Implications of self driving cars

Prof Dr Bart van Arem
Director TU Delft Transport Institute

Infrastructure of the Netherlands

<table>
<thead>
<tr>
<th></th>
<th>Highway density</th>
<th>Waterway density</th>
<th>Railway density</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belgium</td>
<td>0.60</td>
<td>0.18</td>
<td>0.03</td>
</tr>
<tr>
<td>Netherlands</td>
<td>0.24</td>
<td>0.15</td>
<td>0.02</td>
</tr>
<tr>
<td>Japan</td>
<td>0.08</td>
<td>0.01</td>
<td>2.12</td>
</tr>
<tr>
<td>Hungary</td>
<td>0.08</td>
<td>0.01</td>
<td>0.07</td>
</tr>
<tr>
<td>Latvia</td>
<td>0.02</td>
<td>0.01</td>
<td>0.05</td>
</tr>
<tr>
<td>South-Africa</td>
<td>0.44 (0.05 paved)</td>
<td>0.01</td>
<td>0.07</td>
</tr>
</tbody>
</table>

Transport in the Netherlands

- Motorways with daily volume over 180,000 vehicles:
  - Netherlands: 15
  - United Kingdom: 2
  - Germany: 2
What are self-driving cars?

Self-driving cars can improve traffic efficiency and safety. Netherlands to facilitate large scale testing of self driving vehicles.

What is automated driving?

Partial automation
Available, Mercedes S class Limited scope
High automation
Massive worldwide R&D
Full automation
Decades away unless on dedicated infrastructure or driving very slowly.

Summary of SAE International’s Draft Levels of Automation for On-Road Vehicles (July 2013)

<table>
<thead>
<tr>
<th>Level</th>
<th>Description</th>
<th>Limitations or Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No driver</td>
<td>Completely manual</td>
</tr>
<tr>
<td>1</td>
<td>Driver</td>
<td>Driver is primary</td>
</tr>
<tr>
<td>2</td>
<td>Driver</td>
<td>Driver is primary</td>
</tr>
<tr>
<td>3</td>
<td>Driver</td>
<td>Driver is primary</td>
</tr>
<tr>
<td>4</td>
<td>Automated</td>
<td>System is primary</td>
</tr>
<tr>
<td>5</td>
<td>Full automation</td>
<td>System is primary</td>
</tr>
</tbody>
</table>

Dutch minister of Infrastructure and Environment Mrs Melanie Schultz

Self driving cars can improve traffic efficiency and safety.

Available, Mercedes S class Limited scope

Massive worldwide R&D

Decades away unless on dedicated infrastructure or driving very slowly.
Adaptive Cruise Control function

\[
\begin{align*}
\text{Regular cruise control:} & \quad a_{\text{ref},i} = r_a \cdot (v_{\text{ref}} - v) \\
\text{Distance keeping:} & \quad d_{\text{ref}} = d_i + t_{\text{ref}} \cdot v \\
\text{Speed synchronization:} & \quad a_{\text{ref},i} = k_s \cdot (d - d_{\text{ref}}) + k_v \cdot v_{\text{ref},i} \\
\text{Distance keeping:} & \quad a_{\text{ref},i,\text{ACC}} = \min(a_{\text{ref},i}, a_{\text{ref},i}) \\
\end{align*}
\]

Cooperative Adaptive Cruise Control function

\[
\begin{align*}
\text{Regular cruise control:} & \quad a_{\text{ref},i} = r_a \cdot (v_{\text{ref}} - v) \\
\text{Distance keeping:} & \quad d_{\text{ref}} = d_i + t_{\text{ref}} \cdot v \\
\text{Speed synchronization:} & \quad a_{\text{ref},i} = k_s \cdot (d - d_{\text{ref}}) + k_v \cdot v_{\text{ref},i} \\
\text{Distance keeping:} & \quad a_{\text{ref},i,\text{ACC}} = \min(a_{\text{ref},i}, a_{\text{ref},i}) \\
\end{align*}
\]

Technologies Adaptive Cruise Control

- Radar
  - Long range 70 GHz 100-150m
  - Short range 24 GHz 20 m
- Video camera
  - now: monocular
  - Stereovision
- Dedicated Short Range Communication
  - IEEE 802.11p (wifi) 200-300 m

Huge investments in technology

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

- Performance
- Complexity
- Security
- Privacy
- Liability
- Failure modes
- Weather conditions
- Energy
- Cost

Fundamental changes in driving behaviour

- Workload,
- Driving performance,
- Attention,
- Situation awareness,
- Risk compensation,
- Driver Vehicle Interface,
- Acceptance,
- Mode transition,
- Purchase and use

Driver in control

Vehicle in control

Driver supervision
Potential impacts on traffic

- Solve traffic jams by increased outflow
- Prevent traffic jams by better stability
- Better distribution of traffic over network
- Decreased congestion delays
- Decreased stability by lack of anticipation
- No accidents (?)
- Better energy efficiency
- Increased risk of congestion
- Decreased throughput by larger headways
- Decreased stability by lack of anticipation

Car driving more attractive!

<table>
<thead>
<tr>
<th>Automation Level</th>
<th>Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Partial automation</td>
<td>Better comfort, less accidents, less congestion</td>
</tr>
<tr>
<td>High automation</td>
<td>Travel time can partially be used for other purposes</td>
</tr>
<tr>
<td>Full automation</td>
<td>Travel time can fully be used for other purposes</td>
</tr>
</tbody>
</table>

More car trips?

- Decreasing congestion makes latent demand manifest
- Car trips become more attractive
- Changes in activity patterns?
- 100% capacity increase
- Car trips valued as high quality rail

4.8% VMT increase (Gucwa, 2014)
The road to automated driving...

- Collect, analyse and publish large scale real-world experience
- Case studies for regional transport networks
- Regulations, type approval
- Awareness, ambitions, expectations, reality checks

Thank you!

Cars automatic in 20 years

Tell it we don't appreciate these types of jokes and to come back right away