Automated Mobility-on-Demand, Accessibility and Residential Relocation: a simulation-based analysis

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Outline

- Motivation
- Objectives
- Methods
- Application
- Results
- Conclusions
Motivations
Automated Vehicles (AVs) – mobility’s next ‘big thing’?

1st prototype of Autonomous Buggy

2010

Autonomous Car @One-North pilot

2015

Delphi acquires nuTonomy (Spin-off)

2017
Levels of Automation

1. E.g. Cruise Control
2. Tesla’s autopilot
3. Driver required, can pass ‘safety-critical’ functions to car
4. Can be programmed not to drive in certain conditions
5. Full automation
### Automation – when…?

**AVs and the Automakers (plans circa 2017)**

<table>
<thead>
<tr>
<th>Automaker</th>
<th>Key partnerships</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>GM</td>
<td>Cruise Automation and Lyft</td>
<td>Nothing specific</td>
</tr>
<tr>
<td>Ford</td>
<td>Argo AI</td>
<td>Level 4 2021</td>
</tr>
<tr>
<td>Honda</td>
<td>Cruise (GM)</td>
<td>Highways by 2020</td>
</tr>
<tr>
<td>Toyota</td>
<td></td>
<td>Highways by 2020</td>
</tr>
<tr>
<td>Renault-Nissan</td>
<td>Microsoft</td>
<td>Urban by 2020</td>
</tr>
<tr>
<td>Volvo</td>
<td>Uber</td>
<td>Highway by 2021</td>
</tr>
<tr>
<td>Hyundai</td>
<td>Bosch, Uber; Trucks</td>
<td>Highway 2020; urban 2030</td>
</tr>
<tr>
<td>Daimler</td>
<td></td>
<td>4 and 5 by Early 2020s</td>
</tr>
<tr>
<td>Fiat-Chrysler</td>
<td></td>
<td>Unclear</td>
</tr>
<tr>
<td>BMW</td>
<td>Intel, Mobileye</td>
<td>4 or 5 by 2021</td>
</tr>
<tr>
<td>Tesla</td>
<td></td>
<td>Opaque…</td>
</tr>
</tbody>
</table>

Company press releases, etc.
‘Self-Driving’ Cars Begin to Emerge from a Cloud of Hype

Developers try to overcome a multitude of technical challenges before vehicles drive on their own.

By: Steven E. Shladover

September 25, 2021

At the time, virtually every major motor vehicle manufacturer and high-tech company predicted widespread deployment of automated driving systems (ADS) by 2020.
Automation – when…?

‘Self-Driving’ Cars Begin to Emerge from a Cloud of Hype

Developers try to overcome a multitude of technical challenges before vehicles drive on their own

By: Steven E. Shladover

September 25, 2021

The technology will initially be implemented for specialized uses such as local package delivery, long-haul trucking on motorways, urban transit services on fixed routes and, in more limited locations, for urban and suburban automated passenger ride hailing.
Mobility-on-Demand

Uber

https://secondmeasure.com/datapoints/rideshare-industry-overview/
Mobility-on-Demand

Uber

Rideshare - Monthly Sales

Indexed U.S. Sales*


Lyft 30%
Ubber 70%

December 2021
Share of Sales

* Indexed to rideshare Jan 2016 sales (=100).
* Some Uber Eats sales are indistinguishable from Uber rides sales, especially in May-Aug. 2019. Corporate spending and purchases made with Uber Cash are not included.

https://secondmeasure.com/datapoints/rideshare-industry-overview/
Automated Mobility-on-Demand (AMoD)

• Convergence of automation and sharing (shared AV or SAV)

• Potential benefits: efficiency, reliability, safety, affordability, accessibility…

Waymo’s driverless taxi service can now be accessed on Google Maps

Kirsten Korosec
@kirstenkorosec / 2:00 PM EDT • June 3, 2021

https://techcrunch.com/2021/06/03/waymos-driverless-taxi-service-can-now-be-accessed-on-google-maps/
AVs, SAVs & AMOD: potential impacts (vehicle miles traveled, vmt)

<table>
<thead>
<tr>
<th>Influencing Factor</th>
<th>Increases VMT</th>
<th>Decreases VMT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rebound effect</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Car-sharing and reduced vehicle ownership</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Driverless taxis</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Greater sprawl</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Substitute for intracity or intercity public transportation</td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>

Total VMT
AVs, SAVs & AMOD: potential impacts

Evaluating the systemic effects of automated mobility-on-demand services via large-scale agent-based simulation of auto-dependent prototype cities

Jimi B. Oke\textsuperscript{a,b,*}, Arun Prakash Akkinepally\textsuperscript{b}, Siyu Chen\textsuperscript{b}, Yifei Xie\textsuperscript{b}, Youssef M. Aboutaleb\textsuperscript{b}, Carlos Lima Azevedo\textsuperscript{c}, P. Christopher Zegras\textsuperscript{d}, Joseph Ferreira\textsuperscript{d}, Moshe Ben-Akiva\textsuperscript{d}

Metro Area “like Boston”:
- AMOD increases VKT
- AMOD w/ transit integration (AMOD TI) \( \rightarrow \) (slightly) better outcomes (VKT and congestion).
AVs, SAVs & AMOD: potential longer term impacts

I. Walking-Horsecar Era
II. Streetcar Era
III. Recreational Auto Era
IV. Freeway Era
V. Post-2000?

Muller, 2004
AVs & Traditional Urban Economic Theory

Automation and urban development

Should we expect anything different?
AVs, SAVs & AMOD: potential longer term impacts

• Value of time and generalized costs of travel
  • Congestion *may* decrease
  • Tolerance for congestion *will* increase
  • \( \rightarrow \) expansionary

• Parking
  • Policy (and sharing) matters

• Infrastructure, Urban & Building Design
  • Smaller footprints? Need for less “room for error”
  • SAVs+EVs: seamless interfaces between public/private spaces

• AVs Demand for density and the future of agglomeration economies
  • Centripetal <> Centrifugal?
  • Many other things matter here: ‘future of work’, post-pandemia, etc.
Research Objectives
Knowledge gaps

• Little attention on AMoD impacts on accessibility, long-term mobility choices, and urban growth patterns
• Existing studies lack spatiotemporal & demographic granularity
• Realistic depiction of housing market behaviours is also missing: only consumer choices, no supply-side behaviours or bargaining processes
Research Questions

• What is the impact of AMOD on individuals’ **accessibility** and how does the effect vary across socioeconomic groups?
• How might we expect **residential location patterns** to change under different AMOD scenarios?
Methods
Research Design

- Agent-based microsimulation
  - Modelling individual (heterogenous) long-term mobility decisions
- Scenario analysis
  - Comparative analysis of hypothetical future AMOD scenarios
- SimMobility
  - An integrated *agent-* and *activity-based* simulation platform
• Microsimulation (Agent-based) Integrated/ modular platform
• Activity-Based Persons and goods
• Multiple spatial-temporal scales
• Dynamic plan/action-transaction behavioral models
• Multimodal networks
• Open-source
SimMobility Mid-Term: Activity-based model

Integrates:
- Pre-day
- Within-day
- Supply

→ Theoretically consistent link to Long-Term Activity-Based Accessibility (ABA)

→ Economic Evaluation Criterion

Oh et al, 2020
Activity-based Accessibility (ABA)

Benefit ("Expected Maximum Utility") of the Day Pattern Choice (conditional upon given location)

Oh et al, 2020
SimMobility Long-Term: Dynamic real-estate market

Zhu et al. 2018

Pre-process
Stock
Choice/Behavioral model
Process
★ Direct link to Mid-term Simulator (logsum accessibility)
SimMobility Long-Term: ABA-links (to mid-term)

Zhu et al. 2018

Direct link to Mid-term Simulator (logsum accessibility)
Application
Study Area

Source: Zhou et al., (2022)
Data

• **Synthetic population** (1.9 million households & 6.7 million individuals)
  • Based on Household Interview Travel Survey (HITS) data
  • Built environment: various sources

• Activity-based models (mid-term)
  • Estimated with HITS data
  • Calibrated with transit smartcard (EZLink) data & SP survey data on AMOD adoption

• Housing market models
  • Estimated with REALIS transaction data, HDB resale data & HITS data
Scenarios

Baseline

Partial Automation (PA)

Full Automation (FA)
Other simulation specifications

• Housing market simulation: 10 repeated **one-year** runs of daily market dynamics for each scenario

• AMoD pricing: 75% of conventional taxis & additional 30% **off** for shared rides
  - Additional modifications to utility function based on SP survey
    (Seshadri et al, 2019)

• AMoD level-of-service & fleet size (4-, 6-seaters): updated/optimized through feedback loops between mid-term & long-term modules
Results
Accessibility Impacts (Overall)

Compared to Baseline

Source: Zhou et al., (2022)
Accessibility Impacts (Gender)

Source: Zhou et al., (2022)
Accessibility Impacts (Age)

Source: Zhou et al., (2022)
Accessibility Impacts (Income)

Source: Zhou et al., (2022)
Accessibility Impacts (car owners)

Source: Zhou et al., (2022)
Accessibility Impacts (across space)

Zone-averaged ABA by residence

Baseline

PA

FA

Source: Zhou et al., (2022)
Housing Market Summary

Source: Zhou et al., (2022)
Residential Relocation (% difference in total population change by zone, relative to baseline)

Source: Zhou et al., (2022)
Residential Relocation (by HH Types, % difference in FA relative to baseline)

Average household size

Average household income

% of movers with children

% of movers with multiple workers

Source: Zhou et al., (2022)
Conclusions
Key Findings

Full substitution of private cars with AMoD: measurably distinct influences on individual accessibility

• Mostly *more privileged* groups experience larger accessibility impacts
• Full Automation: City center more attractive
  - especially for larger & richer households with kids
Discussion

• AMoD service (under our hypothetical design)
  - not yet able to fill private mobility’s shoes w.r.t. accessibility

• Full Automation (AMoD with private mode ban)
  - reduces social inequality in accessibility (what would happen with just private ban?)

• Induced Sprawl?
  - Little evidence in either scenario (unique to Singapore?)

• Central areas (with better transit & denser amenities): more attractive
  - Possible gentrification effects in Full Automation
Future Research

• AMoD impacts on weekly (and longer) activity patterns

Hermawan et al, 2022
Future Research

• AMoD impacts on weekly (and longer) activity patterns
• Varying taste parameters across different scenarios
• Intra-household dynamics (Accessibility) and residential decisions
• Sensitivity analysis of pricing & fleet size
• Broader examination of longer term impacts (job and school location changes, new development (residential and commercial), & (maybe) demographic changes
• Extensions to broader impacts – carbon, local AQ, accidents…
Acknowledgements

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References


Thanks for your attention