Cooperative Vehicle Automation: the soft sides and the hard constraints

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Dutch society and economy depend on transport

- Dense road network
- Port of Rotterdam
- High traffic volumes
- Schiphol airport
Self driving cars can improve traffic efficiency and safety. Netherlands to facilitate large scale testing of self driving vehicles.

Dutch minister of Infrastructure & Environment Mrs Melanie Schultz.
<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></td>
<td>0</td>
<td>Non-Automated</td>
<td>the full-time performance by the human driver of all aspects of the dynamic driving task</td>
<td>Human driver</td>
<td>Human driver</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td></td>
<td>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>Some driving modes</td>
<td>Some driving modes</td>
</tr>
<tr>
<td></td>
<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>Some driving modes</td>
<td>Some driving modes</td>
</tr>
<tr>
<td></td>
<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 would respond appropriately to a request to intervene</td>
<td>System</td>
<td>System</td>
<td>Some driving modes</td>
<td>Some driving modes</td>
</tr>
<tr>
<td></td>
<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>Some driving modes</td>
<td>Some driving modes</td>
</tr>
<tr>
<td></td>
<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>All driving modes</td>
<td>All driving modes</td>
</tr>
</tbody>
</table>

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DITCM symposium Smart Mobility on the Road, Helmond, 30 March 2015
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Challenge the future

Cooperative Adaptive Cruise Control function

Regular cruise control
\[ a_{ref_v} = r_s \left( v_{ref} - v \right) \]

Distance keeping
\[ d_{ref} = d_0 + t_{ref} \cdot v \]

Speed synchronisation
\[ a_{ref_d} = k_d \left( d - d_{ref} \right) + k_v v_{rel_p} + \frac{k_v}{n-1} \sum_{j=i-n}^{i-2} v_{rel_j} \]

Wilmink, Klunder & van Arem (2007)
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Milanes et al, 2014
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Challenge the future

Potential impacts on traffic

- Solve traffic jams by increased outflow
- Prevent traffic jams by better stability
- Better distribution of traffic over network

Less congestion delay

Non connected
Large penetration

- Decreased throughput by larger headways
- Decreased stability by lack of anticipation

Increased risk of congestion
A20: bottleneck motorway, no more space to expand

How can AVs relieve congestion here?

Implications of automated driving

(Milakis, van Arem, & van Wee, 2015; work in progress)
Development of automated vehicles in the Netherlands: scenarios for 2030 and 2050

(Milakis, Schnelder, van Arem, van Wee, & Correia, 2015; work in progress)
Implications of AVs for National Transport Model

- Updated every 2 year to identify main transport problems
- Used to support major transport infrastructure decisions
- Typical horizon 20 years
- What if AVs could deliver substantial capacity improvement in 20 years?

- Approach
  - Literature study on potential roadway capacities and value of time
  - Sensitivity analyses
  - Research plan

100% capacity increase

Car trips valued as high quality rail

4-8% VMT increase (Gippsa, 2014)
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

The soft sides and hard constraints

- Cooperative technology leverages automation
- Real congestion bottlenecks are major challenges
- Societal and economic implications potentially large