The Future of Mobility: Automated Driving, Connected Cars, and Shared Mobility

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Vehicles Evolving Quickly along Several Dimensions

• Growth in vehicle communications and connectivity
• Increase in electronic content and amount and importance of software
• Proliferation of sensor-based safety systems
• Electrification of the powertrain
• Changing mix of vehicle types (goodbye cars?)
• Increased competition from many directions
• Advent of mobility services (end of ownership?)
• Emergence of highly automated vehicles

Credit: Colin Anderson
THE CENTER FOR AUTOMOTIVE RESEARCH (CAR)

Automotive industry contract research and service organization (non-profit) with more than 30 years experience forecasting industry trends, advising on public policy, and sponsoring multi-stakeholder communication forums.

RESEARCH
Independent research and analysis on critical issues facing the industry.

EVENTS
Industry-driven events and conferences that deliver content, context, and connections.

CONNECTIONS
Consortia that bring together industry stakeholders in working groups and offer networking opportunities and access to CAR staff.
Tartan Racing is united to catalyze a technical, cultural, and industrial revolution for a new class of robotics to advance the state-of-the-art in driver safety.
Driver Assistance Available Today

Source: Texas Instruments
And Coming Soon (Very Soon in Some Cases)!
Prototypes, Test Vehicles, Early Deployment Vehicles

Robo-Taxis
- Waymo
- Drive.ai

Low-Speed Shuttles
- Navya Arma
- May Mobility

Urban Delivery
- Nuro
- Ford

Long-Haul Freight
- Daimler
Audi’s Piloted Driving System (zFas)

Hidden from view is the artificial intelligence enabling it all to work.

Audi A7 Self-Driving Concept Car that drove itself >550 miles from S.F. to CES in January 2015
Automated Vehicles Driven by Artificial Intelligence

While sensors of various types (e.g., cameras, RADAR, Lidar, etc.) serve to replace human senses (the driver’s eyes and ears, especially), artificial intelligence is the leading candidate to replace the driver’s brain for decision making.
Potential Effects of Automated Vehicles on Travel

• Most simulations of AVs predict an increase in overall vehicle miles traveled.
• AVs could enable more efficient use of existing parking supply and lower parking demand.
• AVs bring opportunities and challenges for public transit, biking, and walking.

Zero occupancy travel of shared AVs is estimated to be 7.7% to 11% of total VMT.

Automated Vehicle Interior Concepts

- **Office on wheels**
- **GM concept: no steering wheel or pedals**
- **Mercedes concept: rear-facing seats**
- **Enhanced accessibility**
- **Adient concept: rotating seats**
## Automated Vehicle Deployment Models
### Pilots and Early Deployments

<table>
<thead>
<tr>
<th>Robo-taxi</th>
<th>Low-speed shuttle</th>
<th>Urban delivery</th>
<th>Long-haul freight</th>
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<tbody>
<tr>
<td><strong>Waymo</strong> Phoenix area, AZ (since Apr 2017)</td>
<td><strong>Navya</strong> Sion, CH (Jun 2016)</td>
<td><strong>Ford</strong> Ann Arbor, MI (Sept 2017) – with Domino’s</td>
<td><strong>Daimler</strong> Nevada (since May 2015)</td>
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<td><strong>nuTonomy</strong> Boston, MA (since Dec 2017) – with Lyft Singapore, SG (since 2018)</td>
<td>Las Vegas, NV (since Nov 2017)</td>
<td><strong>Nuro</strong> Scottsdale, AZ (since Aug 2018) – with Kroger</td>
<td><strong>Waymo</strong> Atlanta, GA (since May 2018)</td>
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<td><strong>Uber</strong> Pittsburgh, PA (Sept 2016 – March 2018)</td>
<td>Neuhausen Rheinfall, CH (since Mar 2018)</td>
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<td>Tempe area, AZ (Feb 2017 – Mar 2018)</td>
<td>Ann Arbor, MI (since Jun 2018)</td>
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<td><strong>GM/Cruise</strong> San Francisco, CA (since Sept 2017)</td>
<td>EasyMile Arlington, TX (since Aug 2017)</td>
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<td><strong>Voyage</strong> San Jose, CA (since Sept 2017)</td>
<td>Berlin, DE (since Dec 2017)</td>
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<td>San Ramon, CA (since Apr 2018)</td>
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<td>Forus, NW (since Jun 2018)</td>
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<td>2getthere Capelle aan den IJssel, NL (since Dec 2006)</td>
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<td>Masdar City, UAE (since Nov 2010)</td>
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<td>May Mobility Detroit, MI (since Jul 2018)</td>
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Note: For robo-taxis, low-speed shuttles, and urban delivery, only pilots and early deployments open to the general public or to a select user group are included.
Deployment Timeline
Automated Driving Systems (SAE J3016 Levels 3-5)

- **Audi**
  - L4 – “Highway Pilot” – Commercial Deployment

- **Bosch**
  - L3 – Platform – Commercial Deployment

- **comma.ai**
  - L4 – Commercial Deployment

- **Honda**
  - L3 – “Automated HW Driving” – Commercial Deployment

- **Lyft (with GM)**
  - L4 – Taxi – Commercial Deployment

- **Nissan**
  - L4 – “Autonomous Drive” – Commercial Deployment

- **BMW (with Mobileye)**
  - L4/5 – “Highly/Fully – Commercial Deployment

- **Continental (with Nvidia)**
  - L2-5 – Platform – Commercial Deployment

- **Daimler (with Bosch and Nvidia)**
  - L4 – Taxi – Commercial Deployment

- **Lyft (with GM)**
  - L4 – Taxi – Commercial Deployment

- **Nissan**
  - L4 – Taxi, Delivery Vehicle – Production Ready

- **Volvo**
  - L4 – Commercial Deployment

- **Aptiv**
  - L4 – Taxi – Pilot

- **EasyMile**
  - L4 – Fixed Route Shuttle – Pilot

- **GM (with Cruise)**
  - L4 – Taxi – Pilot

- **Voyage**
  - L4 – Taxi – Pilot

- **Waymo**
  - L4 – Delivery Vehicle – Pilot

- **Nuro**
  - L4 – Delivery Vehicle – Pilot

- **Tesla**
  - L4 – Personal Vehicle/Taxi – Commercial Deployment

- **Aptiv (with Mobileye)**
  - L4/5 – “Turnkey Solution”

- **Daimler (with Bosch and Nvidia)**
  - L4 – Taxi – Pilot

- **GM (with Cruise)**
  - L4 – Taxi – “Commercial Launch at Scale”

- **Uber**
  - L4 – Taxi – Commercial Deployment (suspended)

- **Easymile**
  - L4 – Fixed Route Shuttle – Pilot

- **GM (with Cruise)**
  - L4 – Taxi, Delivery Vehicle – Pilot

- **May Mobility**
  - L4 – Fixed Route Shuttle – Pilot

- **nuTonomy (with Lyft)**
  - L4 – Taxi – Pilot

- **2getthere**
  - L4 – Shuttle on Dedicated Lane – Commercial Deployment

- **Navya**
  - 2016 – L4 – Shuttle on Dedicated Lane – Pilot

- **Uber**
  - 2016 – L4 – Taxi – Pilot

- **Aptiv (with Lyft)**
  - L4 – Taxi – Pilot

- **drive.ai**
  - L4 – Taxi – Pilot

- **Ford (with Argo.AI)**
  - L4 – Taxi, Delivery Vehicle – Pilot

- **Lyft (with GM)**
  - L4 – Taxi – Commercial Deployment

- **Nissan**
  - L4 – Taxi, Delivery Vehicle – Pilot

- **nuTonomy (with Lyft)**
  - L4 – Taxi – Pilot

- **2getthere**
  - 2006 – L4 – Shuttle on Dedicated Lane – Commercial Deployment

- **Navya**
  - 2016 – L4 – Shuttle on Dedicated Lane – Pilot

- **Uber**
  - 2016 – L4 – Taxi – Pilot

- **Voyage**
  - L4 – Taxi – Pilot

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  - L4 – Delivery Vehicle – Pilot

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Shared Mobility Services

Shared mobility services are transportation solutions enabled by emerging technologies and wireless connectivity that allow for more convenient, efficient, and flexible travel.
The most important effects of new mobility services on the automotive industry will be how customers interact with vehicles and their expectations and uses of these vehicles, not on total vehicle sales.
Shared Mobility Services
Opportunities for the Auto Industry

The rise of shared mobility services is part of a mobility evolution that brings many opportunities for the auto industry.

New services
New vehicle concepts
New functionalities
New ownership models
New business partnerships
Shared Mobility Services in North America

600+ cities with ridesourcing
20+ cities with pooled rides
10+ cities with microtransit
400+ cities with carshare (round trip, free floating, P2P)
400+ cities with bikeshare (stationed, dockless) & scooters

Source: Shared Use Mobility Center
Shared Mobility Services in North America

Ridesourcing

Pooled rides and ridesharing

Microtransit

Bikesharing (stationed)

Bikesharing (dockless)

Scooter sharing

Carsharing (round trip)

Carsharing (free floating)

Carsharing (P2P)

Source: Shared Use Mobility Center, CAR research
Conclusions

• Increasing vehicle automation appears to be inevitable, but levels 4 and 5 remain challenging (is more and better driver assistance perhaps a better option?)

• Deep learning is promising, but it is just one tool for automated driving
  • New approaches are coming, including those that better combine processing with memory like your brain (such as IBM’s neuromorphic TrueNorth chip); 
    *neuromorphic*: use of very-large-scale integration (VLSI) systems containing electronic analog circuits to mimic neuro-biological architectures present in the nervous system

• Predictions/estimates of when level 4 and 5 vehicles will be here are fraught with error (AKA over-optimism?)
  • Early versions will cost many tens of thousands of dollars over current vehicle prices
  • Heavy trucks and freight might well be the first major application (unless you count warehousing—Amazon has already done that)

• Mobility services, combined with automation, will be highly disruptive to the industry and its retail model

• Both automation and IMS have enormous potential to alter the transportation-land use equation and, together, how we access vehicle travel
THANK YOU