The Future of Transportation: Achieving Equity and Mobility through Self-Driving Vehicles

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Overview

- Levels of vehicle automation
- Concept vehicle and transportation system
- Motivating factors for improved transportation
- Potential benefits of self-driving vehicles
- Trends: Transportation in the year 2045
- Opportunities
- Challenges
- VTTI’s Automated Vehicle Research
Are we there yet? Are we there yet? Are there yet?
### SAE J3016: Taxonomy and Definitions for Terms Related to On-Road Motor Vehicle Automated Driving Systems

<table>
<thead>
<tr>
<th>SAE Level</th>
<th>Name</th>
<th>Steering, acceleration, deceleration</th>
<th>Monitoring 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></td>
<td></td>
<td></td>
<td>All driving modes</td>
</tr>
<tr>
<td>1</td>
<td>Driver assistance</td>
<td></td>
<td></td>
<td></td>
<td>Some driving modes</td>
</tr>
<tr>
<td>2</td>
<td>Partial automation</td>
<td></td>
<td></td>
<td></td>
<td>Some driving modes</td>
</tr>
<tr>
<td>3</td>
<td>Conditional automation</td>
<td></td>
<td></td>
<td></td>
<td>Some driving modes</td>
</tr>
<tr>
<td>4</td>
<td>High automation</td>
<td></td>
<td></td>
<td></td>
<td>Some driving modes</td>
</tr>
<tr>
<td>5</td>
<td>Full automation</td>
<td></td>
<td></td>
<td></td>
<td>All driving modes</td>
</tr>
</tbody>
</table>

Source: Adapted from SAE Standard J3016 (SAE, 2014).
Nissan IDS Concept Technology

- Connectivity
- Mapping
- Machine vision
- 360 recognition
  - Radar, Lidar, other
- Dynamic scheduling
- Pedestrian/cyclist
- Wireless charging lanes/parking
- Transfer of control
- Piloted parking

Video Courtesy of Nissan Newsroom
What’s the Future of Transportation?

Second only to housing, currently transportation costs are the largest expense for American households – costing more than food, clothing, and healthcare

Motivating Factors for Improved Transportation

• Communities designed with the car in mind

• Urban sprawl
  – Difficult to get anywhere without a car
  – Highest transportation expenditures

• American Public Transportation Association
  – Small towns and rural communities
    • 2/3 of all residents have limited transportation options
    • 41% of residents have no access to transit
    • 25% have below-average transit services

• Who’s living without a car? (Berube, Deakin, & Raphael, 2006)
  – 20% of African-American households
  – 14% of Latino households
  – 13% of Asian households
Potential Benefits of Self-Driving Vehicles

- Health
- Employment
- Age in place
- Quality of life
- Safety

~32,000 vehicle related fatalities
~5,000 pedestrians and bicyclist
How will the future look if we don’t invest in a new transportation system?
Trends: 2045

- Population will grow by **70 million** and will have **twice** the number of **seniors**
- People will start moving towards **megaregions**
- **Freight** will increase by **45%** due to online shopping
- People will **reduce trips** by **private car** in favor of other modes of transportation
- Consolidation of airline hubs and many mergers will make us **rethink traditional travel**
- **Robotic** systems will assist with infrastructure maintenance
- **Climate change** will alter sea level, increase temperatures, and develop more frequent and adverse climate events (e.g., hurricanes)
Opportunities for Current and Emerging Self-Driving Vehicle Applications

• Mobility On-Demand
  – **Group rapid transit**: public transportation, vanpools, and ridesharing
  – **Personal rapid transit**: personal vehicles, last-mile services (including parking valet alternatives), taxi and on-demand services
Potential Challenges Associated with Implementation

- Legacy vehicles
- Fail-safe & fail-operational states
- Safe harbor
- External communications
- Security
- Accessibility
- Multi-jurisdictional collaboration
- Policies
Automated Vehicle Research

- Sample studies
  - Human Factors Evaluation of Level 2 and Level 3 Automated Driving Concepts
  - Automated Vehicle Crash Rate Comparison Using Naturalistic Data
Human Factors Evaluation of Level 2 and Level 3 Automated Driving Concepts

- Experiment 1 (L2 ADS)
- 2009 Chevy Malibu

- Experiment 2 (L2 ADS)
- 2010 Cadillac SRX

- Experiment 3 (L3 ADS)
- 2012 Lexus RX450h
## Experimental Design

### Experiment 1 – L2
- Alert Type (within)
  - Cautionary
  - Staged
  - Imminent
- Alert Modality (within)
  - Unimodal
  - Multimodal
- 25 participants
- One 90-min session

### Experiment 2 – L2
- Driving Session (within)
- Event Type (within)
  - Alert
  - No Alert
  - No Lane Drift
- Prompt Condition (between)
  - 2-s
  - 7-s
  - No prompt
- 56 participants
- Three 60-min sessions

### Experiment 3 – L3
- Driving Session (within)
- Alert Type (within)
  - Staged
  - Imminent – External Threat
  - Imminent – No External Threat
- 25 participants
- Three 30-min sessions

- Alerting operators to regain control
- System prompt effectiveness over time
- Human – automation system performance over time
Key Takeaways

• Take Over Request
  • Most effective hand-off strategies were those that incorporated nonvisual components
    – Effective countermeasures to primary task reversals when drivers performed non-driving tasks

• Regain Control
  • L2 mean of 1.3 s (S.E. = 0.1 s)
    – Imminent visual and haptic alert
  • L3 mean of 2.3 s (S.E. = 0.2 s)
    – Imminent visual plus auditory alert

• Trust
  • High trust in automation for both levels of automation but calibrated
    – Trust was reduced after events where something occurred unannounced
Vehicle Automation Theories

- Primary Task Reversal
- Alert Annoyance Habituation
Automated Vehicle Crash Rate Comparison Using Naturalistic Data
SHRP 2 Naturalistic Data Study

- 34 million VMT
- 2 petabytes of data
- 3,542 drivers
- > 3,300 vehicles
- > 1,600 crashes
- 4,368 data years
- 5,512,900 trip files
What can 1,000,000 hours of watching and measuring drivers can tell you?
Heinrich Triangle

Crash (L1)

Crash (L2)

Crash (L3)

Crash (L4)

Near Crash

Crash Relevant Conflict
Self-Driving Car Project Data

- Data received for period 2009 - October 31, 2015
  - Mountain View, CA
  - 1,266,611 miles
  - 2010: First crash
  - 2012: First crash in autonomous mode

- 16 Crashes
  - 5 driver in control
  - 11 autonomous
    - None at-fault
## SHRP 2 and Self-Driving Car Crash Summary

<table>
<thead>
<tr>
<th>Crash Severity Level</th>
<th>SHRP 2 - Overall</th>
<th>SHRP 2 - with Police Report</th>
<th>Self-Driving Car</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 1</td>
<td>120</td>
<td>34</td>
<td>2</td>
</tr>
<tr>
<td>Level 2</td>
<td>179</td>
<td>12</td>
<td>2</td>
</tr>
<tr>
<td>Level 3</td>
<td>633</td>
<td>0</td>
<td>7</td>
</tr>
</tbody>
</table>
Crash Comparison

- SHRP 2 Age-Adjusted
- Self-Driving Car in Autonomous Mode

<table>
<thead>
<tr>
<th>Level</th>
<th>SHRP 2</th>
<th>Self-Driving Car</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 1</td>
<td>2.5</td>
<td>1.6</td>
</tr>
<tr>
<td>Level 2</td>
<td>3.3</td>
<td>1.6</td>
</tr>
<tr>
<td>Level 3</td>
<td>14.4</td>
<td>5.6</td>
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</tbody>
</table>
What else is VTTI doing?

- Policy impact
- Develop advanced testing facilities
- Perform pragmatic research
Smart Road Test Track & All-Weather Testing

Virginia International Raceway

NextGen DAS

MiniDAS

Virginia Connected Corridor

Sample Test Route

Virginia Automated Corridor