Steering/Acceleration/Deceleration</th>
<th>Monitoring of Driving Environment</th>
<th>Fallback Performance of Dynamic Driving Task</th>
<th>System Capability (Driving Modes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No Automation</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>
</tr>
<tr>
<td>1</td>
<td>Driver Assistance</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>
</tr>
<tr>
<td>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>
</tr>
<tr>
<td>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>
</tr>
<tr>
<td>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>
</tr>
<tr>
<td>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>
</tr>
</tbody>
</table>
## Example Systems at Each Automation Level

<table>
<thead>
<tr>
<th>Level</th>
<th>Example Systems</th>
<th>Driver Roles</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Adaptive Cruise Control OR Lane Keeping Assistance</td>
<td>Must drive other function and monitor driving environment</td>
</tr>
<tr>
<td>2</td>
<td>Adaptive Cruise Control AND Lane Keeping Assistance Traffic Jam Assist (Mercedes, Volvo, Infiniti)</td>
<td>Must continuously monitor driving environment (system nags driver to try to ensure it)</td>
</tr>
<tr>
<td>3</td>
<td>Traffic Jam Pilot Automated parking with supervision</td>
<td>May read a book, text, or web surf, but be prepared to intervene when needed</td>
</tr>
<tr>
<td>4</td>
<td>Highway driving pilot Closed campus driverless shuttle Driverless valet parking in garage</td>
<td>May sleep, and system can revert to minimum risk condition if needed</td>
</tr>
<tr>
<td>5</td>
<td>Automated taxi (even for children) Car-share repositioning system Drives anywhere people can drive</td>
<td>No driver needed</td>
</tr>
</tbody>
</table>
Automation Is a Tool for Solving Transportation Problems

- Alleviating congestion
  - Increase capacity of roadway infrastructure
  - Improve traffic flow smoothness
- Reducing energy use and emissions
  - Improve traffic flow smoothness
  - Aerodynamic “drafting”
- Improving safety
  - Reduce and mitigate crashes

...BUT the vehicles need to be ‘connected’ to gain these benefits
Improving Safety

• Current traffic safety sets a very high bar:
  
  – 3.3 M vehicle **hours** between fatal crashes (375 years of non-stop driving)
  
  – 65,000 vehicle **hours** between injury crashes (7+ years of non-stop driving)

• How much safer does an automated system need to be? (2X? 5X? 10X?)
• How do you determine that the automated system has reached its safety goal?
No Automation and Driver Assistance (Levels 0, 1)

• Primary safety advancements are likely at these levels, adding machine vigilance to driver vigilance
  – Safety warnings based on ranging sensors (and V2V, I2V communications soon)
  – Automation of one driving function facilitating driver focus on other functions

• Widely available on cars and trucks now
Partial Automation (L2) and Conditional Automation (L3)

- Safety impacts depend on driver interactions with system
- L2 already available on some cars and will be introduced on many more within the next year
- Major challenges with driver mis-use:

Mercedes S-Class

Infiniti Q50
High Automation (Level 4)

- Safety improvement, based on required ability to automatically transition to minimal risk condition
- Only usable without a driver in certain places or under certain conditions:
  - Automated people movers on closed guideways (40 years of experience)
  - Limited-access highways (all major vehicle companies targeting these for 2020-2025 period)
  - Limited speed range (urban shuttles, Google pod cars)
  - Locations with infrastructure protected and certified (CityMobil2 in Europe) or meticulously mapped (Google)
  - Limited weather or lighting conditions
High Automation (Level 4) – Special applications

- Buses on separate transitways
  - Narrow right of way – easier to fit in corridors
  - Rail-like quality of service at lower cost
- Heavy trucks on dedicated truck lanes
  - (cooperative) Platooning for energy and emission savings, higher capacity
- Automated (driverless) valet parking
  - More compact parking garages
- Driverless shuttles within campuses or pedestrian zones
  - First mile/last mile access to line-haul transit
- When? Could be just a few years away
“Driverless” L4 Low-Speed Shuttle Demo in La Rochelle, France
Full Automation (Level 5)

- Electronic taxi service for mobility-challenged travelers (young, old, impaired)
- Shared vehicle fleet repositioning (driverless)
- Driverless urban goods pickup and delivery
- Full “electronic chauffeur” service

- Many decades away because ubiquitous operation without driver poses huge technical challenges
Why will this take so long?

- Impossibility of specifying and designing for all hazards the vehicle will encounter
  - Other road users, environmental conditions, internal fault conditions…
- No viable technology to develop and verify complex safety-critical software making life-or-death decisions
- Sensor signal processing to achieve near-zero false negatives and false positives
  - Distinguishing genuine hazards from benign objects