Connected and Automated Vehicles

Jay Hietpas, P.E.
Connected and Automated Vehicles Director
Presentation Overview

- Connected and Automated (CAV) Background

- CAV Activities in Minnesota
Connected Automation

Autonomous Vehicles
Operates in isolation from other vehicles using sensors

Connected Automated Vehicle
Uses connected and automated technologies

Connected Vehicles
Communicates with vehicles and infrastructure
Levels of Automation

- **0**: No Automation
- **1**: Driver Assist
- **2**: Partial Automation
- **3**: Conditional Automation
- **4**: High Automation
- **5**: Full Automation

Society of Automotive Engineers (SAE) Levels of Automation
Items Being Considered

- Automated & Connected Vehicles
- Truck Platooning
- Electric Vehicles
- Mobility as a Service (MAAS)
- Automated Delivery Services
GM will make an autonomous car without a steering wheel or pedals by 2019

'Platoons' of autonomous trucks will drive together

Toyota-Denso joint venture to buy up to 10% of autonomous vehicles from Volvo

Tesla to introduce DSRC-based connected vehicles in the USA from 2021
Pieces of Automation Already Available

• Adaptive Cruise Control
• Self Parking Features
• Lane Departure Systems
• GM Super Cruise / Tesla Auto-Pilot
• V2I – Signal Systems (Audi, BMW, Apps)
• Self Driving Tests
What is the Impact to Minnesota?

- Safety
- Changes in operations
- Infrastructure Changes
- Regulation
- Mobility Opportunities
- Business Opportunities
What are the Challenges?

- Snow / Ice
- Salt
Other Impacts

Parking Impacts  Freight  Cyber Security
Pavement Markings  Geometric Design
Licensing Laws  Bridge Loads
Smart Signs  Pavement Impacts
Traffic Operations  Revenue
Mixed Traffic (AV & Non-AV)  Staffing
Land Use / Planning
Activities in Minnesota

• CAV-X Office
  • Policy
  • Research & Implementation Funding

• CTS Automated Vehicle Visioning Workshop

• Executive Order 18-04

• MnDOT CAV Strategic Plan

• Autonomous Shuttle Testing

• Connected Corridors Project
Executive Order – Expected Outcomes

Advisory Council

• Study, assess, and prepare for the transformation and opportunities associated CAVs

• Develop recommendations for changes in state law

• Submit Report to Legislature by December 1, 2018.

• Establish programs for development, testing, and deployment;
Minnesota Connected and Automated Vehicles EO Organization Structure

Advisory Council

I-CAV Team

- Transportation Infrastructure
- Cyber security and data privacy standards
- Vehicle Registration, Driving Training, Licensing
- Insurance
- Traffic Regulations
- Economic Development, Business Opportunities, Workforce Development
- Accessibility and Equity
- Policy and Planning

Stakeholders

Stakeholders

Stakeholders

Stakeholders

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MnDOT CAV Strategic Vision

Outreach

Multi-Modal

Strategic Staffing

Operation

Regulation

CAV Strategic Plan

Long Range Planning

Capital Needs

Research

Partners
Project Goals

Snow and Ice Testing
Identify Infrastructure
Identify Operations Impacts
Improve Future Mobility Options
Increase Minnesota’s Influence
Develop Partnerships
Public Feedback
Downtown Minneapolis - Nicollet Mall Demo

TOTAL riders for the 3 day demo: 1279
Connected Vehicles Corridor
Connected Vehicle Applications

• 1: Signal Phase and Timing (SPaT)
• 2: Transit/Pedestrian Conflict Warning
• 3: Snow Plow Signal Priority
• 4: CV Data Exchange
• 5: Mobile Work Zone Warning System
• 6: Transit/MnPASS Lane Status Notification System
Thank you again!

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Planning for Connected and Automated Vehicles
Planning

The nation, state, region and local governments are facing great opportunity with automated vehicle technologies, yet also great uncertainty as this new technology develops and is implemented across our various environments.
As yet, CAV has Uncertain Outcomes....

<table>
<thead>
<tr>
<th>COULD DECREASE DUE TO</th>
<th>IMPLICATION</th>
<th>COULD INCREASE DUE TO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle sharing, higher vehicle costs</td>
<td>Vehicle Ownership</td>
<td>Smaller, lighter-weight vehicles lower cost, new types of vehicles</td>
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<tr>
<td>Increased travel willingness / better use of in-vehicle</td>
<td>Land Use Density</td>
<td>Network effects, shared &amp; transit vehicles, less parking</td>
</tr>
<tr>
<td>travel</td>
<td>VMT / Trips</td>
<td>Lower operating costs, zero-occupant trips, mode shift, expanded mobility for non-drivers, increased travel willingness</td>
</tr>
<tr>
<td>Vehicle sharing, denser development</td>
<td></td>
<td>Reduced headways, smoother traffic flow, shorter signal lag times, fewer crashes, and real-time route optimization</td>
</tr>
<tr>
<td>Follows all road rules / defensive driving</td>
<td>Road Capacity / Speed</td>
<td></td>
</tr>
<tr>
<td>Machine precision</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low-emission vehicles, right-sized vehicles, eco-driving</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vehicles avoid deficiencies, smoother traffic flow</td>
<td></td>
<td></td>
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<tr>
<td>AI (deep learning) displaces workers</td>
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How will autonomous vehicles arrive?

- **Fully Autonomous**
  - **Personal Automation**
  - **Shared Automated/Platooning**

- **Semi-Autonomous**
  - **Business as Usual**
  - **Shared Mobility**

- **Driver**
  - **Personally Owned**
  - **Mobility Fleets**

Source: Maricopa Association of Governments
Agency Roles

Definition and understanding of various public agency roles is still evolving…..

• MnDOT
• Local governments
• University
• Transit operators
• Metro Council as the Metropolitan Planning Organization
Regional Outcomes and Goals

Successful implementation of CAV technology means positive impacts on the outcomes and goals identified by the region….

• Thrive regional outcomes: Stewardship, Prosperity, Equity, Livability, and Sustainability
• Transportation goals: System Stewardship, Safety and Security, Access to Destinations, Competitive Economy, Healthy and Equitable Communities, Leveraging Transportation Investments to Guide Land Use
Council MPO Roles

• Connect the development and deployment of CAV to regional outcomes and goals
• Provide a forum and process for policy-makers and the public to be involved
• Ensuring concerns of all modes and users are addressed
• Monitor national and state activities and trajectory of CAV adoption, share knowledge
• Scenario and performance based planning
Potential Penetration of AV

Source: Maricopa Association of Governments; HDR Engineering, Inc.
FHWA Scenario Planning

2035 CV/AV Scenarios

- **Enhanced Driving Experience**
  - Managed Automated Lanes
  - Ultimate Traveler Assist
  - AV lane networks
  - Ultra-Connectivity
  - AV travel is consolidated to a large-scale lane network with significant consumer adoption
  - AV adoption stalls, CV becomes ubiquitous

- **Slow Roll**
  - Slow Roll
  - Minimal Plausible Change
  - Accounts for advances in safety technology, TSMO and mobility services

- **Driver Becomes Mobility Consumer**
  - Niche Service Growth
  - High AV/CV in certain cases
  - Niche applications for CV/AV dominate the landscape
  - Competing Fleets
  - Automated TNC fleets compete
  - Level-4 AV is safe for most trips, travel is dominated by competing fleets
  - Automated Integrated Mobility
  - Automated mobility-as-a-service
  - Strong public-private partnership for system optimization

- **Trajectories towards CV/AV Advancements**
  - TODAY (circa 2017)
Council Focus Areas

MPO work efforts will focus on understanding the impacts of CAV on:

- Travel behavior
- Revenues
- Investment needs
- Equity
- Land use
Work Program Activities

• Participation in local and national activities
  – Governor’s CAV Advisory Council
  – MnDOT CAV Strategic Plan
  – CTS CAV Workshop June 2018
  – AMPO Draft National Framework for Regional CAV Planning
  – FHWA CAV scenario modeling

• TPP Work Program
  – Regional framework and issues analysis
  – Scenario modeling and performance measurement
  – Integrating CAVs into the Congestion Management Process
  – Emerging truck technologies
  – Transportation investment needs assessment
2017 Work
Owned/Shared Scenario Modeling

• Modeled changes in highway system performance at various levels of CAV deployment and combinations of owned versus shared CAVs

• Outcomes examined:
  – Vehicle miles traveled (VMT) and congested VMT
  – Average speeds
  – Number and % of unoccupied vehicle trips
  – % VMT occurring in unoccupied vehicles
2017 CAV Modeling Conclusions

• Number of vehicle trips and vehicle miles traveled increases substantially due to new unoccupied vehicle trips under both scenarios

• Number of congested miles increased substantially under both scenarios

• Worst case congestion scenario is during mixed fleet of CAV and non-CAV

• Number of vehicles in the region decreases under both owned and shared scenarios
Why Shared Autonomous Vehicles are Coming - Fast

Thomas Fisher
Professor and Director
Minnesota Design Center, University of Minnesota
The change will happen faster than you think
A big driver of this change: cost of driving

Despite high costs and fast depreciation, substantial utilization can make shared, high-tech “mobility vehicles” economically compelling.

Today’s car
- Cost per mile: 21¢

Future mobility car
- Cost per mile: 17¢

The “mobility vehicle” is based on a small sedan that costs $25,000 and is completely replaced every three years with no residual value. It is shared and, therefore, driven 40,000 miles per year. The average NYC cab is driven an average of 70,000 miles per year.

Fixed Costs (per mile)
- Depreciation, insurance, finance, and registration-related costs

Operating Costs (per mile)
- Gas, maintenance, and tires

Sources:
- AAA, NYC Taxi and Limousine Commission, “KPMG LLP’s Me, my vehicle, my life... in the ultra connected age”
A second driver: safety

U.S. Fatality Reduction Expected with Autonomous Vehicles
(Units in deaths per 100 million vehicle miles traveled)

- 2013 National Average: 1.1
- Autonomous Vehicle: 0.2
A third driver: reduced pollution

Three Revolutions in Urban Transportation

**Business-as-Usual Scenario**

21st Century Technology

Through 2050, we continue to use vehicles with internal combustion engines at an increased rate, and use transit and shared vehicles at the current rate, as population and income grow over time.

**2 Revolutions (2R) Scenario**

Electrification + Automation

We embrace more technology. Electric vehicles become common by 2030, and automated electric vehicles become dominant by 2040. However, we continue our current embrace of single-occupancy vehicles, with even more car travel than in the BAU.

**3 Revolutions (3R) Scenario**

Electrification + Automation + Sharing

We take the embrace of technology in the 2R scenario and then maximize the use of shared vehicle trips. By 2030, there is widespread ride sharing, increased transit performance—with on-demand availability—and strengthened infrastructure for walking and cycling, allowing maximum energy efficiency.

**Number of Vehicles on the Road by 2050**

- **Business-as-Usual Scenario**: 2.1 billion
- **2 Revolutions (2R) Scenario**: 2.1 billion
- **3 Revolutions (3R) Scenario**: 0.5 billion

**CO₂ Emissions by 2050**

- **Business-as-Usual Scenario**: 4,600 megatonnes
- **2 Revolutions (2R) Scenario**: 1,700 megatonnes
- **3 Revolutions (3R) Scenario**: 700 megatonnes

[www.itdp.org](http://www.itdp.org)
The big stick driving the change: insurance

<table>
<thead>
<tr>
<th>Future state</th>
<th>Stakeholder model</th>
<th>Stakeholder</th>
<th>Primary coverages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personally owned driver-driven</td>
<td>Traditional personal auto insurance</td>
<td>Vehicle owner (individual)</td>
<td>Driver liability, collision, comprehensive</td>
</tr>
<tr>
<td>Driver-driven</td>
<td>Fleet (e.g., yellow cab, limo)</td>
<td>Vehicle owner (commercial)</td>
<td>Driver liability, collision, comprehensive</td>
</tr>
<tr>
<td>Owner/operator (e.g., black car)</td>
<td>Owner/operator (individual)</td>
<td>Vehicle owner (individual)</td>
<td>Driver liability, collision, comprehensive</td>
</tr>
<tr>
<td>Shared driver-driven</td>
<td>Rental</td>
<td>Vehicle owner (commercial)</td>
<td>Comprehensive, liability (e.g., road worthiness)</td>
</tr>
<tr>
<td>Autonomous</td>
<td>Personal autonomous vehicle insurance</td>
<td>Vehicle owner (individual)</td>
<td>Comprehensive, liability (e.g., road worthiness)</td>
</tr>
<tr>
<td></td>
<td>AV system manufacturer/ OS provider (commercial)</td>
<td>AV system manufacturer/ OS provider (commercial)</td>
<td>AV product liability</td>
</tr>
<tr>
<td>Shared autonomous</td>
<td>Commercial autonomous vehicle insurance</td>
<td>AV system manufacturer/ OS provider (commercial)</td>
<td>AV product liability</td>
</tr>
</tbody>
</table>
Today’s infrastructure will go through this change
Opportunities and Challenges

The route to the autonomous car

**Advantages**

- Safety: 90% of recent traffic accidents are currently caused by human errors.
- Economic benefits: Stanway estimates that autonomous cars will average US$ 1.3 trillion per year for the US economy, globally this translates into US$ 5.8 trillion.

**Potential obstacles**

- Liability: Who accepts responsibility in the case of an accident?
- Legislation: US laws on the introduction of autonomous vehicles mean that US$ 10.8 billion had to be raised to keep the Highway Trust Fund solvent until May 2015.

**Consumer adoption**

- Once people accept and trust the technology, adoption rates are expected to climb.

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This reflects a larger value shift: sharing economy
Public rights of way will feel the change first
Creating a lot more space for other things
Cities will gain about 30% more land
Homeowners will gain land and interior space
The suburban landscape will change the most
Parking ramps will have to find other uses
Highways will become multi-modal