Connected and Autonomous Vehicles: The Future is Near!

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University Transportation Center
Carnegie Mellon University
Overview

Benefits
- Safety
- Accessibility
- Mobility
- Efficiency

Reducing the overall cost of driving:
  - Accidents
  - Time
  - Fuel
  - Maintenance
  - Health - Mortality
  - Environmental Damages

Challenges
- Technology
- Deployment and Adoption
Why Autonomous?

- **Safety**
  - More than one million people die every year in automobile accidents.
  - Add that to the injuries caused by accidents, global annual cost is over $500 billion a year.

- **Accessibility**
  - Low quality of life for elderly and people with disabilities.

- **Mobility**
  - Congestion problems: 5.5 billion hours wasted in traffic.

- **Efficiency**
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Technology Challenges

- Uncertainty of the real world
- Complexity of the real world
- Failure recovery
- Vehicular communications
- Affordability
- Maintenance
Policy Issues Impacting Successful Deployment

- Liability Issues
  - Insurance policies
  - Types of claims
  - Responsible parties

- Regulatory Issues
  - Standards
  - Signs
  - Education

- Rebound Effects
  - Traffic congestion
  - Lifestyle
  - Environment and Externalities

- Financial Issues
  - Taxes
  - User Fees

- Privacy Issues

Who?

<table>
<thead>
<tr>
<th>Autonomous Vehicle Driver</th>
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<tbody>
<tr>
<td>Standard Vehicle Driver</td>
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<tr>
<td>Auto Manufacturers</td>
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<tr>
<td>Society at Large</td>
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<tr>
<td>Government</td>
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<td>Insurance Companies</td>
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</tbody>
</table>

Potential Challenges

- Cost - Perception - Privacy
- Perception - Interaction
- Timing & Market Adjustments - Liability Concerns
- Equity Issues - Zoning Issues
- Regulations - Standards - Finances - Education
- Pricing Strategies

It was not me, it was the car!

Who?

Autonomous Vehicle Driver
Standard Vehicle Driver
Auto Manufacturers
Society at Large
Government
Insurance Companies

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Successful Deployment

Optimizing Benefits while Minimizing Costs
CMU Projects

- **ECE Department - NavLab: Technology**

- **Civil Engineering – Mechanical Engineering:**
  - Connected and autonomous vehicles 2040 vision
  - Potential energy savings from autonomous vehicles
  - Potential cost savings (i.e. time, accidents, environmental damages)
Autonomous Driving

NavLab: Intelligent Vehicles

Robotics Institute 25th anniversary

- Autonomous vehicles
- Pedestrian tracking
- Sensors and movement prediction
NOVEMBER 3, 2007:
“BOSS” WINS DARPA URBAN CHALLENGE
Autonomous Driving

Winner Urban Challenge 2007

2012 GM Lab

Carnegie Mellon
Automated Vehicle
Trunk Space?

Usable
CMU Projects

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"I have 18-month-old twins. They might not ever drive a car; I think autonomous vehicles are going to happen, and I think PennDOT should embrace that. This is the future of transportation. We need to do the research today."

Secretary Barry Schoch, Pennsylvania Department of Transportation
December 2012
Post Gazette

• Design Year: 2040
• Boundary: Pittsburgh region
• Timeframe: one year
• Impacts to:
  - Design and Investment Decisions
  - Existing Infrastructure
  - Workforce Training Needs
  - Driver Licensing
  - Communication Devices Investments
  - Freight Flow
Presentations & Breakout Sessions

Presentations

- Overview of CAV – Kevin Gay (Volpe) and John Capp (GM)
- Impacts to Infrastructure and Design – Christopher Hill (Booz Allen) and Raj Rajkumar (CMU)
- Impacts to Freight – Ali Maleki (Ricardo) and Cem Hatipoglu (FMCSA)
- Driver Licensing and Workforce – Elizabeth Birriel (FDOT), Bernard Soriano (CA DMV) and Neil Shuster (AAMVA)

Breakout Sessions

- Impacts to Existing Infrastructure, Design and Investment Decisions
- Impacts to Freight Flow
- Impacts to Driver Licensing Issues and Workforce Training Needs
- Communication Device Investments and Real Time Data Usage
Breakout Sessions Commonly Emphasized Points

- P3 opportunities will become crucial for the process.
- Market forces will drive the direction.
- Uncertainties are significant.
- Legislative policy changes will be important.
- Interstates and especially rural interstates should be the primary focus of implementation/assessment.
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Objective & Assumptions

Objective:
Developing base, optimistic, and pessimistic case estimates of fuel use changes

Main assumptions:
- NHTSA levels 0 to 2 (0 – 10 years): Automation of specific vehicle functions but not fully autonomous self-driving vehicles.
- Light duty vehicles
- Private ownership
## Impacts of NHTSA Automation Levels on Energy Use

<table>
<thead>
<tr>
<th>Automation Level</th>
<th>Technology</th>
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<tbody>
<tr>
<td>Level 0: No Automation</td>
<td>Lane departure warning</td>
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<tr>
<td></td>
<td>Collision warning</td>
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<tr>
<td></td>
<td>Blind spot warning</td>
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<td></td>
<td>Speed limit detection</td>
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<td>Traffic warning</td>
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<td>Vehicle-to-vehicle communication</td>
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<tr>
<td>Level 1: Function Specific Automation</td>
<td>Adaptive cruise control</td>
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<tr>
<td></td>
<td>Lane keeping</td>
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<tr>
<td></td>
<td>Collision detection braking</td>
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<tr>
<td></td>
<td>Active braking</td>
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<tr>
<td></td>
<td>Parking aid system</td>
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<tr>
<td></td>
<td>Dynamic route guidance</td>
</tr>
<tr>
<td>Level 2: Combined Function Automation</td>
<td>Platooning (low penetration)</td>
</tr>
<tr>
<td></td>
<td>Platooning (high penetration)</td>
</tr>
</tbody>
</table>
Energy Use Impacts

- Reducing accident related congestion
- Reducing non-accident related congestion
- Increasing driving efficiency
- Operational load
- Rebound in travel demand
Energy Savings Potential by Automation Level

- Rebound
- Operational Load
- Efficient driving
- Other reduced congestion
- Fewer accidents

Energy Savings Potential (gal/veh/yr)

Level 0 (all features)  Level 1 (best features)  Level 2 (low penetration)  Level 2 (high penetration)
Energy Savings Potential by Technology

[Graph showing energy savings potential by technology level with specific values and categories for different technologies and levels.]
Results

- Energy savings likely increase with degree of automation.

- Energy savings are highly likely to be positive and significant, but the amount of savings is uncertain.

- An annual saving of 70 gallons per vehicle (0.8 metric tons of GHG emissions per vehicle) represents a 15% reduction in gasoline consumption (accounting rebound effect as well as energy consumed to operate automation equipment.)
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In short...

- Researchers at CMU are working collaboratively on various aspects of connected and autonomous vehicles.

- Most of what we hear about implies level 4 automation, not much on transitions or challenges.

- Benefits will likely to be more significant as we enter levels 3 and 4 automation.

- Great deal of uncertainty.

The Best News:

Future is Near!
Thanks to:

Mr. Allen Biehler  (UTC – CMU)
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Dr. Jeremy Michalek  (Mechanical Engineering – CMU)
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Thank You!
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