Autonomous Vehicles and Potential Impacts on DOT Maintenance Operations

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Nomenclature - Connected

Vehicles Connected to:

Each other
- Speed
- Braking
- Other information needed to make decisions

Infrastructure
- Roadway conditions
- Signal condition
- Levels of congestion on various routes
- Much more
Nomenclature – Autonomous

http://www.ill.mit.edu/publications/imagespublications/urbanchallenge1.jpg


http://si.wsj.net/public/resources/images/BN-MC635_0114dr_P_20160114143938.jpg


These are available today
Self Driving Vehicles are Not a New Idea

1957 Advertisement about electricity and electronics.

Herbie the Love Bug from the 1968 Disney Shows.

Knight Rider series in the 80’s
Navigation Technology

✓ High Resolution Mapping
✓ Machine Vision: LIDAR, cameras, sensors, etc.
  • GPS and other signals
✓ Road Fingerprinting
✓ Crowd Sourcing
✓ Connected AV Infrastructure

✓ Technology Affecting Maintenance of Roads
When ??

Tesla predicts fully autonomous available 2018

Google predicts fully autonomous available 2020

Source: IHS

http://1.bp.blogspot.com/-68WQ4LKWiTg/VltzSFdmlBI/AAAAAAABEwI/jvUXiYz1dyY/s1600/levels_of_autonomy.png
## Rate of Adoption of Technology

<table>
<thead>
<tr>
<th>Technology</th>
<th>Years to 90% Adoption in US</th>
<th>Percent Adoption per year</th>
<th>Barriers to Adoption Rate</th>
<th>Benefited Rate of Adoption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automobiles</td>
<td>75</td>
<td>1.2</td>
<td>Infrastructure, Manufacturing, cost</td>
<td>Tax Dollars/Fees Funded infrastructure expansion</td>
</tr>
<tr>
<td>Electricity</td>
<td>42</td>
<td>2.1</td>
<td>Infrastructure, Production</td>
<td>Tax Dollars/Fees Funded infrastructure expansion</td>
</tr>
<tr>
<td>Telephone</td>
<td>73</td>
<td>1.2</td>
<td>Infrastructure</td>
<td>Tax Dollars/Fees Funded infrastructure expansion</td>
</tr>
<tr>
<td>Radio</td>
<td>23</td>
<td>3.9</td>
<td>Infrastructure</td>
<td>Widespread Distribution from single place</td>
</tr>
<tr>
<td>Television</td>
<td>13</td>
<td>6.9</td>
<td>Infrastructure, cost</td>
<td>Widespread Distribution from single place</td>
</tr>
<tr>
<td>Cable/Pay TV</td>
<td>Introduced in the early 1960's never achieved 90%, grew at a rate of 1.8 per year</td>
<td>Infrastructure, cost, competition</td>
<td>Widespread Distribution from single place</td>
<td></td>
</tr>
<tr>
<td>Cell phone</td>
<td>14</td>
<td>6.4</td>
<td>Infrastructure, cost</td>
<td>Initial Infrastructure in place (Telephone &amp; Cable)</td>
</tr>
<tr>
<td>Internet</td>
<td>20</td>
<td>4.5</td>
<td>Infrastructure, cost</td>
<td>infrastructure in place, cell phones</td>
</tr>
<tr>
<td>Smartphone</td>
<td>3</td>
<td>30.0</td>
<td></td>
<td>Cost</td>
</tr>
<tr>
<td>Clothes Washer</td>
<td>76</td>
<td>1.2</td>
<td>Cost</td>
<td>Cost</td>
</tr>
<tr>
<td>Air Conditioning</td>
<td>53</td>
<td>1.7</td>
<td>Cost</td>
<td>Cost</td>
</tr>
<tr>
<td>Stove</td>
<td>58</td>
<td>1.6</td>
<td>Cost</td>
<td>Cost</td>
</tr>
<tr>
<td>Microwave</td>
<td>27</td>
<td>3.3</td>
<td></td>
<td>Cost</td>
</tr>
<tr>
<td>Connected Vehicle</td>
<td>?</td>
<td>Maybe Never</td>
<td>The &quot;connected&quot; part of the infrastructure</td>
<td>Infrastructure in place, manufacturing in place, computer technologies mature at a much faster pace</td>
</tr>
<tr>
<td>Autonomous Vehicle</td>
<td>?</td>
<td>likely quicker than we expect</td>
<td></td>
<td>Infrastructure in place, manufacturing in place, computer technologies mature at a much faster pace</td>
</tr>
</tbody>
</table>

- Primarily ownership or equipped
- Autonomous vehicles may never reach 90% ownership
- Transportation on demand concept (Uber, Lyft, etc.) growing at a rapid pace
  - May use 90% utilization as the measure of adoption
Certainties with Autonomous Vehicles

**The Car** – will grow smarter and more efficient, with high-efficient engines, lighter materials and autonomous driving vehicles

**The Industry** – will evolve with new competition from tech companies, and suppliers capable of producing high-tech parts at low prices

**The Passenger** – will look at cars differently; sharing cars and using them as a space to consume media and make calls

**Roadway** - Many and most characteristics about the transportation infrastructure will not change for a long time; pavement and bridges must be maintained

**DOT/DMV** - The role will evolve, but how and when is uncertain
Uncertainties with Autonomous Vehicles

Rate of Acceptance - How fast AV services will be accepted, safe, useful, and successful

Infrastructure Requirements – may change in response to CV/AV

Migration to electric vehicles – may change revenue collection method

Public Transit and Freight – may shift to smaller vehicles and more demand responsive

Transportation Network Management – may change and how optimized

Transportation Funding Model – may evolve in anticipation of the change

Vehicle Ownership? – may change to transportation as a service
Projection – AV Ownership

Current Ownership

Single Ownership

Multiple Ownership

Corporate Ownership
Possible Trends – # of Vehicles

% AV Ownership

# of Vehicles

AV Ownership Type
Possible Trends – Vehicle Miles Travelled

Uber announced over 2 Million miles driven December 2017
Possible Trends - Parking

Parking Spaces / Facilities Required vs. % AV Ownership

AV Ownership Type

Conventional Garage Designed to Adapt to Autonomous Vehicles
PHASE 1: 2018 - 2025

Today, the typical car is used only 1% of the time. 35% of the time it is parked. In garage, at house or on the street.

However, by the time today’s garages are built, self-parking cars and shared fleets will be a reality.

By 2025, fully autonomous cars are expected to be within the general public for an additional $50,000 for an additional $50,000.
Possible Trends – Capacity

• Capacity should increase, regardless of the ownership model
• More efficient use of ROW and intersections
• But, with less parking and more vehicles on the road, do we lose this advantage?

AV Managed Lanes

Autonomous Intersection Management
State Legislation

House Bill 469 - 2017 Session
• Allows the operation of fully autonomous vehicle if it meets the five requirements
• Exempts fully autonomous vehicles from certain laws
• Establishes a minimum age of 12
• Registered owner responsible for moving violations the vehicle may commit
• Prohibits a local government from passing laws or ordinances restricting AV operations
• Establishes the Fully AV Committee
  – 1st meeting in March 2018; next in Aug 2018
  – Formed Work Groups
  – Business, Infrastructure, Legislative, Research, and Operations

House Bill 716
Truck Platooning (connected Vehicles)
• Provides the DOT the ability to regulate truck platooning through traffic ordinances
• Our approach:
  – Test vendor technology on the NC test bed
  – Allow the technology on specific highways
  – 30-40 foot spacing (prevents infill)
  – Platoons of 3 truck combinations
Ongoing Research in NC

- North Carolina Turnpike Authority (NCTA): selected as 1 of 10 proving grounds across US
  - Testing Platooning and Advanced Driver Assist
- NC State University
  - Eco-PRT (automated transit shuttle)
  - Lab for testing AV technology
- Duke University
  - Humans and Autonomy Lab
  - Human factor research projects
- NC A&T University
  - GM/SAE Challenge
- UNC - Highway Safety Research Center
  - Multidisciplinary committee looking at AV issues
  - AV-related projects below:
    - Advanced Analytics for Vulnerable Road User Scenarios; Development and Evaluation of Vehicle to Pedestrian (V2P) Safety Interventions; Concept of Operations for an Autonomous Vehicle Dispatch Center; Machine Learning Tools for Informing Transportation Technology Design
- ELF, a company in Durham, built their first AV bike
- DSRC deployed in various locations across the state
  - Part of the AASHTO Signal Phase and Time (SPaT) challenge (in Cary and Concord)
### Status of NC Pavement Marking

#### 2017 NC MOBILE AUDIT

<table>
<thead>
<tr>
<th>Status</th>
<th>Interstate</th>
<th>Primary</th>
<th>Secondary</th>
<th>All Routes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>2017 State Totals Failing</strong></td>
<td>9.5%</td>
<td>8.2%</td>
<td>15.3%</td>
<td>39.9%</td>
</tr>
<tr>
<td><strong>2017 State Totals Marginal</strong></td>
<td>0.0%</td>
<td>11.3%</td>
<td>27.1%</td>
<td>13.7%</td>
</tr>
<tr>
<td><strong>2017 State Totals Passing</strong></td>
<td>90.5%</td>
<td>80.5%</td>
<td>57.6%</td>
<td>48.3%</td>
</tr>
</tbody>
</table>

*Minimum Reflectivity - 100*

**2017 NC State Totals**

- Interstate: 90.5%
- Primary: 80.5%
- Secondary: 57.6%
- All Routes: 48.3%
## Status of Retroreflectivity Minimum on State Maintained Roads, 2017 Audit

<table>
<thead>
<tr>
<th>Type</th>
<th>Total Miles</th>
<th>* % Meet Standard</th>
<th>* Miles Out of Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interstate</td>
<td>1,257</td>
<td>90.5%</td>
<td>120</td>
</tr>
<tr>
<td>Primary</td>
<td>13,805</td>
<td>80.5%</td>
<td>2,686</td>
</tr>
<tr>
<td>Secondary</td>
<td>64,546</td>
<td>27.1%</td>
<td><strong>45,000</strong></td>
</tr>
</tbody>
</table>

* Estimates are based on random samples during 2017 audit

** Not all secondary roads require pavement marking (~20% unmarked); this estimate provides a rough order of magnitude
Imagine if it only cost $1,000 per lane mile to equip every road with something that will allow Autonomous Vehicles to fully operate.

Who are we fooling, nothing can be done for $1,000 a mile - let’s say we put a device every 20 feet that provides all the information needed and it cost $100 to install.

NC has over 225,000 lane miles and that would be equal to $225 million for the $1000 per lane mile, and $6 billion for the $100 every 20 feet option. This does not include maintaining the road or the technology. This is greater than the NC Annual budget.

The United States has 8,656,070 lane miles, and it would cost $8.7 billion and $252 billion.
What is Certain?
The way we fund transportation at the State will have to change
We are Confident

• Connected and Autonomous Vehicles are on the near horizon
• C / AV will revolutionize the transportation industry in multiple ways
  – Fatalities will be greatly reduced on our roadways; moving towards our goal of zero
  – Congestion will be less significant in our lives
  – Expand mobility to the underserved
• Pavement markings and the condition of road is important, regardless of AV
• Legislative bodies will figure out the funding
  – Already making headway now
For More Information Contact:
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http://www.ncav.org/