SPaT Technology
APWA Conference

John Thai, P.E.
City of Anaheim
April 10, 2019
Vehicles Designed for Comfort – then and now
Vehicles with Advanced Safety Features – then and now
Vehicles Designed for Productivity – then and now
Why Connected Vehicle Technology?
Connected and Autonomous Vehicles

SAE AUTOMATION LEVELS

<table>
<thead>
<tr>
<th>Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No Automation</td>
</tr>
<tr>
<td>1</td>
<td>Driver Assistance</td>
</tr>
<tr>
<td>2</td>
<td>Partial Automation</td>
</tr>
<tr>
<td>3</td>
<td>Conditional Automation</td>
</tr>
<tr>
<td>4</td>
<td>High Automation</td>
</tr>
<tr>
<td>5</td>
<td>Full Automation</td>
</tr>
</tbody>
</table>

- **Level 0 (No Automation):** Zero autonomy; the driver performs all driving tasks.
- **Level 1 (Driver Assistance):** Vehicle is controlled by the driver, but some driving assist features may be included in the vehicle design.
- **Level 2 (Partial Automation):** Vehicle has combined automated functions, like acceleration and steering, but the driver must remain engaged with the driving task and monitor the environment at all times.
- **Level 3 (Conditional Automation):** Driver is a necessity, but is not required to monitor the environment. The driver must be ready to take control of the vehicle at all times with notice.
- **Level 4 (High Automation):** The vehicle is capable of performing all driving functions under certain conditions. The driver may have the option to control the vehicle.
- **Level 5 (Full Automation):** The vehicle is capable of performing all driving functions under all conditions. The driver may have the option to control the vehicle.
# Connected and Autonomous Vehicles

## The 5 levels of driving automation

<table>
<thead>
<tr>
<th>Level</th>
<th>Human driver</th>
<th>Automated system</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>1</td>
<td>DRIVER ASSISTANCE</td>
<td>SOME DRIVING MODES</td>
</tr>
<tr>
<td>2</td>
<td>PARTIAL AUTOMATION</td>
<td>SOME DRIVING MODES</td>
</tr>
<tr>
<td>3</td>
<td>CONDITIONAL AUTOMATION</td>
<td>SOME DRIVING MODES</td>
</tr>
<tr>
<td>4</td>
<td>HIGH AUTOMATION</td>
<td>SOME DRIVING MODES</td>
</tr>
<tr>
<td>5</td>
<td>FULL AUTOMATION</td>
<td>SOME DRIVING MODES</td>
</tr>
</tbody>
</table>

For on-road vehicles

- Steering and acceleration/deceleration
- Monitoring of driving environment
- Monitoring when automation fails
- Automated system is in control

Source: SAE International
Lexus’ Vision of Level 2 Autonomous Vehicle

Lexus CoDrive

Function that provides steering support that is in line with the intentions of the driver and lane-changing support

Dynamic Radar Cruise Control

1. 100 km/h (set vehicle speed)
   - Constant speed cruising
   - No preceding vehicle
2. 100 → 80 km/h
   - Preceding vehicle detected (80 km/h)
   - Constant speed cruising
3. 80 → 0 km/h
   - Preceding vehicle stopped
4. Driver start-off operation → Follow-up cruising restarts
   - Preceding vehicle starts off

Lane Tracing Assist

1. Lane marker recognition by camera
2. Path of preceding vehicle
Based on (1) (2), support steering operation necessary for lane keeping
When the lane marker is not clear or faded, such as in a traffic jam, use (2) to assist in following the preceding vehicle

Lane Change Assist (Japan only)

1. After the driver confirms safety, a lane change instruction is issued by using the turning signal
2. The system executes lane change with steering control while confirming peripheral safety
3. Switch to Lane Tracing Assist (LTA) after lane change
   - Signal turns off automatically

LEXUS First
Lexus Safety System + A
How Does CV (BSM) Technology Work?
How Does CV (SPaT) Technology Work?

A local or state back office, private operator, or traffic management center collects and processes data from the roads and vehicles.

Backhaul (fiber optics cables) connect controllers to the back office, ensuring timely data processing.

An in-vehicle red light violation warning alerts a driver who is about to run a red light.

A traffic signal controller transfers information on the signal phase (green, yellow, red) and the amount of time remaining until the light changes to the RSU, which then broadcasts that data to the vehicle.

A roadside unit (RSU) transmits data to the vehicle.

On-board equipment receives data from the RSU radio and displays an appropriate alert to the driver.

Source: GAO analysis of Department of Transportation documents | GAO-15-778
A Closer Look at the On-Board Unit (OBU) and the Roadside Unit (RSU)

Vehicle-to-Vehicle (V2V):
- Intersection Movement Assist (IMA)
- Left Turn Assist (LTA)
.... etc.

Mobility:
- Transit Signal Priority
- Fleet Management
.... etc.

Vehicle-to-Infrastructure (V2I):
- Curve Speed Warning (CSW)
- Transit Pedestrian Warning
.... etc.

Environment:
- Eco Cooperative Adaptive Cruise Control
- Eco-traffic signal timing
.... etc.
SPaT Connectivity Diagram

Figure 13. Latency Requirements of Active Safety Applications

Communications Technologies

<table>
<thead>
<tr>
<th>Technology</th>
<th>Latency (in seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.9 GHz DSRC</td>
<td>0.002 secs</td>
</tr>
<tr>
<td>Most Stringent latency requirement for Active Safety</td>
<td>0.02 sec</td>
</tr>
<tr>
<td>Least stringent latency requirement for Active Safety</td>
<td>1 sec</td>
</tr>
</tbody>
</table>

- WiFi 802.11 (3 – 5 secs)
- Cellular (1.5 – 3.5 secs)
- Bluetooth (3 – 4 secs)
- WiMax (1.5 – 3.5 secs)

ACTIVE SAFETY LATENCY REQUIREMENTS

- Traffic Signal Violation warning: 0.1 sec
- Curve Speed Warning: 1 sec
- Emergency Electronic Brake Lights: 0.1 sec
- Pre-Crash Sensing: 0.02 sec
- Cooperative Forward Collision Warning: 0.1 sec
- Left Turn Assistant: 0.1 sec
- Lane Change Warning: 0.1 sec
- Stop Sign Movement Assistance: 0.1 sec
Typical RSU/OBU Installations
The Interoperability Twist in Anaheim...
RSU/OBU Interoperability Demonstration for SPaT

Savari
TrafficCast
Siemens
A Preview of CV Applications...

- **Forward Collision Warning**: Warnings the driver when a vehicle ahead is stopped or traveling slower and there is a risk of a rear-end collision.

- **Motorist Advisories and Warnings**: Issues advisories to drivers about deteriorating road and weather conditions on specific roadway segments.

- **Red Light Violation Warning**: Issues warning to the driver if he is about to run a red light.
A Preview of CV Applications...

Forward Collision Warning
Warms the driver when a vehicle ahead is stopped or traveling slower, and there is a risk of a rear-end collision.
A Preview of CV Applications...
A Preview of CV Applications...

1. **Lane Change Warning/Blind Spot Warning**
   - Warns drivers when changing lanes if there is a car in a blind spot.

2. **Queue Warning and Speed Harmonization**
   - Warns drivers of congestion ahead, as well as provides target speed advice.

3. **Eco-Traffic Signal Priority**
   - Gives signal priority to transit vehicles approaching a signalized intersection, taking into consideration the vehicle’s location, speed, type, schedule, and number of passengers. Priority decisions are based on real-time traffic and emissions data to produce the least amount of emissions at signalized intersections.
Toyota and Lexus Chose DSRC Technology

Toyota and Lexus to Launch Technology to Connect Vehicles and Infrastructure in the U.S. in 2021

Will Provide Enhanced Safety Benefits to Drivers, Including Increased Road Safety and Efficiency, While Enabling Greater Advances in Connected- and Automated-Driving Systems

Plan Accelerates Adoption of Vehicle-to-Vehicle and Vehicle-to-Infrastructure Communications Capabilities

Will Begin Deploying 5.9 GHz Dedicated Short-Range Communications (DSRC); Encourages All Automakers to Adopt DSRC in the U.S.

April 16, 2018

PLANO, Texas, April 16, 2018 – Imagine a world where vehicles could ‘talk’ to each other and to the surrounding environment to help keep their drivers and their passengers safe.

Toyota and Lexus want to advance that conversation, which is why the companies plan to start deployment of Dedicated Short-Range Communications (DSRC) systems on vehicles sold in the United States starting in 2021, with the goal of adoption across most of its lineup by the mid-2020s. Toyota and Lexus plans to introduce DSRC represent a significant step forward in creating a safer and more efficient driving ecosystem while advancing connected and automated technology deployment.

“By allowing vehicles’ intelligent systems to collaborate more broadly and effectively through DSRC technology, we can help drivers realize a future with zero fatalities from crashes, better traffic flow and less congestion,” said Jim Lentz, CEO of Toyota Motor North America (TMNA).