Transformational Transportation Technologies: Shared Ride Research at CMU

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Several Transformational Technologies Are Active Now

• Alternative fuels: batteries, biofuels, fuel cells, natural gas
• Energy efficiencies: hybrid vehicles, lower weight.
• Sensing and Automation: infrastructure, vehicles
• Communications (Connectivity): cell, dedicated short range communications, bluetooth and wifi
• Data analytics: vehicle control, travel choices
Transportation Challenges

• Provide mobility services to economy and society
• Reduce costs, energy use and emissions
• Support economic growth
• Improve safety and resilience
• Provide sustainable funding
Federal Fuel Tax Revenue for Different Vehicles (Cents/Mi.)
After Decades of Progress, Road Fatalities Are Going Up

Source: Data from IIHS, 2017
40,000 Road Fatalities = 1 Plane Crash Every 3.3 Days

Image: United, Wikimedia
A spectrum of new mobilities

“Conventional” transportation

On-demand ridesharing in conventional vehicles

Increasing degree of “disruption”

Fully connected and automated transportation

Transformative changes to safety, mobility, energy, and the environment
Traffic21 Institute

• Housed in Heinz School, but inter-disciplinary faculty and projects.

• Managed jointly with University Transportation Centers (Technologies for Safe and Efficient Transportation and Mobility21) and Metro21.

• Numerous Special Interest Groups: Ride Sharing/Mobility Services, Bicycling, Connected and Automated Vehicle Policy, Vehicle Electrification + Traffic21 and Metro21 Faculty
A CAVs update to the proverbial three-legged stool

- How do connected and automated vehicles (or fuels or operations) affect these outcomes of interest?
- How do interactions between vehicles (and fuels and operations) affect these outcomes of interest?
Transportation Network Companies (TNCs) move people differently.

The net effect on energy and emissions is unknown.

More trips and “empty miles” could drive up energy use and emissions.

Figure source: Henao (2017)
Research Question: Do Uber and Lyft change personal vehicle ownership, use, and air pollution?

We apply an econometric approach using real-world public data:

<table>
<thead>
<tr>
<th>Publicly Available Data:</th>
<th>Regression Model</th>
<th>Estimated Outcome Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>• DOT: vehicle ownership, VMT, and gasoline usage at the state level</td>
<td>• Leverage unique Uber market entry dates by time and location</td>
<td>What is Uber market entry’s association with...</td>
</tr>
<tr>
<td>• EPA: criteria pollutant emissions</td>
<td>• Control for potential confounding factors (population, economics, etc.)</td>
<td>• Ownership</td>
</tr>
<tr>
<td>• Uber and Lyft market entry dates (Uber dates previously published; Lyft data from Lyft)</td>
<td></td>
<td>• VMT</td>
</tr>
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<td></td>
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Uber entry is associated with changes in vehicle ownership, use, and pollution:

Policy Implications:

• At the state level, these metrics offer no basis for preventative policy.

• New questions are raised regarding pricing and paying for reductions in negative externalities.
Shared Bicycles

• Electric bicycle technology, data analytics
Smart Mobility Solutions

• Working with 9 municipalities on a variety of smart mobility implementations: parking operations, ride sharing apps, safety improvements.

Early Automation Saves Lives and Money
Active and Warning Crash Avoidance Technologies Becoming More Common

• Market penetration rates of technologies dependent on regulation, technology advancement, and costs

• Is the fleet-wide adoption of crash avoidance technologies feasible from an economic perspective?

Corey Harper, Chris Hendrickson and Costa Samaras
Cost-Benefit Analysis of Early Automation Features

• Observed insurance data from the Insurance Institute for Highway Safety (IIHS).

• 2012 FARS and GES used to estimate related fatal and non-fatal crashes, respectively.
Observed Crash Frequency Reduction is Small

- First generation devices will be improving in effectiveness and in human/computer interaction: new forward collision systems that apply braking automatically.
- Rebound effects can be a problem: I feel safer driving with warning systems available and pay less attention to driving...
Injury Crashes Addressed by Each Technology

- **Blind Spot Monitoring**: Lane Change Crashes 5%
- **Lane Departure Warning**: Lane Departure Crashes 6%
- **Forward Collision Warning**: Rear-end Collisions 14%
- All Other 2012 Crashes: 75%
Three Existing Level 1 Technologies Could Improve Safety

<table>
<thead>
<tr>
<th>Technology</th>
<th>All Crashes</th>
<th>Injury Crashes</th>
<th>Fatal Crashes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blind Spot Monitoring</td>
<td>267,000</td>
<td>17,000</td>
<td>280</td>
</tr>
<tr>
<td>Lane Departure Warning</td>
<td>262,000</td>
<td>58,100</td>
<td>9,000</td>
</tr>
<tr>
<td>Forward Collision Warning</td>
<td>795,000</td>
<td>58,000</td>
<td>750</td>
</tr>
<tr>
<td>Total</td>
<td>1,320,000</td>
<td>133,100</td>
<td>10,100</td>
</tr>
<tr>
<td>Percent of Total Crashes</td>
<td>23.5%</td>
<td>8.2%</td>
<td>32.6%</td>
</tr>
</tbody>
</table>

Fatalities Avoided Per 100,000 Drivers With These Technologies
Benefits are Social Costs of Crashes; Costs Are Tech Prices

**Data**
- **Benefits**
  - FARS/GES
  - Total number of crashes relevant to FCW, BSM, and LDW
  - Assumes 100% effectiveness in crash prevention.
  - Changes in crash frequency and severity based on IIHS data.

**Data Analysis**
- **Costs**
  - Current $2015 pricing of FCW, BSM, and LDW.
  - Annualize Cost over car lifetime using new car interest rate.
  - Multiply annualized cost by the total number of LDV in the US.

**Bounding**
- **Upper**
  - The Upper and lower bound fleet-wide net benefits were estimated by taking the difference of the upper and lower bound annual benefits and total annual technology purchasing costs.
Lower Bound Net-Benefit About $4B

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<td>Costs</td>
<td>Public Revenue</td>
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Annual Lower Bound Costs and Benefits ($Billion)

- Private Insurers
- Third-Parties
- QALYs
- Households
Upper Bound Net-Benefit is About $200B

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<td>$0</td>
<td>$50</td>
<td>$200</td>
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- **Annual Upper Bound Costs and Benefits ($Billion)**
  - Private Insurers
  - Third-Parties
  - QALYs
  - Households
  - Public Revenue

- **Upper Bound Net-Benefit** is about $200B
  - Benefits: $200B
  - Costs: $50B
  - Net-Benefit: $150B
These Transformative Technologies have been Decades in Development

• Building on fundamental results in information technology, materials, sensors and circuits.
• We are fortunate to have opportunities for change with these technologies!
Moore’s Law – The number of transistors on integrated circuit chips (1971-2016)

Moore’s law describes the empirical regularity that the number of transistors on integrated circuits doubles approximately every two years. This advancement is important as other aspects of technological progress – such as processing speed or the price of electronic products – are strongly linked to Moore’s law.

The data visualization is available at OurWorldInData.org. There you find more visualizations and research on this topic. Licensed under CC-BY-SA by the author Max Roser.
1984
- The Terregator’s top speed was a few centimeters per second; it could avoid obstacles.
- NavLab launched. Its goal: apply computer vision, sensors and high-speed processors to create vehicles that drive themselves.

1986
Humans or computers controlled NavLab1, a Chevy van. Top speed: 20 mph.

1990
NavLab 2, a US Army HMMWV, wrangled rough terrain at 6 mph. Highway speed: 70 mph.

1995
NavLab 5, a Pontiac Trans Sport, traveled from Pittsburgh to San Diego in the “No Hands Across America Tour.”

2000
NavLab 11, a Jeep, was equipped with Virtual Valet.

2005
Sandstorm and Highlander placed 2nd and 3rd in the DARPA Grand Challenge.

2007
Carnegie Mellon’s “Boss” won the DARPA Grand Urban Challenge by outmaneuvering other vehicles along the 55-mile course.

2014
Carnegie Mellon’s 14th self-driving vehicle is a Cadillac SRX that:
- avoids pedestrians and cyclists
- takes ramps and merges
- recognizes and obeys traffic lights
- looks like other Cadillac SRXs
In summary

• We are progressing fairly rapidly on technology, but differential rates for different technologies.
• Various views on deployment:
  - Connected vs. autonomous vs. integrated
  - Incremental automation versus driverless deployment
• Most of what we hear about in the press implies full automation, not much on transitions or challenges.
• Benefits already accruing for partial automation, and more benefits will come with greater and better automation.
• Great deal of uncertainty.