Will self-driving cars help or hurt efforts to cut emissions?

Don MacKenzie
Civil & Environmental Engineering
When is automation coming?
Partial automation is already mainstream

Lane keeping
Traffic jam assist / low speed follow

Adaptive Cruise Control
Automated Emergency Braking


http://www.autoblog.com/2015/10/19/2016-honda-civic-first-drive-review-

http://www.ford.com/cars/fusion/gallery/photos/

Applications requiring (near) universal automation are decades away

Autonomous Vehicle Plan for the I-5 Seattle/Vancouver B.C. Corridor

By Tom Alberg, Managing Director, Madrona Venture Group, Craig Mundie, former Chief Research and Strategy Officer, Microsoft Corporation, Daniel Li, Associate, Madrona Venture Group, Connor Raikes, Consultant
Market intro. to peak growth is ~10 years, could be ~5 years by 2030

New automotive features rarely grow by more than 10% per year

It will be decades before all vehicles can drive themselves.

Fraction of New Vehicles Equipped

- Initial market introduction 2017
- 10-year developmental lag
- 10% maximum growth

Fleet Turnover

- 60% of cars last 15+ years
- Average US car is 11 years old
What will automation mean for energy demand and emissions?
Energy and environment are not driving the conversation on automation, but...

**Capacity**

[Image of a highway]

http://www.tech-faq.com/vehicle-platooning.html

**Safety**

[Image of a car and safety features]


**Access**

[Image of a person driving]

https://www.pinterest.com/pin/33003009739432031/

**Comfort / Time Use**

[Image of a person in a car]

Automation offers substantial energy & environmental benefits...

**Travel Demand**
- Per-mile / per-minute pricing

**Design**
- Right-sizing
  - Lower performance
  - Reduced crashworthiness
  - New vehicle concepts

**Fuels**
- Lower infrastructure costs
  - Self-refueling

**Emissions** = **Person Miles** • \( \frac{\text{Vehicle Miles}}{\text{Person Mile}} \) • \( \frac{\text{BTUs}}{\text{Vehicle Mile}} \) • \( \frac{\text{Emissions}}{\text{BTU}} \)

**Mode Structure**
- On-demand mobility
  - Robo-taxis
  - Shared vehicles
  - Personal transit
  - Occupancy rates

**Operations**
- Platooning
- Congestion relief
- Traffic smoothing
- Eco-driving
- Optimal speed/routing
Automation offers substantial energy & environmental benefits… and risks

**Travel Demand**
- Per-mile / per-minute pricing
- Underserved populations
- Lower cost (VOTT)
- Land use changes

**Design**
- Right-sizing
  - Lower performance
  - Reduced crashworthiness
- New vehicle concepts
  - “Mobile Barcalounger”

**Fuels**
- Lower infrastructure costs
- Self-refueling

**Emissions** = **Person Miles** \( \cdot \) **Vehicle Miles** \( \frac{\text{Person Mile}}{\text{Person Mile}} \) \( \cdot \) **BTUs** \( \frac{\text{Vehicle Mile}}{\text{Vehicle Mile}} \) \( \cdot \) **Emissions** \( \frac{\text{BTU}}{\text{BTU}} \)

**Mode Structure**
- On-demand mobility
  - Robo-taxis
  - Shared vehicles
  - Personal transit
- Occupancy rates
- Deadheading

**Operations**
- Platooning
- Congestion relief
- Traffic smoothing
- Eco-driving
- Optimal speed/routing
- Highway speeds

**Eco-driving**
- Optimal speed/routing
- Highway speeds
Our goal was to place some bounds on these impacts and explore net effects.
Automation making vehicle travel cheaper, safer, more convenient, will increase demand

"It was the same distance, but the commute felt like it took half the time"

https://www.teslamotors.com/customer-stories/how-autopilot-added-years-my-life
The biggest risk* from automation comes from induced demand

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

*http://dx.doi.org/10.1016/j.tra.2015.12.001

Emerging consensus that mobility services are key to unlocking many benefits of automation.
Paying by the trip is expected to reduce travel demand

(a) Future competitive situation - Urban setting.

(Full) Automation makes mobility services more feasible, and more essential

- Platooning
- Congestion mitigation
- Eco-driving
- Higher highway speeds
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- Increased features
- Infrastructure footprint*
- Improved crash avoidance
- De-emphasized performance
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- Vehicle right-sizing

% changes in energy consumption due to vehicle automation

-60% -40% -20% 0% 20% 40% 60%

Changed mobility services
Questions for you

• How many of you have used Uber, Lyft, or a similar service?

• How many of you have used UberPool, Lyft Line, or a similar service?

• Why?
### Shared cars are not the same as shared rides

Cost of a Lyft ride in Seattle:

\[
\text{Cost} = \text{Cost per mile} + \text{Multiplier} \times \text{Rate per minute} = 1.35/\text{mi} + 3 \text{ min/mi} \times 0.20/\text{min} = \$1.95/\text{mi}
\]

- **With Driver**
  - Solo: $2.00
  - Shared: $1.00

- **Car only**
  - Solo: $0.50
  - Shared: $0.10

*Automation reduces incentive to share rides*
By reducing total cost of mobility services, automation reduces incentive to share rides

With safe, on-demand mobility, we could "right-size" vehicle for specific trips' needs.

With safe, on-demand mobility, we could "right-size" vehicle for specific trips' needs.


How much right-sizing will consumers embrace?

http://www.iappfusion.com/carros/toyota_iroad.png


Mobility services providers are already starting to right-size
Right-sizing is largest opportunity

- Platooning
- Congestion mitigation
- Eco-driving
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% changes in energy consumption due to vehicle automation
Shared mobility fleets should have fewer emission-intensive cold starts

• Rule of thumb:
  – “80% in first 30 seconds, 90 % in first 5 minutes”

<table>
<thead>
<tr>
<th></th>
<th>Tier 2-Bin 5 (15)(^a)</th>
<th>Initial Engine Start</th>
<th>Engine Restart</th>
</tr>
</thead>
<tbody>
<tr>
<td>THC (mg)</td>
<td>878</td>
<td>191</td>
<td>44</td>
</tr>
<tr>
<td>NO(_x) (mg)</td>
<td>552</td>
<td>228</td>
<td>6</td>
</tr>
<tr>
<td>CO (mg)</td>
<td>31290</td>
<td>2970</td>
<td>1253</td>
</tr>
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\(^a\) Tier 2-Bin 5 g/\text{mi} converted to FTP-75 mg

Will car ownership end in major cities?

SELF-DRIVING CARS

Lyft’s President Says Car Ownership Will ‘All But End’ in U.S. Cities by 2025

Kia Kokalitcheva
Sep 18, 2016

Ride-hailing company Lyft has a bold prediction: Private car ownership will "all but end" in major U.S. cities by 2025—just nine years from now.
What happens when you want to go off the beaten track?
A suite of services can help
The Vision: Shared, automated, electric vehicles
Automation could facilitate alternative fuels adoption

Less range anxiety

Reduced infrastructure investment


http://www.lawyersforcleanenergy.com/content/can-ev-car-sharing-counter-range-anxiety
Mobility services fleets can make electric vehicles more cost effective

Present Value of Fuel Savings

Annual Vehicle Miles Traveled

$5,000
$4,000
$3,000
$2,000
$1,000
$-

0 5,000 10,000 15,000 20,000 25,000 30,000 35,000
How do impacts evolve over time?
Impacts will likely depend on level of automation

- Platooning
- Congestion mitigation
- Eco-driving
- Higher highway speeds
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% changes in energy consumption due to vehicle automation

SAE Level

2
3
4
5
Thank you!
Appendix: SAE levels of automation
SAE has emerged as preferred taxonomy for levels of automation

<table>
<thead>
<tr>
<th>Level</th>
<th>Name</th>
<th>Narrative definition</th>
<th>DDT</th>
<th>OEDR</th>
<th>DDT fallback</th>
<th>ODD</th>
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<tbody>
<tr>
<td>0</td>
<td>No Driving Automation</td>
<td>The performance by the driver of the entire DDT, even when enhanced by active safety systems.</td>
<td>Driver</td>
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<td>Driver</td>
<td>n/a</td>
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<tr>
<td>1</td>
<td>Driver Assistance</td>
<td>The sustained and ODD-specific execution by a driving automation system of either the lateral or the longitudinal vehicle motion control subtask of the DDT (but not both simultaneously) with the expectation that the driver performs the remainder of the DDT.</td>
<td>Driver and System</td>
<td>Driver</td>
<td>Driver</td>
<td>Limited</td>
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<td>2</td>
<td>Partial Driving Automation</td>
<td>The sustained and ODD-specific execution by a driving automation system of both the lateral and longitudinal vehicle motion control subtasks of the DDT with the expectation that the driver completes the OEDR subtask and supervises the driving automation system</td>
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<td>Driver</td>
<td>Driver</td>
<td>Limited</td>
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<td></td>
<td>ADS (“System”) performs the entire DDT (while engaged)</td>
<td></td>
<td>System</td>
<td>Fallback-ready user (becomes the driver during fallback)</td>
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<td>Conditional Driving Automation</td>
<td>The sustained and ODD-specific performance by an ADS of the entire DDT with the expectation that the DDT fallback-ready user is receptive to ADS-issued requests to intervene, as well as to DDT performance-relevant system failures in other vehicle systems, and will respond appropriately.</td>
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<td>System</td>
<td>System</td>
<td>System</td>
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<td>System</td>
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SAE emphasizes "who does what, when"

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