How Revolutionary Might the Transport Revolutions Be?
Some (Not-so-Great) Insights from Recent Evidence

Ram M. Pendyala, Professor and Interim Director
School of Sustainable Engineering and the Built Environment

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Three Revolutions

1 Electrification
2 Sharing
3 Automation

Scenarios & Parameters  Models & Simulations  Fake Forecasts

So little is known about the future

Behaviors Defined by Attitudes, Perceptions, Preferences, Values, and Evolutionary Dynamics

Electrification on the rise

Global Sales of Electric Vehicles and Plug-in Hybrids

- China
- Other
- Belgium
- Canada
- Sweden
- France
- UK
- Japan
- Germany
- Norway
- USA

EVVOLUMES.COM

Electrification on the rise
But Modest in Share…

Question:
To what degree is Electrification a Revolution?
Sharing and Hailing

<table>
<thead>
<tr>
<th>Service type</th>
<th>Service model</th>
<th>Business model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carsharing</td>
<td>• Round-trip / One-way</td>
<td>• Fleet-based (Public / Private)</td>
</tr>
<tr>
<td></td>
<td>• Free floating / Station-based</td>
<td>• Community-based</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Peer-to-peer</td>
</tr>
<tr>
<td>Bikesharing / Scooter sharing</td>
<td>• Round-trip / One-way</td>
<td>• Fleet-based (Public / Private)</td>
</tr>
<tr>
<td></td>
<td>• Docked-based / GPS-based</td>
<td>• Peer-to-peer</td>
</tr>
<tr>
<td>Dynamic carpooling</td>
<td>• Vanpooling / Carpooling</td>
<td>• Public-private partnership</td>
</tr>
<tr>
<td></td>
<td>• Short-distance / Long-distance</td>
<td>• Peer-to-peer</td>
</tr>
<tr>
<td></td>
<td>• On-demand / Pre-arranged</td>
<td></td>
</tr>
<tr>
<td>Ride-hailing</td>
<td>• Single-user / Pooling</td>
<td>• Private (For Hire-services)</td>
</tr>
<tr>
<td></td>
<td>• On-demand / Pre-arranged</td>
<td>• (In some case) Subsidized by public</td>
</tr>
<tr>
<td>Microtransit</td>
<td>• Fixed / Flexible route</td>
<td>• Public-private partnership</td>
</tr>
<tr>
<td></td>
<td>• On-demand / Flexible scheduling</td>
<td></td>
</tr>
</tbody>
</table>


Not a Lot of Sharing, But a Lot of Hailing

**Basic Ride-hailing Concept**

- **Navigation**
- **Fare/time estimation**
- **Request Notification**
- **Request Acceptance**
- **Payment and Feedback**

![Basic Ride-hailing Concept Diagram]
Dramatic Growth

Ride hailing ↑
Taxi ↓
Bus ↓
Ride hailing plus taxi ridership will exceed total bus ridership by 2018


Mode Share in National Household Travel Survey

<table>
<thead>
<tr>
<th>Mode</th>
<th>1995</th>
<th>2001</th>
<th>2009</th>
<th>2017</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personal Vehicle</td>
<td>86.1</td>
<td>87.2</td>
<td>87.4</td>
<td>86.4</td>
</tr>
<tr>
<td>Public Transit – BUS</td>
<td>1.1</td>
<td>1.0</td>
<td>0.8</td>
<td>1.0</td>
</tr>
<tr>
<td>Public Transit – RAIL</td>
<td>0.7</td>
<td>0.4</td>
<td>0.2</td>
<td>0.5</td>
</tr>
<tr>
<td>Walk</td>
<td>5.2</td>
<td>8.0</td>
<td>8.6</td>
<td>8.8</td>
</tr>
<tr>
<td>Bicycle</td>
<td>0.8</td>
<td>0.8</td>
<td>0.8</td>
<td>0.9</td>
</tr>
<tr>
<td>Taxi + For Hire</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
<td>0.3</td>
</tr>
<tr>
<td>Rental Car (incl Car Share)</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>0.2</td>
</tr>
<tr>
<td>Other</td>
<td>2.5</td>
<td>2.3</td>
<td>2.0</td>
<td>1.8</td>
</tr>
</tbody>
</table>
Less than 1% share
Not quite the Revolution yet…?

Uber Proposals Value Company at $120 Billion in a Possible IPO
Lots of investors counting on the Revolution of Ride-hailing 😊


Question:
What is an Autonomous Vehicle?
**Definition**

“An autonomous vehicle is one that can drive itself from a starting point to a predetermined destination in “autopilot” mode using various in-vehicle technologies and sensors, including adaptive cruise control, active steering (steer by wire), anti-lock braking systems (brake by wire), GPS navigation technology, lasers and radar.”

Source:
https://www.gartner.com/it-glossary/autonomous-vehicles/

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**History**

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>1948</td>
<td>Introduction of Cruise Control</td>
</tr>
<tr>
<td>1999</td>
<td>FCC allocates 75 MHz of spectrum to Dedicated Short Range Communications</td>
</tr>
<tr>
<td>2007</td>
<td>Google begins self-driving car project</td>
</tr>
<tr>
<td>2009</td>
<td>Mercedes and Infiniti produce cars with radar sensors and some autonomous driving features</td>
</tr>
<tr>
<td>2013</td>
<td>NHTSA releases initial policy on autonomous vehicles</td>
</tr>
<tr>
<td>2015</td>
<td>Uber hires 40 Carnegie Mellon robotics researchers to work on autonomous vehicles; Ford begins testing its self-driving cars in CA, AZ, MI</td>
</tr>
<tr>
<td>2016</td>
<td>NHTSA issues guidelines for testing and deployment of autonomous vehicles</td>
</tr>
<tr>
<td>2017</td>
<td>Major acquisitions and partnerships (GM and Cruise Automation; GM and Lyft; Toyota and Jaybridge Robotics; Uber and Volvo)</td>
</tr>
<tr>
<td>2017</td>
<td>NHTSA issues revised safety guidelines for autonomous vehicles</td>
</tr>
</tbody>
</table>

Source:
Will AVs be on streets?

It’s happening!
Waymo Now Giving Self-Driving Car Rides to the Public in Phoenix
Average Joes are about to get a crack at riding in the company's autonomous minivans.


Transition To Autonomous Cars Will Take Longer Than You Think, Waymo CEO Tells Governors

Street intersection in New York

Street Intersection in Chandler

SOCIETY OF AUTOMOTIVE ENGINEERS (SAE) AUTOMATION LEVELS

<table>
<thead>
<tr>
<th>Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No Automation</td>
</tr>
<tr>
<td></td>
<td>Zero autonomy; the driver performs all driving tasks</td>
</tr>
<tr>
<td>1</td>
<td>Driver Assistance</td>
</tr>
<tr>
<td></td>
<td>Vehicle is controlled by the driver, but some driving assist features may be included in the vehicle design</td>
</tr>
<tr>
<td>2</td>
<td>Partial Automation</td>
</tr>
<tr>
<td></td>
<td>Vehicle has combined automated functions, like accelerations and steering, but the driver must remain engaged with the driving task and monitor the environment at all times</td>
</tr>
<tr>
<td>3</td>
<td>Conditional Automation</td>
</tr>
<tr>
<td></td>
<td>Driver is a necessity, but is not required to monitor the environment. The driver must be ready to take control of the vehicle at all times with notice</td>
</tr>
<tr>
<td>4</td>
<td>High Automation</td>
</tr>
<tr>
<td></td>
<td>The vehicle is capable of performing all driving functions under certain conditions. The driver may have the option to control the vehicle</td>
</tr>
<tr>
<td>5</td>
<td>Full Automation</td>
</tr>
<tr>
<td></td>
<td>The vehicle is capable of performing all driving functions under all conditions. The driver may have the option to control the vehicle</td>
</tr>
</tbody>
</table>

Source: https://www.nhtsa.gov/technology-innovation/automated-vehicles-safety
Question: What are the benefits of an Autonomous Vehicle?

33 million
Forecast of Autonomous-Vehicle Sales to top in 2040

$7 trillion
Global passenger economy could be worth by 2050

Sources:
https://www.cnbc.com/2017/06/01/the-7-trillion-promise-of-self-driving-vehicles.html
Automated vehicles have the potential to remove human error from the crash equation.

Source: https://www.nhtsa.gov/technology-innovation/automated-vehicles-safety

Smooth traffic flow, reduced traffic congestion, fuel costs and vehicle emissions.

Source: https://www.nhtsa.gov/technology-innovation/automated-vehicles-safety
Mobility

There are 49 million Americans over age 65; 53 million people have some form of disability. New mobility options may be provided.

AVs would enable new employment opportunities for approximately 2 million individuals with disabilities.

Sources:

Economic and societal benefits

Vehicle crashes in 2010 cost $242 billion in economic activity, and $594 billion due to loss of life and decreased quality of life due to injuries.

Source:
What do people think about Autonomous Vehicles?

A Literature Review

- Cost
- Impacts
- Mode choice
- Adoption
- Policies and regulations
- Traffic safety
- Traffic congestion
- Vehicle ownership
- Environmental impacts
- Travel behavior
- Accessibility

"Most Americans are aware of the effort to develop driverless vehicles and express somewhat more worry than enthusiasm about their widespread adoption."

35% of Americans have heard a lot about the effort to develop driverless vehicles

35%Very
59A little
6Nothing at all

Public somewhat more worried than enthusiastic about driverless vehicles

- % of U.S. adults who say the development of driverless vehicles makes them feel...
- Very
- Somewhat
- Not too
- Not at all

<table>
<thead>
<tr>
<th></th>
<th>Very</th>
<th>Somewhat</th>
<th>Not too</th>
<th>Not at all</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enthusiastic</td>
<td>11</td>
<td>28</td>
<td>30</td>
<td>22</td>
</tr>
<tr>
<td>Worried</td>
<td>14</td>
<td>39</td>
<td>35</td>
<td>11</td>
</tr>
</tbody>
</table>

Note: Respondents who did not give an answer are not shown.
“Automation in Everyday Life”

Sources:
http://www.pewinternet.org/2017/10/04/americans-attitudes-toward-driverless-vehicles/
“Just over half of Americans would not want to ride in a driverless vehicle if given the opportunity; a lack of confidence/trust in robotic decision-making and general safety concerns lead their list of worries.”

Source: http://www.pewinternet.org/2017/10/04/americans-attitudes-toward-driverless-vehicles/

AV adoption

Public perception

60% of UK citizens believe that driverless or autonomous cars will one day outnumber conventional vehicles.

31% of respondents believe that the number of autonomous cars on the roads will outnumber conventional cars as early as the next 10 to 15 years.

Public perception

24% of participants said that they would feel comfortable as a passenger in a driverless or autonomous car in a 2017 survey.

19% in 2018.
Will you consider riding in a fully AV?

55% of respondents in The Gartner Consumer Trends in Automotive online survey from the US and Germany will not consider riding in a fully AV.

71% may consider riding in a partially autonomous vehicle.

Sources:

"If the only vehicles available were completely self-driving or partially self-driving, how concerned would you be about riding in such vehicles?"

Source:
Vehicle manufacturers are considering using one of three levels of automation in future vehicles. Which level would you prefer to have in your personal vehicle?

Source:

Would you buy a fully autonomous vehicle?

Source:
"Many Americans would personally feel **unsafe** sharing the road with an autonomous vehicle..."

**Roughly two-thirds of Americans would feel unsafe sharing the road with autonomous freight trucks**

% of U.S. adults who say they would feel ___ safe sharing the road with...

- Very
- Somewhat
- Not too
- Not at all

| Driverless passenger vehicles | 11 | 37 | 35 | 17 |
| Driverless freight trucks     | 8  | 26 | 33 | 32 |

Note: Respondents who did not give an answer are not shown.
“Automation in Everyday Life”

Sources:
http://www.pewinternet.org/2017/10/04/americans-attitudes-toward-driverless-vehicles/
How would people feel about sharing the road with a self-driving vehicle?

37% Would make no difference
4% Are unsure
13% Would feel safer
46% Would feel less safe

Source:

Fear about riding in a fully autonomous vehicle

78% early 2017
63% early 2018
73% may 2018

Survey taken few weeks after the Uber fatal accident in Tempe, AZ

Sources:
Consumers not ready for full autonomy


Consumers not ready for full autonomy

“imagine that self-driving vehicles were on the market now either for purchase or rental. What is the likelihood that you would ride in a self-driving vehicle for everyday use?”

Sources:

“Should the government regulate self-driving cars?”

26% think it should somewhat regulate these vehicles

54% believe the government very much should regulate

9% feel the government should not regulate very much

11% don’t know or give no answer

Sources:
“Should the government support self-driving cars?”

47% believe the national government should not be supportive in allowing self-driving cars on highways

27% believe it should be supportive

26% do not know or give no answer

“Should states and localities allow test rides of self-driving cars on highways in order to perfect the technology?”

45% feel that they should not

30% believe they should

25% are uncertain

Sources:
**Forbes**

10 Million Self-Driving Cars Will Hit The Road By 2020 -- Here’s How To Profit

*Olivier Garret*, CONTRIBUTOR, MAR 3, 2017

**Conservative Prediction: 10 Million Self-Driving Cars by 2020**

As I said above, my research leads me to believe that there will be 10 million self-driving cars on the road by 2020, with one in four cars being self-driving by 2030.

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**The New York Times**

*Navy Returns to Compasses and Pencils to Help Avoid Collisions at Sea*


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**Public opinion divided**

Considerable uncertainty on public acceptance and interest

**Long way to go to full automation**

Will take a very long time for this revolution to play out

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https://www.forbes.com/sites/oliviergarret/2017/03/03/10-million-self‐driving‐cars‐will‐hit‐the‐road‐by‐2020‐heres‐how‐to‐profit/#7ae6e3397e50


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Question: What is going on with travel demand?

Are We Missing Revolutions Currently Underway?

Disruption due to Socio-demographic shifts, attitudinal shifts, e-commerce, and IoT.
National VMT and VMT per Capita, Percent Change from 1992

Annual Vehicle-Distance Traveled (Billion Miles) % change from 1992
- VMT per Capita % change from 1992

We are missing Revolutions playing out NOW

The Internet of Everything (IoE)
Socio-economic and demographic shifts
Aging & Millennials

Changing Attitudes

Sources: