Overview

• Automated vehicles overview
• Terms and SAE levels
• Business models
• Timing
• Possible impacts and unintended consequences
• 3 Revolutions: shared, automated, electric
• Policy
How Automation Works

http://articles.sae.org/15067/

Sense   Decide   Act
How Automation Works

https://spectrum.ieee.org/automaton/robotics/artificial-intelligence/how-google-self-driving-car-works
How Automation Works

How Automation Works

2015

“Firefly” hit public roads for the first time

We explored what fully self-driving cars could be like by designing a new reference vehicle, nicknamed “Firefly,” from the ground up. These cars had custom sensors, computers, steering and braking, but no steering wheel or pedals.

https://waymo.com/journey/

Sense  Decide  Act
Operational Design Domain (ODD)

<table>
<thead>
<tr>
<th>Location</th>
<th>Road Type</th>
<th>Time of Day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Driver Awareness</td>
<td>Speed</td>
<td>Weather</td>
</tr>
</tbody>
</table>

Image from Waymo Safety Report
Vocabulary Matters

The Way We Define Automated Driving Is Hell And It's All Of Our Faults

Ryan Felton
Today 12:03pm • Filed to: SELF-DRIVING CARS

https://jalopnik.com/the-way-we-define-automated-driving-is-hell-and-its-all-1819834702
Terrified *New York Times* Columnist Confuses Volvo with Magical "Driverless Car"

"Driverless," "Semi-Driverless"—what the hell is David Leonhardt talking about?

By Lawrence Ulrich  October 24, 2017

Driverless Cars Made Me Nervous. Then I Tried One.

David Leonhardt  Oct. 22, 2017
Trust Matters

Watch LeBron James Nervously Ride in a Self-Driving Car

<table>
<thead>
<tr>
<th>SAE Level</th>
<th>Name</th>
<th>Narrative Definition</th>
<th>Execution of Steering and Acceleration/Deceleration</th>
<th>Monitoring of Driving Environment</th>
<th>Fallback Performance of Dynamic Driving Task</th>
<th>System Capability (Driving Modes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No Automation</td>
<td>the full-time performance by the human driver of all aspects of the dynamic driving task, even when enhanced by warning or intervention systems</td>
<td>Human driver</td>
<td>Human driver</td>
<td>Human driver</td>
<td>n/a</td>
</tr>
<tr>
<td>1</td>
<td>Driver Assistance</td>
<td>the driving mode-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the human driver perform all remaining aspects of the dynamic driving task</td>
<td>Human driver and system</td>
<td>Human driver</td>
<td>Human driver</td>
<td>Some driving modes</td>
</tr>
<tr>
<td>2</td>
<td>Partial Automation</td>
<td>the driving mode-specific execution by one or more driver assistance systems of both steering and acceleration/deceleration using information about the driving environment and with the expectation that the human driver perform all remaining aspects of the dynamic driving task</td>
<td>System</td>
<td>Human driver</td>
<td>Human driver</td>
<td>Some driving modes</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Automated driving system (&quot;system&quot;) monitors the driving environment</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Conditional Automation</td>
<td>the driving mode-specific performance by an automated driving system of all aspects of the dynamic driving task with the expectation that the human driver will respond appropriately to a request to intervene</td>
<td>System</td>
<td>System</td>
<td>Human driver</td>
<td>Some driving modes</td>
</tr>
<tr>
<td>4</td>
<td>High Automation</td>
<td>the driving mode-specific performance by an automated driving system of all aspects of the dynamic driving task, even if a human driver does not respond appropriately to a request to intervene</td>
<td>System</td>
<td>System</td>
<td>System</td>
<td>Some driving modes</td>
</tr>
<tr>
<td>5</td>
<td>Full Automation</td>
<td>the full-time performance by an automated driving system of all aspects of the dynamic driving task under all roadway and environmental conditions that can be managed by a human driver</td>
<td>System</td>
<td>System</td>
<td>System</td>
<td>All driving modes</td>
</tr>
</tbody>
</table>
SAE Levels Deep Dive

*Figure 1: Description and comparison of automated vehicle functionality levels*[^1]


[^1]: Source: U.S. Energy Information Administration
**SAE Levels Deep Dive**

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<table>
<thead>
<tr>
<th>Fully Manual</th>
<th>Fully Automated</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>I would perform all of the driving tasks.</strong></td>
<td>The system would perform all of the driving tasks in all situations.</td>
</tr>
<tr>
<td>The system could help with speed control and steering, but not both at the same time.</td>
<td>The system could perform most of the driving tasks in some situations, but might ask me to take control at some points.</td>
</tr>
<tr>
<td>The system could help with speed control and steering at the same time, but I would need to keep my hands on the wheel.</td>
<td>The system could perform all of the driving tasks in some situations. I would NOT need to take over control at any time.</td>
</tr>
</tbody>
</table>

**Figure 1.** After a survey introduction, participants were presented with this graphic representing seven categories of automation, ranging from SAE Level 0 (fully manual, far left box) to SAE Level 5 (fully automated, far right box). These seven categories provide layman’s definitions of the division of driving task responsibility between driver and system.

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*Abraham et al, 2017*
Level 2-3: Special Challenge

• Levels 2 and 3 require the human driver be ready to take control
• People are people
• What could go wrong?
Figure 3. Simplified visualization of level classification distributions. Colored boxes indicate mean ranking, and black lines represent bounds of the first and third quartiles.

Abraham et al, 2017
Automated

- Automated Vehicle
- Advanced Driver Assistance Systems (ADAS)
- Highly Automated Vehicle
- Autonomous Vehicle
- Driverless Vehicle
- XaaS
  - VaaS
  - TaaS / MaaS
Connected

- V2X
- V2V
- V2I
- V2P/B
Shared

- Carsharing
- Pooling
- Ridesharing
- Ride Hailing
Electric

- HEV
- PEV
  - BEV
  - PHEV
  - EREV
- FCEV
Business Models

• ADAS / Level 2: driver assist
  • Present in many models
• Low speed shuttles
  • Many demonstrations ongoing
• Fleet self-driving – level 4 and 5
  • Testing and demonstration
• Personally owned HAVs
  • Not yet available
• Freight last mile
  • Testing and demonstration
• Freight highway
  • Testing and demonstration
Timing. Short answer: Nobody Knows

What percentage of miles will be provided by highly automated TaaS by 2030? (Each dot represents one study)

Announced “highly automated” vehicle launches
Timing. Short answer: Nobody Knows

Low TaaS Scenario

High TaaS Scenario

0.5 trillion passenger miles as TaaS

5.8 trillion passenger miles as TaaS
Possible Energy Impacts

Wadud, McKenzie, Leiby 2015
Urban LDV passenger kms by scenario, USA

- Electric vehicle travel reaches nearly 1/3 of PKMs by 2030
- Automated vehicle travel not significant by 2030 in any scenario, but dominates in 2R and 3R 2050. Results in much higher travel in 2R

<table>
<thead>
<tr>
<th></th>
<th>2015</th>
<th>2030</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base Year</td>
<td>BAU</td>
<td>2R</td>
<td>3R</td>
</tr>
<tr>
<td>United States</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>BAU</td>
<td>2R</td>
<td>3R</td>
</tr>
</tbody>
</table>

**Passenger Kms of LDV Travel**

- **Shared AV/EV**
- **Shared EV**
- **Shared ICE**
- **Private AV/EV**
- **Private EV**
- **Private ICE**

*Source: ITDP (Institute for Transportation & Development Policy)*

UCDAVIS
SUSTAINABLE TRANSPORTATION ENERGY PATHWAYS
Peril

- Faster Travel and Productive use of Time Supports Sprawl
- Large Vehicles with Poor Fuel Economy
- Lots of Empty Vehicle-Miles, Low Sharing
Promise

- Mostly Shared Use
- Match Vehicle to Trip
- Electrification of Most Miles
- Urban Form Adapted to Automation
Disruptive technologies such as **shared mobility**, **electrification** and **autonomous vehicles** are bringing big changes in:

- Transportation supply
- Transportation demand

Need for rigorous research and impartial policy analysis to understand the impacts of these revolutions, and guide industry investments and government decision-making.
A three-part strategy to address key challenges facing government and industry decision makers, including vehicle use, traffic congestion, air pollution, energy use, and equity gaps:

1. Rigorous Research and Data Gathering
2. Decision-support Analysis and Research Summaries
3. Policy Outreach and Engagement

The Program builds on the leadership and expertise of other centers at ITS Davis.
Research activities of the 3 Revolutions Future Mobility Program include:

- **Data collection and analysis** of behavioral and attitudinal data on shared mobility, adoption of electric vehicles and of connected/automated vehicles;

- **Forecasting and simulation models** of the impacts on activity participation, travel patterns, vehicle ownership, and vehicle miles traveled;

- **Behavioral experiments** to understand the impacts of the adoption of new transportation technologies;

- **Policy analysis** and simulation of future transportation scenarios; and

- **Analysis of environmental, economic and equity impacts** of emerging transportation trends and evolving lifestyles.
Outreach Objectives

• **Convene** Bring local, state, regional, national and international stakeholders to the table for events

• **Educate:** Summarize policy relevant research findings and best practices through development of policy briefs, white papers, etc.

• **Amplify:** Ensure that the research materials do not sit on a shelf by focusing on strategic media and social media outreach.

3Rev.UCDavis.edu
Events To date;

**November 2016:** Kickoff event 3 Revolutions Conference

**April 2017:** Transportation Policy Forum, *UC Center Sacramento*

**June:** Pooling & Pricing Workshop, *UC Davis*

**August:** Special Working Session, *Asilomar*

**September:** League of CA Cities, *Sacramento*

**October:** Policy Workshop Meeting of the Minds Annual Summit, *Cleveland, OH*
2018 Future Events

January
TRB Workshop plus a series of Capitol Hill Briefing(s), USDOE, & USDOT Briefings (all details TBD)

February
2nd Annual 3 Revolutions Conference
February 26-27, 2018 at UC Davis
Need: Principles

• Safety
• Equity
• Security

• Cost effectiveness
• Equity
• Congestion management
• People first
• Reduce energy use and emissions
Now is the Time

States with Enacted Autonomous Vehicle Legislation

Last Thoughts

• New technologies and business models are a risk and an opportunity

• This is a unique time to get the policy framework in place to get benefits from automated vehicles (and minimize unintended consequences)

• The transportation system could be much better
  • Safety, congestion, pollution, equity

• The role of public policy is to help us do the things that are hard but are still a good idea
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Phone: 650/906-5586
Thank You.

dokbrown@ucdavis.edu
# Rough guide to the three scenarios

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Automation</th>
<th>Electrification</th>
<th>Shared Vehicles</th>
<th>Urban Planning/ Pricing/TDM Policies</th>
<th>Aligned with 1.5 Degree Scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td>Business as usual, Limited Intervention</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>No</td>
</tr>
<tr>
<td>1R Automation only</td>
<td>HIGH</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>No</td>
</tr>
<tr>
<td>2R With high Electrification</td>
<td>HIGH</td>
<td>HIGH</td>
<td>Low</td>
<td>Low</td>
<td>Maybe</td>
</tr>
<tr>
<td>3R With high shared mobility, transit, walking/cycling</td>
<td>HIGH</td>
<td>HIGH</td>
<td>HIGH</td>
<td>HIGH</td>
<td>YES</td>
</tr>
</tbody>
</table>
## Does the User Pay?

<table>
<thead>
<tr>
<th>Priced</th>
<th>Unpriced / Partially Priced</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle</td>
<td>Infrastructure Use</td>
</tr>
<tr>
<td>Fuel</td>
<td>Congestion</td>
</tr>
<tr>
<td>Accidents</td>
<td>Parking</td>
</tr>
<tr>
<td>Time</td>
<td>Pollution</td>
</tr>
</tbody>
</table>
The Stickiness of “Free”