AGENDA

- Present and discuss the following topics:
  - Connected and Automated Vehicle Systems
  - Transportation Systems
  - Infrastructure Investments
  - Land Use
  - Legal and Regulatory Considerations

- Collect stakeholder feedback
Intelligent Transportation Systems (ITS)
- Electronics, communications, or information processing used singly or in combination to improve the efficiency or safety of a surface transportation system (CFR 940.1)

Connected Vehicle Systems
- Any system enabling the exchange of digital information between a vehicle and the world (e.g., another vehicle, infrastructure)

Automated Vehicle Systems
- Any electronic system that influences the lateral or longitudinal operation (or both) of a vehicle
CONNECTED VEHICLE SYSTEMS
ENABLING THE EXCHANGE OF DIGITAL INFORMATION BETWEEN A VEHICLE AND THE WORLD

1: Physical (PHY) Layer
2: Data Link Layer
3: Network Layer
4: Transport Layer
5: Session Layer
6: Presentation Layer
7: Application Layer

Network
Language
Application
CONNECTED VEHICLE SYSTEMS

EXAMPLE USES

In-dash Internet Access
Music over Bluetooth
Vehicle-to-Vehicle for Safety

Network
Cellular 4G
Public Internet (TCP/IP)
Bluetooth
.mp3 file
DSRC (IEEE 802.11P)
SAE J2735

Language

Application
Web Browser
Info-tainment
Crash Avoidance

© CENTER FOR AUTOMOTIVE RESEARCH 2016
Network
- Government-licensed 5.9 GHz wireless band using specific family of industry standards including IEEE 802.11p

Language
- Vehicles and infrastructure on public dedicated short-range communications (DSRC) network using SAE J2735 data dictionary

Applications
- To improve safety, mobility, and environmental impacts of highway travel

Basis of Ann Arbor Safety Pilot
U.S. DOT CONNECTED VEHICLE PROGRAM

APPLICANTS

Highlighted in NHTSA Regulatory Proposal:

- Left-Turn Assist
- Intersection Movement Assist
- Forward Collision Warning + Electronic Emergency Brake Lights
- Do Not Pass Warning
- Blind Spot + Lane Change Warning

© CENTER FOR AUTOMOTIVE RESEARCH 2016
The term “connected vehicle” can apply to dozens of unique technologies and applications.

Connected vehicle systems can be combined with automated vehicle systems and ITS.

The USDOT Connected Vehicle Program is one example.

- This concept is also known as connected ITS (C-ITS).
- Uses dedicated short-range communication (DSRC) at 5.9 GHz.
- NHTSA is pursuing a potential mandate for vehicle-to-vehicle (V2V) connectivity.
- Vehicle-to-infrastructure (V2I) applications also are in development.

Michigan DOT is actively pursuing DSRC-based solutions.
AUTOMATED VEHICLE SYSTEMS
ANY ELECTRONIC SYSTEM THAT INFLUENCES LATERAL AND/OR LONGITUDINAL OPERATION OF A VEHICLE

Monitoring
- Sensors, cameras, radar, etc.

Agency
- Information processing

Action
- Physical actuation systems
AUTOMATED VEHICLE SYSTEMS
COMPONENT EXAMPLES

Automated Vehicle Technologies

- Monitoring
  - Sensors
  - Communication
  - HMI

- Agency
  - Software
  - Processor(s)
  - Digital Maps

- Action
  - Powertrain
  - Brake
  - Steering

© CENTER FOR AUTOMOTIVE RESEARCH 2016
AUTOMATED VEHICLE SYSTEMS
SAE INTERNATIONAL TAXONOMY

Levels 0-2
Available Today

Levels 3-5
Automated Driving Systems (ADS)
Future

0: No Driving Automation
1: Driver Assistance
2: Partial Driving Automation
3: Conditional Driving Automation
4: High Driving Automation
5: Full Driving Automation
Automated Vehicle Systems (SAE Levels 0-5)
- ABS, Electronic Stability Control
- Conventional Cruise Control
- Automated Crash Avoidance/Mitigation (AEB)

Driving Automation Systems (SAE Levels 1-5)
- Automated Parking
- Adaptive Cruise Control (ACC)
- ACC + Lane Keeping

Automated Driving Systems (ADS)
(SAE Levels 3-5)
- Highway Pilot
- Automated Taxi
- Driverless Shuttle
AUTOMATED DRIVING SYSTEMS (ADS)
CONNECTIVITY PRACTICALLY REQUIRED

- Cloud-based Digital Maps
- Fleet Telematics
- Vehicle Condition and Health Monitoring
- Realtime Traffic and Environmental Data
- Trip and Routing Instruction

Connectivity via cellular (4G LTE, 5G), encrypted Wi-Fi, or similar wireless network.
AUTOMATED DRIVING SYSTEMS (ADS)
PROMISES, PROMISES

Tesla
“Autopilot 2.0”
(Level 3 in 2017, with subsequent updates to higher levels)

Audi
“Piloted Driving”
(Level 3)

Honda
“Automated HW Driving”
(Level 3?)

Nissan
“Autonomous Drive”
(Level 3?)

Lyft/GM
Automated Taxis
(Level 4)

Mercedes
“Autonomous Drive”
(Level 4)

Volvo
“DriveMe” Pilot
(Level 3)

“DriveMe” Deployment
(Level 3? 4?)

Volvo
“DriveMe” Deployment
(Level 3 4?)

Lyft/GM
Automated Taxis
(Level 4)

Ford
Automated Ridesharing
(Level 4)

BMW
“Highly/Fully Autonomous”
(Level 4 5?)

Uber
Autonomous Taxis
(Level 4)
Driving automation systems are defined by SAE J3016.

SAE levels 3-5, known as *automated driving systems (ADS)*, are systems that perform the entire driving task for sustained periods.

ADS practically requires connectivity.

There are nearly zero ADS-equipped vehicles in public operation today. (Exceptions are low-speed shuttle pilot programs.)


We can only guess when ADS-equipped vehicles will be adopted or how they will affect the transportation system.
CONNECTED AND AUTOMATED VEHICLE SYSTEMS DISCUSSION
TRANSPORTATION SYSTEMS
TRAVEL DEMAND AND VEHICLE MILES TRAVELED (VMT)

Factors that could lead to an **increase** in VMT

- Increased travel demand
- Zero occupancy travel
- Parking located too far from points of interest
- Reduced trip chaining
- Mode shift away from mass transit
- Greater urban sprawl
- Significant share of privately owned cars
- Increased mobility of non-drivers
- Increased automated freight and delivery

Factors that could lead to a **decrease** in VMT

- Pay-per-use programs discourage unnecessary travel
- Lower car ownership
- Increased vehicle occupancy
- First-and-last-mile solution with transit
- Overall lower number of vehicles
- Less travel related to searching for parking
- Denser land development (less parking)
- Increased walking and biking
VEHICLE OWNERSHIP

Private ownership scenario

- Private ownership to take full advantage of added convenience
- Cars as a symbol of status and freedom
- Primarily for higher income households
- Mostly for exurban and rural areas

Shared-use/On-demand scenario

- Access to CAVs as a service
- CAVs owned by fleet operators
- Lower transportation costs for users with average or shorter commutes
- Mostly for denser urban areas
POSSIBLE ENERGY IMPACTS OF AUTOMATED VEHICLES

Scenario change in total light-duty vehicle fuel demand

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Private Ownership, Fuel Savings Only</td>
</tr>
<tr>
<td>2</td>
<td>Private Ownership, Fuel Use Increase Only</td>
</tr>
<tr>
<td>3</td>
<td>Private Ownership, Combined Effects</td>
</tr>
<tr>
<td>4</td>
<td>Shared Vehicles, Fuel Savings Only</td>
</tr>
<tr>
<td>5</td>
<td>All Identified Potential Fuel Use Increases</td>
</tr>
<tr>
<td>6</td>
<td>Vehicle Electrification</td>
</tr>
<tr>
<td>7</td>
<td>All Identified Potential Fuel Savings</td>
</tr>
<tr>
<td>8</td>
<td>All Effects</td>
</tr>
</tbody>
</table>

Source: NREL, 2013
TRANSFORMATION OF PARKING

V2I will enable more efficient use of existing parking supply.

Potential changes:
- Less parking demand (with shared CAVs)
- Smaller parking spots, less on-site and on-street parking
- Parking relocated on the back of lots or outside prime locations

Opportunities
- Lower or no parking requirements
- Reduced need for new municipal parking
- Reconversion in drop-off/pick-up areas
- Road diets

Threats
- Possible decline of municipal revenues
- Relocation of CAV parking impacts both VMT and congestion
TRANSFORMATION OF PARKING

TRANSITION PERIOD

One parking level for CAVs
Four parking levels for conventional cars
Floor heights compatible with use change.

Concept: Arrowstreet Architecture
TRANSFORMATION OF PARKING
CONNECTED AND AUTOMATED VEHICLES ONLY

CAVs only
One parking level for CAVs.
Ground floor converted to access area.
Top floors converted to other uses.

Upper levels evolve into residential, office, recreation and entertainment spaces.

Vehicles automatically charge when not being driven.

Users call cars via personal mobile devices and pick up vehicles in retrieval zones.

Concept: Arrowstreet Architecture

© CENTER FOR AUTOMOTIVE RESEARCH 2016 24
INTERACTION WITH NON-MOTORIZED TRAFFIC

- Automated driving promises increased safety for pedestrians and cyclists.
- CAVs can free up space for pedestrian areas and bike lanes (through road diets).
- Non-motorized transportation networks could become even more fragmented, especially in urban settings.
- Planning and design will need to consider non-motorized modes and CAVs equally to avoid unintendedly discouraging biking and walking.
IMPLICATIONS FOR MASS TRANSIT

- Passenger CAVs may reduce public transit demand.
- Equity issues and digital divide might be exacerbated.

Automated public transit could:
- be more affordable
- improve service in low-density areas
- act as feeder service to rail or BRT
- decrease wait times
- lead to job loss among public transit employees.

Pilot projects for automated transit already exist, mostly in Europe.
IMPLICATIONS FOR MASS TRANSIT

AUTOMATED SHUTTLES

Level 4 Automation, available today: low speed, fixed route, limited conflicts

- Navya Arma
- Easymile EZ10
- Local Motors Olli
- 2getthere
- Auro

© CENTER FOR AUTOMOTIVE RESEARCH 2016
Application of the connected vehicle concept to transit.

Goal: develop safety, mobility, and environmental applications.

Example: 3 University of Michigan transit buses retrofitted with connected vehicle technologies.
CROSS-CUTTING ISSUES

- Companies are developing automated vehicles that can function in today’s (imperfect) roads.

- Automated vehicles may not require significant infrastructure investment before they can be used.

- In the long term, gradual infrastructure changes could maximize the benefits of automated vehicles.

- V2I applications may require significant public investment.

- Ultimately, it is a matter of public policy choice.
MODIFICATIONS TO EXISTING INFRASTRUCTURE
ROAD MARKINGS

- Clear lane markings are beneficial for CAV operation, but are not necessary.
- Lane marking improvements are useful for non-CAVs too.
- AASHTO and SAE are working on a guideline for CAV-oriented lane markings specifications.
MODIFICATIONS TO EXISTING INFRASTRUCTURE

SIGNAGE AND SIGNALIZATION

- Traffic signal updates are necessary to enable V2I.
- V2I communication may replace some functions of signs and signals.
- Pedestrians, cyclists, or vehicles without V2I/V2V still need signs and signals.

Concepts of free-flow intersections would make access of pedestrians, cyclists, human-driven cars more difficult unless other modifications also are made.

Concept of Autonomous Intersection Management (AIM) – Massachusetts Institute of Technology (MIT), Swiss Institute of Technology (ETHZ), Italian National Research Council (CNR)

https://www.youtube.com/watch?v=4CZc3erc_l4
MODIFICATIONS TO EXISTING INFRASTRUCTURE
LANE WIDTH AND ROAD CAPACITY

- CAVs could allow for:
  - Reduced lane width requirements
  - Reduced number of lanes
  - Increased road throughput and efficiency
  - Medians to be removed or narrowed

- Space saved could be repurposed: sidewalks, bike lanes, green space.

- Road expansions might become unnecessary.

⚠️ Congestion relief effect could be cancelled out if VMT increases.
MODIFICATIONS TO EXISTING INFRASTRUCTURE
ACCESS MANAGEMENT

- Self-parking vehicles increase need for drop-off/pick-up points.
- Retrofit: curbside and on-site parking, bus stops, turn lanes, frontage and service roads
- Entirely new designs for drop-off/pick-up points
- New forms, location, and design of curb cuts
- Need for design standards for drop-off/pick-up areas

⚠️ Potential conflict with non-motorized traffic on sidewalks and bike lanes.
DIGITAL INFRASTRUCTURE

Potential roles of the public sector

- Creation, maintenance, and distribution of maps for automated driving:
  - Create open-sourced maps
  - Develop open standards
  - Collect and publish pertinent data
- Data exchange partnerships: Waze, Here, INRIX
- Support deployment of broadband: “dig-once” policies

Source: Waze
NEW INFRASTRUCTURE FOR V2I

Example of roadside equipment:

- **Roadside units (RSUs):** Devices that transmit data to, or receive data from, nearby vehicles.

- **Traffic signal controller:** Generates the Signal Phase and Timing (SPaT) message.

- **Traffic Management Center.** Collects and processes aggregated data from the infrastructure and vehicles.

- **Communication links.** Connect roadside equipment to the back office.

- **Support functions.**
NEW INFRASTRUCTURE FOR V2I

- Voluntary deployment over the next decades.
- Costs borne by local and state authorities, eligible for federal aid highway funding.
- AASHTO V2I Deployment Coalition
SE MICHIGAN CONNECTED VEHICLE ASSETS

Vehicle-to-Infrastructure (V2I)
- Red light violation warning
- Work zone warning/management
- Road weather management
- Pavement condition monitoring
NEW INFRASTRUCTURE FOR AUTOMATED DRIVING

Localization beacons
- Might be needed in tunnels and under bridges to improve accuracy of vehicle localization (GPS not adequate in such locations)

Minimal risk condition/fall back
- Might require wide road shoulders or pullout areas where CAVs can safely stop in case of a malfunction.
LAND FORM
MORE SPRAWL SCENARIO

If CAVs lower transportation costs...

- Commuter willingness to travel longer distances to and from work could increase;
- Household and businesses might locate farther from urban cores;
- Low-density land-use patterns, more urban sprawl, and greater infrastructure costs could develop.
LAND FORM
MORE DENSITY SCENARIO

If CAVs contribute to reduced on-site parking needs...

- Valuable, urban-core space could be freed up for redevelopment;
- More space could be dedicated to human occupancy and other non-parking uses;
- Denser, more walkable developments could be created.

“Shuffle City,” a matrix of compact urban cells, on-demand shared workspaces, and a shared mobility network of autonomous vehicles. (Source: Alloybuild)
REGIONAL AND LOCAL PLANNING

Near term

Develop policies for data collection and sharing

Incorporate CAVs in city goals for safety, GHG emissions, congestion

Start considering policies to manage the VMT and sprawl impact

Medium to long term

Update travel demand models and roadway design manuals

Reevaluate road capacity needs and road expansion projects

Reevaluate transit fleet management plans and service delivery plans

Plan infrastructure investments

Take impact of CAVs into account in long range transportation plans
ZONING

Potential changes to zoning ordinances:

- Eliminate or reduce minimum parking requirements
- Develop specifications for parking design for CAVs
- Develop specifications for the design of drop-off/pick-up areas
- Evaluate the opportunity for minimum requirements for drop-off/pick-up areas
LEGAL AND REGULATORY CONSIDERATIONS
LEGAL FRAMEWORKS

- Federal (International)
- State
- Local

Intelligent Transportation Systems

Connected Vehicle Systems

Automated Vehicle Systems

Statute (Legislation)
Regulation
Interpretation
Argument
Precedent

Civil Law
Common (Tort) Law

© CENTER FOR AUTOMOTIVE RESEARCH 2016
Current policy affects mainly state agencies, testing organizations, and manufacturers

No local requirements pending or anticipated

Opportunities for engagement
THINGS THAT COULD CHANGE LEGAL LANDSCAPE

- Automated vehicle deployment
- Connected vehicle mandate
- Federal legislation, regulation, and policy
- State legislation, regulation, and policy
- Local statute and policy
- Divergent case law rulings
LEGAL AND REGULATORY CONSIDERATIONS

DISCUSSION
THANK YOU!
QUESTIONS?

Valerie Sathe Brugeman, Senior Project Manager, Research  
vbrugeman@cargroup.org  
734.929.0474

Adela Spulber, Transportation Systems Analyst  
apulber@cargroup.org  
734.929.0488

Eric Paul Dennis, P.E., Transportation Systems Analyst  
edennis@cargroup.org  
734.929.0495

Center for Automotive Research  
3005 Boardwalk Drive, Suite 200  
Ann Arbor, MI 48108  
www.cargroup.org