Autonomous Vehicle’s Impact on Transportation Infrastructure

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Orange County Public Works
June 11, 2018
I. What is an Autonomous Vehicle (AV)

II. How soon will AV become a reality

III. How will AV impact the transportation infrastructure
   a. Safety
   b. Mobility
   c. Accessibility

IV. What should transportation engineers be ready for
   a. Challenges
   b. Opportunities
# What is an Autonomous Vehicle

**Automatic Levels of Autonomous Cars**

<table>
<thead>
<tr>
<th>Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 0</td>
<td>These cars have no autonomous features.</td>
</tr>
<tr>
<td>Level 1</td>
<td>These cars can handle one task at a time, like automatic braking.</td>
</tr>
<tr>
<td>Level 2</td>
<td>These cars would have at least two automated functions.</td>
</tr>
<tr>
<td>Level 3</td>
<td>These cars handle “dynamic driving tasks” but might still need intervention.</td>
</tr>
<tr>
<td>Level 4</td>
<td>These cars are officially driverless in certain environments.</td>
</tr>
<tr>
<td>Level 5</td>
<td>These cars can operate entirely on their own without any driver presence.</td>
</tr>
</tbody>
</table>

*Source: SAE International*
How soon will AV become a reality

Either passed legislation, issued executive orders, or announced initiatives to accommodate self-driving vehicles on public roads:

- 2012: 6
- 2013: 9
- 2014: 12
- 2015: 16
- 2016: 20
- 2017: 33
- **2018: 37** (5/21/2018)

How soon will AV become a reality

- Sweden: Last December, Volvo launched its Drive Me project, which provided self-driving cars to a number of people.
- China: Shanghai issued its first self-driving licenses in 2018.
- South Korea: The K-City is the largest town model ever built for self-driving car experimentation.
- UK: The government passed a bill to draw up the liability and insurance policies related to autonomous vehicles.
- California: In 2018, DMV allowed fully autonomous vehicles with no driver to operate on its public roads.
- Arizona: Governor Ducey gave the green light for cars without drivers to operate on public roads in 2018.
- Germany: the parliament passed a law last May that allows companies to test self-driving cars on public roads.
- Netherlands: Council of Ministers first approved driverless vehicle road testing in 2015.
- Singapore passed legislation recognizing motor vehicles don’t require a human driver.
- New Zealand: The country has no specific legal requirements for cars to have drivers.

Graphic: Tony Peng | Synced

How soon will AV become a reality

Global Market for Cars

How will AV impact the Transportation Infrastructure

Foreseeable Impacts

- **Safety**
- **Mobility**
  - movement of people and goods
- **Accessibility**
  - the ability to reach desired goods, services, activities and destinations

http://www.vtpi.org/measure.pdf
National Motor Vehicle Crash Causation Survey (NMVCCS), conducted from 2005 to 2007

- **Recognition Errors**: inattention, internal & external distractions, inadequate surveillance... (41%)
- **Decision Errors**: too fast, false assumptions, illegal maneuver, misjudgment... (34%)
- **Performance Errors**: overcompensation, poor directional control, panic... (10%)
- **Non-Performance Errors**: sleep, physical impairment... (7%)
- **Other/Unknown Driver Error** (8%)

https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812115
## Mobility – VMT (Non-Drivers)

<table>
<thead>
<tr>
<th>AGE GROUP</th>
<th>TOTAL DRIVERS</th>
<th>ADDITIONAL DRIVERS</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
<td>% of TTL Drivers</td>
<td>Drivers as % of Age Group</td>
</tr>
<tr>
<td>UNDER 16</td>
<td>397,541</td>
<td>0.2</td>
<td>9.6</td>
</tr>
<tr>
<td>16-19</td>
<td>9,158,699</td>
<td>4.5</td>
<td>44.4</td>
</tr>
<tr>
<td>20-24</td>
<td>17,468,175</td>
<td>8.3</td>
<td>81.1</td>
</tr>
<tr>
<td>25-29</td>
<td>18,431,274</td>
<td>8.8</td>
<td>85.0</td>
</tr>
<tr>
<td>30-34</td>
<td>17,849,093</td>
<td>8.5</td>
<td>89.7</td>
</tr>
<tr>
<td>35-39</td>
<td>18,161,385</td>
<td>8.6</td>
<td>88.4</td>
</tr>
<tr>
<td>40-44</td>
<td>19,177,750</td>
<td>9.1</td>
<td>91.4</td>
</tr>
<tr>
<td>45-49</td>
<td>20,814,204</td>
<td>9.9</td>
<td>91.2</td>
</tr>
<tr>
<td>50-54</td>
<td>20,628,105</td>
<td>9.8</td>
<td>94.8</td>
</tr>
<tr>
<td>55-59</td>
<td>18,439,510</td>
<td>8.8</td>
<td>97.2</td>
</tr>
<tr>
<td>60-64</td>
<td>15,857,585</td>
<td>7.5</td>
<td>100.0</td>
</tr>
<tr>
<td>65-69</td>
<td>11,468,003</td>
<td>5.5</td>
<td>97.3</td>
</tr>
<tr>
<td>70-74</td>
<td>8,230,912</td>
<td>3.9</td>
<td>91.4</td>
</tr>
<tr>
<td>75-79</td>
<td>6,157,899</td>
<td>2.9</td>
<td>84.1</td>
</tr>
<tr>
<td>80-84</td>
<td>4,463,610</td>
<td>2.1</td>
<td>76.7</td>
</tr>
<tr>
<td>85 AND OVER</td>
<td>3,411,194</td>
<td>1.6</td>
<td>60.6</td>
</tr>
<tr>
<td>TOTAL</td>
<td>210,114,939</td>
<td>100.0</td>
<td>85.7</td>
</tr>
</tbody>
</table>

16.4% 14.2%


### Mobility – VMT (Drivers)

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Total Daily Driving Trips</th>
<th>Total Annual Driving Trips</th>
<th>Daily Duration of Driving Trips (minutes)</th>
<th>Annual Duration of Driving Trips (hours)</th>
<th>Estimated Miles Driven Daily (miles)</th>
<th>Estimated Miles Driven Annually (miles)</th>
</tr>
</thead>
<tbody>
<tr>
<td>16-19</td>
<td>1.5</td>
<td>548</td>
<td>28</td>
<td>170</td>
<td>19.7</td>
<td>7,300</td>
</tr>
<tr>
<td>20-29</td>
<td>2.0</td>
<td>730</td>
<td>49</td>
<td>298</td>
<td>31.0</td>
<td>11,315</td>
</tr>
<tr>
<td>30-49</td>
<td>2.3</td>
<td>840</td>
<td>54</td>
<td>329</td>
<td>36.0</td>
<td>13,140</td>
</tr>
<tr>
<td>50-64</td>
<td>2.1</td>
<td>767</td>
<td>47</td>
<td>286</td>
<td>30.0</td>
<td>10,950</td>
</tr>
<tr>
<td>65-74</td>
<td>1.8</td>
<td>657</td>
<td>39</td>
<td>237</td>
<td>23.0</td>
<td>8,395</td>
</tr>
<tr>
<td>75+</td>
<td>1.7</td>
<td>621</td>
<td>36</td>
<td>219</td>
<td>19.0</td>
<td>6,935</td>
</tr>
<tr>
<td>Average</td>
<td>2.0</td>
<td>730</td>
<td><strong>46</strong></td>
<td>280</td>
<td><strong>29.2</strong></td>
<td><strong>10,658</strong></td>
</tr>
</tbody>
</table>


How will AV impact the Transportation Infrastructure
## Mobility – VMT (Drivers)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Daily Driving Time per Driver (min.)</td>
<td>49.35</td>
<td>56.28</td>
<td>62.32</td>
<td>56.09</td>
<td>46</td>
</tr>
<tr>
<td>Daily VMT (mile)</td>
<td>28.49</td>
<td>32.14</td>
<td>32.73</td>
<td>28.97</td>
<td>29.2</td>
</tr>
<tr>
<td>Annual VMT per Driver (mile)</td>
<td>13,125</td>
<td>13,476</td>
<td>13,827</td>
<td>12,888</td>
<td>10,658</td>
</tr>
<tr>
<td>Vehicles per Household</td>
<td>1.77</td>
<td>1.78</td>
<td>1.89</td>
<td>1.86</td>
<td>2.1</td>
</tr>
</tbody>
</table>

## Scenario Analysis

How will AV impact the Transportation Infrastructure

How will AV impact the Transportation Infrastructure

**Case 1: 30-min away**

**Scenario 1: (2 cars)**
- Car 1: AB + BA
- Car 2: AC + CD + DC + CA

**Scenario 2: (1 car)**
- AV: AB + BA + AC + CD + DC + CA + AB + BA

**Case 2: 60-min away**

**Scenario 3: (1 car)**
- AV: AB + BA + AC + CD + DC + CA + AB + BA + AD + DA

**Total VMT Increases**
How will AV impact the Transportation Infrastructure

Accessibility

<table>
<thead>
<tr>
<th>Mode</th>
<th>Cost per passenger-mile</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personal Car</td>
<td>$0.57</td>
</tr>
<tr>
<td>Conv. Taxi</td>
<td>$3.46</td>
</tr>
<tr>
<td>Uber</td>
<td>$2.86</td>
</tr>
<tr>
<td>AV</td>
<td>$0.35</td>
</tr>
<tr>
<td>Public Transit</td>
<td>$0.23</td>
</tr>
<tr>
<td>Work at Home</td>
<td>$0.11</td>
</tr>
</tbody>
</table>

How will AV impact the Transportation Infrastructure:

- Less Ridership in Public Transit
- More trips in Single Passenger Vehicles
- Total VMT Increases

What should Transportation Engineers be ready for

Challenges

• Congestion Increases

• Land Use Change
  o Urban Sprawl

• Infrastructure Integration
  o Emergency Response, Traffic Control, TMC...
  o Pedestrian, Bike, Public Transit

Photo credit: wikipedia.org
What should Transportation Engineers be ready for for

Opportunities

- Congestion Management
  - 2013 -- $124 Billion
  - 2014 -- $160 Billion

- Parking Demand
  - 2002 -- $127 Billion
  - 2005 -- $31,000 ea. in L.A.

Dr. Shoup, Donald. “The High Cost of Free Parking.” 2005
Opportunities – Congestion Management

BPR Volume-Delay Function:

\[ T_f = T_0(1 + \alpha[V/C]^\beta) \]  

- \( T_f \): travel time
- \( T_0 \): free flow travel time
- \( V \): traffic volume
- \( C \): capacity
What should Transportation Engineers be prepared for

Capacity Increases (Roadway Segment)

$q = k \times v$

Where:
- $q$ = Flow (veh/hr)
- $v$ = Speed (mph)
- $k$ = Density (veh/mi)

2200 pc/h/ln $\rightarrow$ 4000 pc/h/ln (82% increase)
What should Transportation Engineers be ready for

Capacity Increases (Intersection)

Platoon Control by V2I Technology

Dr. Henry Liu, Next Generation Traffic Control with Connected and Automated Vehicles, 2016, UMTRI
## Opportunities – Free Flow Time Decreases

<table>
<thead>
<tr>
<th>Road Type</th>
<th>Target Headway</th>
<th>Proportion of the Autonomous Vehicles</th>
<th>Travel Speed Percentage Increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freeway</td>
<td>0.5 s</td>
<td>0%  20%  40%  60%  80%  100%</td>
<td>1.07  1.15  1.26  1.42  1.67</td>
</tr>
<tr>
<td>Major Arterial</td>
<td>0.5 s</td>
<td>0%  20%  40%  60%  80%  100%</td>
<td>1.04  1.1  1.18  1.25  1.39</td>
</tr>
</tbody>
</table>


Opportunities – Parking Demand

Average No. of Vehicles per Household in the U.S.

2.1

An average car is parked 95% of the time. Let’s check...

46 min / day → 3.2% driving time

→ 96.8% idle time

Private Car Parking Demand: -45%

Ownership: -43%
VMT: +75%

$57 Billion Saving

What should Transportation Engineers be ready for

Opportunities – Planning, Design & Operation

• Computer Simulation for better planning and design
• Dynamic Routing for Congestion Mitigation
• Accurate Time Estimate for Transit Scheduling & Mode Choices
Conclusion

• Reality check

• Impact is inevitable

• Visionary planning & advanced technology are necessary
References

- Shoup, Donald C. “The High Cost of Free Parking,” University of California Transportation Center, No. 351, 1997.
THANK YOU

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