Modelling the impact of automated driving -
Private autonomous vehicle scenarios for Germany and the US

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Outline

• Introduction
• Model scheme
  • Vehicle Technology Diffusion Model
  • Travel Demand Model
• Results
• Conclusion and Outlook
Introduction

- Motivation:
  - Market entry of highly and fully automated vehicles (AVs) within next years
  - AVs in private vehicle fleet and new mobility concepts (shared AVs)
  - Impact of autonomous driving on travel demand (VoTTS, new user groups)

![Levels of automation (SAE n.d.)](chart)

Figure 1: Levels of automation (SAE n. d.)
Introduction

• Topic of this study:
  Introduction of Level 4 and Level 5 vehicles into the private vehicle fleet,
  Impact on travel demand, comparison of two scenarios in Germany and the US
• Basis for a subsequent study of new mobility concepts with shared AVs
Methodology: Overview

Figure 2: Overview of model scheme

AV diffusion rates for car segments

assumptions with respect to autonomous driving

vehicle technology diffusion model

scenario-specific

external data: population forecast

aspatial travel demand model

Impact on travel demand
Methodology: Vehicle Technology Diffusion Model

- Estimation of number of newly registered AVs per year
- Differentiated by car segments (specific for the national car market:
  - Germany: small/compact/medium/large, US: small/pick-up/medium/large)
- s-shaped market-take-up
- Differentiation of initial diffusion rates, years of introduction and growth rates

Number of newly registered AVs $P_t$ in year $t$:

$$ P_t = P_{\infty} \times a^{bt} $$

With:

- $P_{\infty}$ maximal number of newly registered AVs (with the assumption of a maximum 95% rate of AVs);
- $a$ quotient of the initial rate of newly registered AVs in the year of introduction;
- $b$ factor of growth;
- $t$ number of years since introduction.
Methodology: Aspatial Travel Demand Model

• Macroscopic and highly aggregated travel demand model (no traffic-analysis-zones)

• Input:
  • NHTS (US) and MiD (Germany) data (household travel surveys) (household, person, trip, vehicle data sets)
  • Socio-demographic forecasts, Studies of valuation-of-travel-time-savings

<table>
<thead>
<tr>
<th>Trip Generation</th>
<th>Trip distribution</th>
<th>Mode Choice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reweighting of data</td>
<td>Distance Choice</td>
<td>Multinomial logit-based model</td>
</tr>
</tbody>
</table>

No traffic assignment
No road infrastructure
Methodology: Overview

Figure 2: Overview of model scheme
Methodology: Scenarios

<table>
<thead>
<tr>
<th>Market introduction of AVs (differentiated by car segments)</th>
<th>trend scenario 2035</th>
<th>extreme scenario 2035</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Level 4</td>
<td>2025-2030</td>
<td>2022-2025</td>
</tr>
<tr>
<td>- Level 5</td>
<td>2030-2034</td>
<td>2025-2028</td>
</tr>
</tbody>
</table>

reduction of value-of-travel-time-savings

<table>
<thead>
<tr>
<th>reduction of access and egress times to and from AVs</th>
<th>reduction of access and egress time from 5 minutes (GER) resp. 4 minutes (U.S.) to 3 minutes</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>car availability of mobility-impaired-people</th>
<th>prioritized distribution of AVs to match the car-availability-ratio of non-mobility-impaired people</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>car availability of other household members</th>
<th>all household members can use a household-owned AV</th>
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</table>

<table>
<thead>
<tr>
<th>car availability of teenagers</th>
<th>minors from 14 years on can use a household-owned AV</th>
</tr>
</thead>
</table>

|                                                           | minors from 10 years on can use a household-owned AV                                        |

Table 1: Overview of scenario assumptions

- Two scenarios for US and Germany
- Differentiated by AV diffusion rates and assumptions of user groups
Results: Fleet size

Figure 3: Share of AVs in the fleet and on newly registered vehicles (share as sum of Level 4 and Level 5 vehicles of all car segments) (own scenario calculation)

- Higher AV share in the extreme scenario and
- Higher AV share in Germany than in the US
Results: Impact on travel demand

<table>
<thead>
<tr>
<th></th>
<th>US</th>
<th>Germany</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>reference scenario</td>
<td>trend scenario 2035</td>
</tr>
<tr>
<td>Increase in vehicle mileage - change to reference scenario</td>
<td>+3.4%</td>
<td>+8.6%</td>
</tr>
<tr>
<td>Modal share car driver (based on number of trips)</td>
<td>65.6%</td>
<td>66.9%</td>
</tr>
<tr>
<td>Change compared to reference scenario</td>
<td>- Absolute +1.3%</td>
<td>+3.8%</td>
</tr>
<tr>
<td></td>
<td>- Relative +2.0%</td>
<td>+5.7%</td>
</tr>
<tr>
<td>Modal share public transport (based on number of trips)</td>
<td>2.6%</td>
<td>2.4%</td>
</tr>
<tr>
<td>Change compared to reference scenario</td>
<td>- Absolute -0.2%</td>
<td>-0.4%</td>
</tr>
<tr>
<td></td>
<td>- Relative -6.3%</td>
<td>-17.6%</td>
</tr>
</tbody>
</table>

Table 2: Overview of the impacts of private AVs on vehicle mileage and modal share

- Moderate increase in vehicle mileage due to new user groups, modal shifts and distance choice
Results: Impact on travel demand

Figure 4: Increase of number of car driver and public transport trips differentiated for distance bands

- Higher increase of trips as car driver for very short and long distance trips
- High rate of decreasing public transport trips for very short and long distance trips
- Stronger effect to the distance travelled in the extreme scenario


## Results: Sensitivity analysis

<table>
<thead>
<tr>
<th>Differentiation of the value-of-travel-time-savings</th>
<th>US</th>
<th>Germany</th>
</tr>
</thead>
<tbody>
<tr>
<td>VoTTS -0%</td>
<td>+2.0%</td>
<td>+2.6%</td>
</tr>
<tr>
<td>VoTTS -25% (original scenario value)</td>
<td>+3.4%</td>
<td>+8.6%</td>
</tr>
<tr>
<td>VoTTS -50%</td>
<td>+5.1%</td>
<td>+15.7%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Differentiation of the road traffic travel speed</th>
<th>US</th>
<th>Germany</th>
</tr>
</thead>
<tbody>
<tr>
<td>velocity +0% (original scenario value)</td>
<td>+3.4%</td>
<td>+8.6%</td>
</tr>
<tr>
<td>velocity +2%</td>
<td>+4.2%</td>
<td>+9.3%</td>
</tr>
<tr>
<td>velocity +5%</td>
<td>+5.4%</td>
<td>+10.4%</td>
</tr>
<tr>
<td>velocity +10%</td>
<td>+7.2%</td>
<td>+10.8%</td>
</tr>
</tbody>
</table>

Table 3: Sensitivity analysis for the value-of-travel-time-savings (VoTTS) and for the differentiation of system velocity

- Uncertainty of decrease of VoTTS and capacity restraint effects
- Higher dependence on change of VoTTS in US than in Germany
- Higher dependence on change of system velocity in Germany than in US
Conclusion and Outlook

- Aggregated models for vehicle technology diffusion and travel demand
- Combining of different models

- Introduction of AVs into the private vehicle fleet leads to a moderate impact on travel demand
  - New user groups
  - Mode shift
  - Distance choice

- Next step: Modelling the introduction of new autonomous mobility concepts (autonomous car sharing & autonomous pooling)
  - Estimation of fleet size, properties of supply and spatial differences
  - Estimation of impact on travel behaviour, in particular mode choice
References


