A Collaborative Approach
Towards a Regional Research and Technology Center

Connected and Automated Vehicles Summit

October 17, 2019

Civil and Environmental Engineering
UNIVERSITY OF WISCONSIN-MADISON
Welcome!

Madison, Wisconsin USA
Connected Vehicles

CV

IoT

V2V

V2I

V2X
CV/AV Simultaneous Operation

**Autonomous Vehicle**
Operates in isolation from other vehicles using internal sensors

**Connected Vehicle**
Communicates with nearby vehicles and infrastructure

**Connected Automated Vehicle**
Leverages autonomous and connected vehicle capabilities
# SAE Levels of Vehicle Automation

<table>
<thead>
<tr>
<th>Level</th>
<th>Description</th>
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<tbody>
<tr>
<td>0</td>
<td>No Automation&lt;br&gt;Zero autonomy; the driver performs all driving tasks.</td>
</tr>
<tr>
<td>1</td>
<td>Driver Assistance&lt;br&gt;Vehicle is controlled by the driver, but some driving assist features may be included in the vehicle design.</td>
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<tr>
<td>2</td>
<td>Partial Automation&lt;br&gt;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.</td>
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<tr>
<td>3</td>
<td>Conditional Automation&lt;br&gt;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.</td>
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<tr>
<td>4</td>
<td>High Automation&lt;br&gt;The vehicle is capable of performing all driving functions under certain conditions. The driver may have the option to control the vehicle.</td>
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<tr>
<td>5</td>
<td>Full Automation&lt;br&gt;The vehicle is capable of performing all driving functions under all conditions. The driver may have the option to control the vehicle.</td>
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</table>
Why the rush to AVs?
Safety!
Smart Cities

- Smart Parking
- Public Safety
- Smart Buildings
- Smart Environment
- Traffic Management
- Smart Energy
- Smart Home
- Intelligent Shopping
- Water Quality
- Gas & Water Leak Detection
- Smart Street Lights
- Electromagnetic Emissions
- Internet of Things
- Open Data
- Education
- Waste Management
- Smart Health
- Electric Vehicle Charging
- Air Pollution

Smart City
What will transport look like in 2069?

- All vehicles SAE Level 5, fully IoT capable, and non-fossil fuel
What will transport look like in 2069?

• All commercial trucking driverless and platooned
What will transport look like in 2069?

Signal-less intersections the norm – vehicles negotiate space-time dynamically
What will transport look like in 2069?

What do you predict??
What will transport look like in 2069?

- It depends on a combination of how we plan it, what people place emphasis on as important, and what the incentives are.
- With connected and automated vehicles, this can be a wide spectrum.
- How do we get there?
  - Multidisciplinary Private/Public Collaboration
  - Research
  - Testing and Validation
  - Public Engagement
  - Urban, Regional, and Rural Planning
  - Artificial Intelligence
  - Navigating the “messy middle”
Human Factors

https://towardsdatascience.com/deep-learning-for-self-driving-cars-7f198ef4cfa2
Wisconsin Full-Scale Driving Simulator
Left-Turn Traffic Signal Operations
FYA Implementation

NCHRP Report 493: Evaluation of Traffic Signal Displays for Protected/Permissive Left-Turn Control

Source: Brehmer et al. 2003
Implementation Flashing Yellow Arrows

- Impacts from exposure to FYA permissive indication
  - Knodler et. al. 2007a, 2007b, 2009
  - Noyce et al. 2007

- FYA and CG indications with and without supplementary signage
  - Brehmer, 2003
  - Schattler et al. 2013, 2015

- Red-light running is a leading cause for intersection crashes in the United States
  - FHWA, 2009
Traffic Control

Four-way traffic light system

Only red and green indications

Yellow indication added

1914

1917

1920

1922

1931

1963

1984

2007

2019

Manual traffic control

Automated traffic control

Pedestrian crossing indications

First automated traffic lights

City-wide intelligent traffic control

Highway ramp metering

Intelligent traffic control

Flashing Yellow Arrow

V2I & I2V

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V2I & I2V
Decision-Making Automation

(source: https://www.shutterstock.com/video/clip-7837867-rush-hour-traffic-midtown-manhattan-night-illuminated)
Research Questions

Automation disengagements

Drivers’ take-over performance

Are drivers capable of cooperating with a shared automation system?

Drivers’ performance after resume control when using a SAE L3 automaton?

How do different situations affect drivers’ reaction time and take-over performance?

How are different automation surprises associated with necessary different lead time?

How does the timing of warnings affect the traffic efficiency as the traffic volume increases?

Does control transitions have an impact on intersection efficiency/safety?

How do different types of messages affect drivers’ permissive left-turn behavior?
Research Gaps and Hypotheses

Automation levels
- SAE Level 3

Driving behavior
- Non-driving related tasks
- Take-Over Request design
- Takeover performance

Situations
- Urban environments
- Signalized intersections
- Permissive left turns

Impact
- Traffic operations and safety at signalized intersections
Take-Over Request Design in Industry

TOR interface when the traffic jam pilot of Audi A8 request drivers to take back control (source: AUDI AG, Image No: A1710305)

The virtual cockpit display of Pilot Assist: (1) Pilot Assist is off when the steering wheel symbol is grey, and (2) Pilot Assist is on when the steering wheel symbol is green (Volvo, 2019).
"Caution Fog" alert and the takeover request (Walch et al, 2015)

"Heavy rain" alert and the takeover request (Vogelpohl et al, 2018)

Takeover-request icon shown on the instrument cluster left: (Erikson and Stanton, 2017); middle: (Naujoks et al., 2018), right (Petermeijer, et al, 2017)

Automation available (left) and request-to-intervene (right): (Jarosch et al, 2019)

Takeover-request icon design (zeeb et al, 2017)
TOR Design

Please resume control and turn left!

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Please resume control and turn left!
Vehicle to Anything Communications
Turning Crosswalk Pedestrian Warning

Source: NYC CV Pilot
Issues Surrounding CV/AV

- Data
- Vehicle Cybersecurity
- Information Privacy
- Vehicle Ethics
- Crashworthiness
- System Disengagements / Driver Re-Engagement
- Complex Driving Situations
- Deep Learning / Artificial Intelligence
- Vehicle Assertiveness
- **Technology – Will we shape it or let it shape us?**
MAASHTO States

- Minnesota
- Wisconsin
- Iowa
- Illinois
- Indiana
- Ohio
- Kentucky
- Missouri
- Kansas
Automated, Connected, Electrified, and Shared (ACES) transportation innovation ecosystem
Cooperative Research

- Regional Research and Technology Center
- Agency – University – Industry Collaborations
Thank You!

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