Automated and Connected Vehicles

Implications for Design & Infrastructure

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Overview

- Technology Overview
  - Automated vs autonomous
  - Automated Vehicle (AV) vs Connected Vehicle (CV)
  - Under the hood: how AVs and CVs work

- Implications for Design & Infrastructure
  - Uncertainties
  - What do we know?
  - What do we do and when?
Defining Terms

- **Autonomous**
  - “existing or acting separately from other things or people”
  - “undertaken or carried on without outside control”

- **Automated**
  - “to run or operate by using machines, computers, etc., instead of people to do the work”

Source: Merriam-Webster Online

Image Credit: Google Official Blog
How Do AVs Work?

- Gather and integrate info from various sensors to understand the world
  - Radar
  - Lidar
  - GPS
  - Camera
  - Ultrasonic
  - HD Maps

Image Credit: UMTRI
Classifying AVs

SAE International, J3016
<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>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>

Tesla, etc.

Test vehicles

SAE International, J3016
Connected Vehicle Overview

- Connected Vehicle (CV)
  - Vehicles talk to each other, the infrastructure, and other modes through 5.9 GHz **DSRC** (potentially Wi-Fi and Cellular as well)
  - AKA: V2V, V2I, V2X
  - Focus on **safety**; also provides environmental and mobility benefits
  - Not telematics!

Image Credit: USDOT
Connected Vehicle Overview

Why Connected Vehicle?

- Anything you can do unconnected, you can do better connected
  - Better information about:
    - Vehicle location and trajectory
    - Traffic, road and weather conditions
  - Better information enables CV applications
    - Improve vehicle operations
    - Optimize system performance
# Connected Vehicle Overview

## V2I Safety
- Red Light Violation Warning
- Curve Speed Gap Warning
- Stop Sign Assist
- Spot Weather Impact Warning
- Reduced Speed/Work Zone Warning
- Pedestrian in Signalized Crosswalk Warning (Transit)

## V2V Safety
- Emergency Electronic Brake Lights (EEBL)
- Forward Collision Warning (FCW)
- Intersection Movement Assist (IMA)
- Left Turn Assist (LTA)
- Blind Spot/Lane Change Warning (BSW/LCW)
- Do Not Pass Warning (DNPW)
- Vehicle Turning Right in Front of Bus Warning (Transit)

## Road Weather
- Motorist Advisories and Warnings (MAW)
- Enhanced MDSS
- Vehicle Data Translator (VDT)
- Weather Response Traffic Information (WxTINFO)

## Environment
- Eco-Approach and Departure at Signalized Intersections
- Eco-Traffic Signal Timing
- Eco-Traffic Signal Priority
- Connected Eco-Driving
- Wireless Inductive/Resonance Charging
- Eco-Lanes Management
- Eco-Speed Harmonization
- Eco-Cooperative Adaptive Cruise Control
- Eco-Traveler Information
- Eco-Ramp Metering
- Low Emissions Zone Management
- AFV Charging / Fueling Information
- Eco-Smart Parking
- Dynamic Eco-Routing (light vehicle, transit, freight)
- Eco-ICM Decision Support System

## Agency Data
- Probe-based Pavement Maintenance
- Probe-enabled Traffic Monitoring
- Vehicle Classification-based Traffic Studies
- CV-enabled Turning Movement & Intersection Analysis
- CV-enabled Origin-Destination Studies
- Work Zone Traveler Information

## Mobility
- Advanced Traveler Information System
- Intelligent Traffic Signal System (I-SIG)
- Signal Priority (transit, freight)
- Mobile Accessible Pedestrian Signal System (PED-SIG)
- Emergency Vehicle Preemption (PREEMPT)
- Dynamic Speed Harmonization (SPD-HARM)
- Queue Warning (Q-WARN)
- Cooperative Adaptive Cruise Control (CACC)
- Incident Scene Pre-Arrival Staging Guidance for Emergency Responders (RESP-STG)
- Incident Scene Work Zone Alerts for Drivers and Workers (INC-ZONE)
- Emergency Communications and Evacuation (EVAC)
- Connection Protection (T-CONNECT)
- Dynamic Transit Operations (T-DISP)
- Dynamic Ridesharing (D-RIDE)
- Freight-Specific Dynamic Travel Planning and Performance
- Drayage Optimization

## Smart Roadside
- Wireless Inspection
- Smart Truck Parking

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Image Credit: USDOT

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Implications for Design & Infrastructure

- Uncertainty abounds
  - VMT and congestion?
  - Deployment timeline?
  - Capabilities and limitations?
  - Vehicle design changes?
  - Ownership model?
  - Human adoption and adaptations?
Implications for Design & Infrastructure

What do we know?

• Today’s limitations ≠ tomorrow’s systems
  • Sensor limitations, for example
    – Camera-based systems rely heavily on lane lines
    – GPS accuracy (3 meters)
    – Weather and lidar, etc.
  • Don’t design tomorrow’s systems based on today’s limitations
Implications for Design & Infrastructure

What do we know?

• AVs/CVs are not human
• Some design principles assume a human operator
  • Sight-distance and perception-reaction times
  • Speed limits
  • E.g., Stopping sight distance model

Function of:
Distance traveled during human perception and reaction + braking distance
Implications for Design & Infrastructure

- Stopping sight distance model example

Function of:
Distance traveled *during human perception and reaction* + braking distance

Replace with a superhuman, very fast computer

Systems designed on human assumptions may need revisiting
Implications for Design & Infrastructure

- Connectivity enables system-level benefits
  - Vehicles can “see around corners” when connected, for example

- Reduce:
  - Crashes
  - Non-recurring congestion

[Image: Image Credit: USDOT]
Implications for Design & Infrastructure

Addition of Safety Apps

- Red Light Violation Warning
- Stop Sign Gap Assist
- Left Turn Assist

Projected Impacts:
- Significant reduction in collisions, injuries, and fatalities at intersections.
- Non-recurring congestion resulting from incidents is reduced by 30%
Implications for Design & Infrastructure

- What do we do?
  - Change infrastructure design to leverage new capabilities?
    - Speed limits?
    - Advisory signs and warnings?
    - Intersection design?
    - Narrower lanes?
  - Change infrastructure operations?
Implications for Design & Infrastructure

Video Credit: MIT News (link)
Implications for Design & Infrastructure

- When do we make changes?
  - UNCERTAINTY!
  - Near to medium term (0 – 10 years, at least)
    - Mixed fleets with humans
    - OK to assume human limitations
  - Long term?
    - Opportunities to change design and increase efficiency, safety, etc.
Thank You!

Questions?

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