Minnesota Autonomous Bus Pilot

April 4, 2018

Project Goals

SNOW & ICE
- Prepare autonomous vehicle industry for snow & ice conditions

OPERATIONS
- Identify challenges and strategies for safe operation of third party autonomous vehicles on MnDOT’s transportation system

MOBILITY
- Prepare for improved mobility services through autonomous vehicles

INFRASTRUCTURE
- Identify the infrastructure that is needed to ensure safe operation of autonomous vehicles

INFLUENCE
- Increase Minnesota’s visibility and influence on advancing autonomous & connected vehicles

PARTNERSHIPS
- Enhance partnerships between government and the autonomous vehicle industry
About the Easy Mile EZ10 Shuttle

<table>
<thead>
<tr>
<th>Criteria</th>
<th>EasyMile EZ10 Shuttle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity</td>
<td>12</td>
</tr>
<tr>
<td>Speed</td>
<td>Avg. 10-15 mph, up to 25 mph</td>
</tr>
<tr>
<td>SAE Level of Autonomy (0-5)</td>
<td>4</td>
</tr>
<tr>
<td>Obstacle Detection</td>
<td>Laser (LiDAR)</td>
</tr>
<tr>
<td>Route Setup</td>
<td>Pre-mapped/pre-programmed</td>
</tr>
<tr>
<td>Navigation</td>
<td>GPS/LiDAR</td>
</tr>
<tr>
<td>Accessibility</td>
<td>Wheelchair ramp</td>
</tr>
</tbody>
</table>

Society of Automotive Engineers (SAE) Levels of Automation
Levels of Automation: Simplified

• Level 0 – Hands and feet ON
• Level 1 – Hands or feet OFF
• Level 2 – Hands and feet OFF, eyes ON
• Level 3 – Hands, feet, eyes OFF, brain ON
• Level 4 – Hands, feet, eyes, brain OFF
  • Constrained environments
• Level 5 – Hands, feet, eyes, brain OFF
  • Unconstrained

Project Phases

Phase 1 • Testing at MnROAD

Phase 2 • Operation during Super Bowl week
  • Open to the public

Phase 3 • Additional tests/demonstrations
  • Investigating public & private partnerships for demonstrating in an operational setting
Demonstration Concepts

**Demonstration Scenarios**

**Examples:**
- Obstacles
- Other vehicles
- Pedestrians
- Bicycles
- Transit Stops
- Stopping/Yield
- Intersections

**Fair Weather Conditions**

**Winter Weather Conditions**
- Snow
- Ice
- Salt

Intent: Lessons Learned!

MnROAD Testing
Demonstration Observations

- **Conditions:**
  - Clear Weather / Bare Pavement
  - Uncontrolled Weather
  - Controlled Weather

- **Introduced Variables:**
  - Shuttle Bus Only
  - Obstacles (Work Zone Barrel)
  - Other Cars, Pedestrians, Bicycles

---

Test Days

<table>
<thead>
<tr>
<th>Day</th>
<th>Time of Day</th>
<th>Temps / Sky Conditions</th>
<th>Pavement Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>12/5/17</td>
<td>Night</td>
<td>23 / Partly Cloudy</td>
<td>Partial Snow Cover</td>
</tr>
<tr>
<td>12/11/17</td>
<td>Morning / Day</td>
<td>Low 30s (Feels 25) / Cloudy</td>
<td>1” Snow on Pavement</td>
</tr>
<tr>
<td>12/18/17</td>
<td>Afternoon / Night</td>
<td>36 (Feals 30) / Cloudy</td>
<td>Mostly Bare Pavement</td>
</tr>
<tr>
<td>1/2/18</td>
<td>Afternoon / Night</td>
<td>13 (Feels -3) / Light Snow, Cloudy</td>
<td>Compacted Snow / Ice Patches</td>
</tr>
<tr>
<td>1/3/18</td>
<td>Afternoon / Night</td>
<td>-3 (Feals -14) / Mostly Clear</td>
<td>Compacted Snow / Ice Patches / Loose Snow</td>
</tr>
<tr>
<td>1/4/18</td>
<td>Morning / Day</td>
<td>-4 (Feels –4) / Mostly Cloudy</td>
<td>Pavement Plowed</td>
</tr>
<tr>
<td>1/5/18</td>
<td>Morning / Day</td>
<td>-13 (Feels -23) / Sunny</td>
<td>Compacted Snow</td>
</tr>
<tr>
<td>1/8/18</td>
<td>Day</td>
<td>22 (Feels 14) / Cloud &amp; Sun</td>
<td>Snow Making</td>
</tr>
<tr>
<td>1/9/18</td>
<td>Morning / Day</td>
<td>40 (Feals 33) / Sunny</td>
<td>Road Salt</td>
</tr>
<tr>
<td>1/10/18</td>
<td>Afternoon / Night</td>
<td>37 (Feels 30) / Misty Rain &amp; Fog</td>
<td>Bare Pavement</td>
</tr>
<tr>
<td>1/11/18</td>
<td>Afternoon / Night</td>
<td>6 (Feals –10) / Wind Gusts 30</td>
<td>Bare / Snow Drifts</td>
</tr>
<tr>
<td>1/12/18</td>
<td>Day</td>
<td>- 9 (Feels – 24) / Sunny</td>
<td>Snow Making</td>
</tr>
</tbody>
</table>
Uncontrolled Testing Conditions

Bare Pavement

Light Misty Rain / Edge of Snow

Mostly Bare Pavement

Compacted Snow / Icy Spots

Uncontrolled Testing Conditions

Trace - 1 Inch Fresh Snow Cover

Loose Snow

Low Visibility

Blowing / Drifting Snow
Controlled Testing Conditions

- Ice for Wheel Path
- Ice Across Lane
- Ice at Start / Stop
- Ice near Intersection

Controlled Testing Conditions

- Road Salt
- Snow Making
- Made Snow Trace – 6 Inches
- Made 3 – 4 Inches of Slush
Interaction with Bicycles

Stop Distance from Bike = 6.5 Ft. (Bumper to Pedal)

Interaction with Other Cars
Snow Making

Snow: Trace to 6 Inches
Slush: Up to 3 Inches
Coverage = 500+ Feet

Snow Making Machine
Nicollet Mall Demo – Ridership numbers

- Day 1 (Friday): 303
- Day 2 (Saturday): 465
- Day 3 (Sunday): 511

TOTAL riders for the 3 day demo: **1279**!

State Capitol Demonstration

March 7, 2018
Next Steps - Summary Report

- Project team is currently working on a draft summary report
- Available by June 30, 2018
- Will cover:
  - Industry research
  - Outreach process
  - Contracting process
  - Stakeholder & Public Demos
  - Testing procedures and observations

Thank you!

Michael Kronzer
ITS Project Manager, MnDOT