Automated Driving – A Silver Bullet for Urban Mobility?

Bart van Arem, Delft University of Technology, The Netherlands

Smart Urban Mobility Symposium – Amsterdam - 29th June 2017
A first drive with fully automated vehicle...
Rivium Buses (Rotterdam)

Separated track
Road based transponders
Supervisory control
Since 1999…
WePod
Automated vehicles can improve traffic efficiency and safety.

Netherlands to facilitate large scale testing of automated vehicles.
Declaration of Amsterdam
Cooperation in the field of connected and automated driving
14-15 April 2016

TU Delft

Spatial and Transport Impacts of Automated Driving
Automated driving

Driver assistance/
Partial automation

Driver needs to be able to
intervene at all times

Automated parking,
autocruise

Conditional/ High
automation

Vehicle in control in special
conditions

Taxibots, platooning,
automated highways

Comfort, efficiency, safety, costs

Mode choice, location choice, urban
and transport planning
Many questions …

When fully automated vehicles will hit the market?
   Will we travel safer?

Are we going to own or share cars?

Will we need more or less road infrastructures?
   Will we still need buses?
   Will there be more or less congestion?

Will we drive longer or shorter distances?
   How much on-street and off-street parking spaces will still be needed?

How will cities evolve?
   Will we consume more or less energy to travel?
Much progress short term and small scale impacts on driver behaviour and traffic flow.

Research on longer term, indirect, wider scale impacts on mobility, logistics, residential patterns and spatial-economic structure in its infancy.

Scientific challenges: understanding the spatial and transport changes

- Automated Driving
- Travel and location choice behaviour
- Freight and Logistics applications
- Infrastructure service networks
- Spatial structure and economy
- Urban design and traffic safety
- Regional spatial and transport system

www.stad.tudelft.nl
Application

- Regional case studies: passenger cars, freight, public transport, parking
- Spatial impacts, urban design, agglomeration
- Business cases
- Modelling tools, impacts, risks, benefits

Metropoolregio Rotterdam-The Hague
Province Zuid-Holland
Province North-Holland
Municipality of Amsterdam
Rotterdam The Hague Airport
Municipality of The Hague
Municipality of Rotterdam
AMS Advanced Metropoliton Solutions
SmartPort
SWOV Institute for Road Safety Research
RET NV
Mobycon
Province Gelderland
DTV Consultants
Connekt ITS Netherlands
Municipality of Delft
Rijkswaterstaat
KiM
CROW
Transdev-Connexxion
RDW
TNO
Goudappel Coffeng
Trust?
Expectations?
Behavior?
Virtual Reality Experiment

- Visit of Welly
- 360° recordings with a dedicated camera
- VR glasses

Nunez Velasco et al (in prep)
Shared automated Mobility, Car Ownership and Urban Parking Management

Vehicle **Automation** & Vehicle **Sharing** can increase efficiency of urban land use and the urban vehicle fleet.

Modeling the interrelation between car sharing, car ownership and urban parking management.
**Which of the following options would you choose for going from your home to your fictive work/educational institution?**

<table>
<thead>
<tr>
<th></th>
<th>auto-to-go</th>
<th>own vehicle</th>
<th>taxi</th>
<th>bus</th>
<th>self-riding vehicles</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cost for the trip</strong></td>
<td>€ 3,60</td>
<td>€ 2,40</td>
<td>€ 3,60</td>
<td>€ 3,60</td>
<td>€ 3,60</td>
</tr>
<tr>
<td><strong>Cost for parking</strong></td>
<td>--</td>
<td>€ 5,00</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td><strong>Time to walk to and from vehicle or bus stop</strong></td>
<td>2 minutes</td>
<td>6 minutes</td>
<td>--</td>
<td>6 minutes</td>
<td>--</td>
</tr>
<tr>
<td><strong>Waiting time</strong></td>
<td>--</td>
<td>--</td>
<td>4 minutes</td>
<td>7 minutes</td>
<td>4 minutes</td>
</tr>
<tr>
<td><strong>Travel time in vehicle</strong></td>
<td>15 minutes</td>
<td>15 minutes</td>
<td>15 minutes</td>
<td>20 minutes</td>
<td>15 minutes</td>
</tr>
<tr>
<td><strong>Time to find a parking spot</strong></td>
<td>4 minutes</td>
<td>4 minutes</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
</tbody>
</table>

840 respondents
Amsterdam, Utrecht, The Hague Rotterdam
Attributes were varied
### Estimated Modal Split

<table>
<thead>
<tr>
<th>Mode</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Car only</td>
<td>22.5%</td>
</tr>
<tr>
<td>Car &amp; walk/bike</td>
<td>41.6%</td>
</tr>
<tr>
<td>Walk/bike only</td>
<td>17.7%</td>
</tr>
<tr>
<td>Public transport only</td>
<td>9.0%</td>
</tr>
<tr>
<td>Car &amp; public transport</td>
<td>9.2%</td>
</tr>
<tr>
<td>Other</td>
<td></td>
</tr>
</tbody>
</table>

840 respondents
Amsterdam, Utrecht, The Hague Rotterdam

**Next step:** Activity based modelling of Amsterdam

Nordhoff et al. (2016), A Conceptual Model to Explain, Predict, and Improve User Acceptance of Driverless Podlike Vehicles, Transportation Research Record

EUREF Campus, Berlin, 8 km/h; 326 respondents, after driving December 2016-April 2017

- Attitude positive, Willingness to share with others
- AV easy to use, High level of trust in AV
- AV considered useful, especially in relation to public transport
- AV considered less useful by car users
Winter et al (2016), Designing an Automated Demand-Responsive Transport System, Transportation Research Record

Vehicle capacity (2-40)
Dwell time (1-6 min)
Initial Vehicle Location
Demand level and randomness

System cost per trip

Vehicle fixed and variable costs
Passenger generalized cost
The new Delft-Zuid Station

ProRail (2014)
Imagine a trip you have to make (home to) a certain activity, like your work, a business meeting or study. Imagine the activity for which you have to travel most frequently. There are different travel alternatives. Which alternative would you choose for this trip?

**Main transport: train**
- Travel time to the station and travel time in train: 30 min
- Costs trip to the station and train ticket 2nd class: €10,00
- Costs trip to the station and train ticket 1st class: €15,00

**Egress**

<table>
<thead>
<tr>
<th>Mode</th>
<th>Waiting time</th>
<th>Travel time</th>
<th>Travel costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bus / train / metro</td>
<td>10 min</td>
<td>5 min</td>
<td>€3,00</td>
</tr>
<tr>
<td>Bicycle</td>
<td>10 min</td>
<td>6 min</td>
<td>€0</td>
</tr>
<tr>
<td>Cybercar – drive yourself</td>
<td>0 min</td>
<td>10 min</td>
<td>€3,00</td>
</tr>
<tr>
<td>Cybercar – automatic driving</td>
<td>6 min</td>
<td>10 min</td>
<td>€15,00</td>
</tr>
</tbody>
</table>

**Walking time to destination**
- 8 min

**Your choice**

- Train + bus/metro
- Train + bicycle
- Train + cybercar (drive yourself)
- Train + cybercar (automated driving)

**Main transport: car**
- Travel time and time required to find a parking place: 45 min
- Fuel costs and parking costs: €15,00

- Walking time to destination: 2 min

N=761
Willingness to pay for 10 minutes travel time reduction

<table>
<thead>
<tr>
<th>Trip segment</th>
<th>Mode</th>
<th>Willingness-to-pay per 10 minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main</td>
<td>Private car</td>
<td>€1.80 - €1.90</td>
</tr>
<tr>
<td>Egress</td>
<td>Bus/tram/metro</td>
<td>€0.55 - €0.65</td>
</tr>
<tr>
<td>Egress</td>
<td>Bicycle</td>
<td>€1.45 - €1.55</td>
</tr>
<tr>
<td>Egress</td>
<td>Automatic vehicle: manually driven</td>
<td>€0.85 - €0.95</td>
</tr>
<tr>
<td></td>
<td>Automatic vehicle: automatically driven</td>
<td>€2.25 - €2.35</td>
</tr>
</tbody>
</table>


1st class passengers prefer AV Dual mode AV first step Trust and reliability important
Effect of vehicle relocations
Liang et al., (2016), Optimizing the service area and trip selection of an electric automated taxi system used for the last mile of train trips, Transportation Research E
Meaningful human control (MHC) of automated driving systems

... so much more than robot-dilemmas

What is MHC?
How to design with MHC?
How can humans execute MHC?
Is MHC still effective?

Use cases

2017-2020 M€ 0,5
Interregional Automated Transport NL–DE

➢ To better prepare mobility and logistics for future markets

Technology development
Acceptance and comfort
Infra adaptations
Business modelling
Airport Shuttle Weeze (D)
FoodValley Wageningen (NL)
Truck Platooning (Flowers) (NL-D)

<table>
<thead>
<tr>
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<th>D</th>
<th>NL</th>
</tr>
</thead>
<tbody>
<tr>
<td>SME</td>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td>LE</td>
<td>2</td>
<td>3</td>
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<tr>
<td>Research</td>
<td>1</td>
<td>2</td>
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<tr>
<td>Public Authorities</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

2017-2020 M€ 8,7

Courtesy Martijn Bruil, Province of Gelderland
Automated transport for disabled people

- Children with Multiple Complex Disabilities
  - Need for flexible and safe transport
  - 400 m between home and day care
  - Steward and helper present

- Light traffic, moderate infrastructure adaptations

- Automate wheelchair ready vehicle?
- Make automate vehicle wheelchair ready?
Automated Vehicles Last Mile
Research Lab Automated Driving Delft
Automated driving can strengthen public transport

Moving into increasingly complex situations
User acceptance growing

Automated driving in passenger cars, freight transport, parcel and pizza delivery…

Smart urban mobility: automated driving, walking, cycling, parking, sharing,…

Thank you!