Help or Hindrance?
Energy & Carbon Impacts of Vehicle Automation

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Help or hindrance? The travel, energy and carbon impacts of highly automated vehicles

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Ease Traffic Jams

The New York Times
Will Robot Cars Drive Traffic Congestion Off a Cliff?

THE TIMES
Road chaos feared as young and old swap bus for a driverless car

Making All Cars Driverless Would Reduce Emissions By 90 Percent
The green argument for driverless cars

Media Coverage
To bound the potential energy and carbon impacts of self-driving/highly automated vehicles?

To identify the key areas that require attention from policymakers?
Methods

Analysis Framework

\[ \text{carbon emissions} \times \text{travel demand} \times \text{energy efficiency of travel} \times \text{carbon intensity of energy} = \text{CO}_2 \]

Method

Identify mechanisms for change

Literature review, simplified calculations, rational assumptions

Scenario building

(... not about uptake, about impacts when commonplace)
Carbon, energy & travel ripple
### Energy efficiency

<table>
<thead>
<tr>
<th>Mechanisms</th>
<th>Energy effects</th>
<th>Automation level</th>
<th>Connectivity level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic flow improvement</td>
<td>✓</td>
<td></td>
<td>V2X</td>
</tr>
<tr>
<td>Eco-routing</td>
<td>✓ ✓</td>
<td></td>
<td>V2X</td>
</tr>
<tr>
<td>Eco-driving</td>
<td>✓</td>
<td></td>
<td>V2X</td>
</tr>
</tbody>
</table>

Early benefits from connectivity and connectedness

Potentially large benefits at high levels of automation and connectivity, but these benefits are highly uncertain, too

………. and depends on innovations in other areas

………. Energy use in computing, data storage, 5G???

| Rightsizing            | ✓ ✓ ✓           |                  | V2I, I2V           |
## Travel demand

<table>
<thead>
<tr>
<th>Mechanisms</th>
<th>Energy effects</th>
<th>Automation level</th>
<th>Connectivity level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distances (location choice)</td>
<td>✗ ✗</td>
<td></td>
<td>I2V</td>
</tr>
<tr>
<td>Modal shift</td>
<td>✗ ✗ ✗ ✗</td>
<td></td>
<td>I2V</td>
</tr>
<tr>
<td>Trip number</td>
<td>✗ ✗</td>
<td></td>
<td>I2V</td>
</tr>
<tr>
<td>New user groups</td>
<td>✗ ✗</td>
<td></td>
<td>I2V, V2I</td>
</tr>
<tr>
<td>Mobility on demand, MaaS</td>
<td>✔ ✔ ✔ ✔ / ✗</td>
<td></td>
<td>I2V, V2I</td>
</tr>
<tr>
<td>Empty running</td>
<td>✗ ✗</td>
<td></td>
<td>I2V, V2I</td>
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</tbody>
</table>

- Small impact at low levels of automation
- Step changes at high levels of automation
- Large uncertainty at high levels of automation
Automation challenges two important hypothesis

Marchetti constant/
Zahavi Travel time budget

Peak car

1 hr/day commute
Travel demand: Own vs. MoD

MoD: Marginal cost pricing – should curb demand in theory

Self-selected bunch

Empty running

pay-as-you-go or mobility packages?

Public transport to MoD? Vicious circle

VMT won’t fall – unless “ridesharing” (still detours+empty runs);
Evidence of some sharing – but who uses MoD?

Some capacity benefits through
“rightsizing” MoD

1 car club car removes 9 cars on street;
Does it matter for ‘running’ energy?
Results (USA)

- Platooning
- Eco-driving
- Congestion mitigation
- De-emphasized performance
- Improved crash avoidance
- Vehicle right-sizing
- Higher highway speeds
- Increased features
- Travel cost reduction
- New user groups
- Changed mobility services
- Infrastructure footprint*

% changes in energy consumption due to vehicle automation

(USA)
Four scenarios *(not predictions!)*

1. **Have our cake & eat it too**
   - Energy Intensity
   - Travel Demand
   - Energy Demand
   - Total Road Transport Energy

2. **Stuck in the middle at L2**

3. **Strong responses**

4. **Dystopian nightmare**
Narrowing the range

- Platooning
- Eco-driving
- Congestion mitigation
- De-emphasized performance
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% changes in energy consumption due to vehicle automation

-60% -50% -40% -30% -20% -10% 0% 10% 20% 30% 40% 50% 60%

Capacity/congestion? ~10%
Transition is a big barrier
Business model? Transition?
Transition again?
VoT reduction smaller
On this side? Business model?
Reliability?
Automation ≠ EVs or FCVs
... but several synergies between automation and low carbon fuel

Computation uses electricity
Unattended refuelling/recharging: inconvenience reduced
High utilisation in a mobility services future: cost efficiency
Lightweighting allows more batteries: range anxiety reduced
... ... all related to full (driverless) automation

Computation power requirements + battery charging cycles
Thank you

The use and usefulness of travel time in fully automated vehicles, 2018 (under review)
Fully automated vehicles: A cost of ownership analysis to inform early adoption, 2017
Help or Hindrance? The travel, energy and carbon impacts of highly automated vehicles, 2016