Minnesota Autonomous Shuttle
NACV Summit
June 12, 2018
Presentation Overview

• Project Overview
• Other CAV Projects and Policy Considerations
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

Public Engagement
Project Timeline

- Industry & Regulatory Environment Research (February 2017)
- Project requirements & RFP development
- Industry Outreach (April 2017)
- RFP finalized & Advertised
- Preferred Vendor Selected/Notice to Proceed (September 2017)
## Industry / Stakeholder Interest

### April 20 Industry Forum

Vendor / Stakeholder Outreach

[www.dot.state.mn.us/autonomous/](http://www.dot.state.mn.us/autonomous/)

### Autonomous Bus Vendors

- Navya
- EasyMile
- Local Motors
- 2getthere
- Autonomous Solutions Inc. (ASI)
- Romaric Corporation
- Velodyne Lidar
- New Flyer Industries
- Gillig
- Hyundai-Kia America Technical Center, Inc. (HATCI)
- SB Drive
- Yutong
- Proterra
- DOTs – Colorado, Connecticut
- Transit Agencies – RTD (Denver), MVTA & DTA (MN)
- Other – Mayo Clinic, FedEx, 3M, University of MN

### Bus / Retrofit Companies

### Public Agencies

![Diagram showing the overlap of autonomous bus vendors, bus/retrofit companies, and public agencies.](image-url)
Vendors Responding to RFP

Local Motors

EasyMile
About the Easy Mile EZ10 Shuttle

<table>
<thead>
<tr>
<th>Criteria</th>
<th>EasyMile EZ10 Shuttle</th>
</tr>
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<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>
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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
Phase I – MnROAD Testing
- MnDOT owned and operated
- Low and high speed testing available (30 – 70 MPH)
- Closed loop = 2.5 miles; I-94 high speed segment = 3.0 miles
- Enabling environment, easily accessible and readily available
- Ability to create varying test conditions
- MnDOT designated AV proving ground site
Demonstration Plan

Testing Scenarios, Schedule & Responsibilities

• Clear Weather & Winter Weather - Under Various Conditions

Track Distance = 4,370 ft. (0.83 miles)
Demonstration Concepts

**Demonstration Scenarios**

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

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

**Fair Weather Conditions**
Observed Sunlight Graph

Time of Day Testing Performed
Temperature

Variation of Temperature During Testing Period

Test Date
12/11/17 12/18/17 1/2/18 1/3/18 1/4/18 1/5/18 1/8/18 1/9/18 1/10/18 1/11/18 1/12/18

Temperature
-30 F -20 F -10 F 0 F 10 F 20 F 30 F 40 F

Actual Temperature
"Feels Like" Temperature
Uncontrolled Testing Conditions

- Bare Pavement
- Mostly Bare Pavement
- Light Misty Rain / Edge of Snow
- 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

Made Snow Trace – 6 Inches

Ice

Made 3 – 4 Inches of Slush
Findings – Bare Pavement / Clear Weather

• Performed Well
• Solid Localization
• Able to Navigate Stops, Starts, Turns, Curves, Intersections
• Good Cars, Peds, Bikes & Obstructions Interaction
• Some Emergency Stops / Slowdowns
Findings – 1 Inch Fresh Snow

- Calm Wind / Low 30s
- Performed Well - Similar to Bare Pavement
- Some Emergency Stops / Slowdowns
- Nice Interaction with Work Zone Barrel Obstructions
- Wheel Wander Observations
Wheel Wander Accuracy
• 3mm – 1 cm
Stop Impact from Car Creep = 5.6 Feet (Bumper to Bumper)
Interaction with Other Cars – Exhaust?
Interaction with Bicycles and Pedestrians
Interaction with Pedestrians

More conservative with higher speeds

Front Stop Distance = 5.3 – 6.6 Ft. (Bumper to Shins)
Side of Bus = 1.6 – 1.8 Ft. (off Wheel Path)
Stop Distance from Bike = 6.5 Ft. (Bumper to Pedal)
Bus Performed Well in Ice
Snow Accumulation in Sensor Housing
Findings – Compacted, Loose & Blowing Snow

- Compacted Snow – Slippage and Localization Issues (Greater with Higher or Variable Speeds)
- Loose & Blowing Snow – Became Obstructions
- Plowed Road - Reduced Blowing Snow but Increased Slippage
- Cold Temps & Compacted Snow Increased Slippage
Made Snow: Trace to > 5 Inches
Made Slush up to 3 Inches
Coverage = 500+ Feet
Snow Cloud
Snow Cloud
Dec. 18th, 2017 Battery Charge Readings
Start Temp.: 36° F; Wind: S 7 mph
Jan. 3rd, 2018 Battery Charge Readings
Start Temp.: 3°F; (-13°F windchill); Wind: WNW 11 mph
Downtown Minneapolis - Niccollet Mall Demo
Downtown Minneapolis - Public Demonstrations

Are you looking forward to having driverless vehicles operate on all roadways in the future?

45 responses

- Yes: 82.2%
- No
- Possibly, if all the bugs can be worked out.
- Unsure about it
- Need own lane
- Some. Not all.
- Not sure if the transition with some driverless and others not is safe

We Want to Hear About Your Ride Experience!

Text MinnEride to 474747
Next Steps for CAV In Minnesota
MnDOT CAV Strategic Vision

CAV Strategic Plan

- Long Range Planning
- Capital Needs
- Research
- Partners
- Regulation
- Operation
- Strategic Staffing
- Multi-Modal
- Outreach
National Items

States with Enacted Autonomous Vehicle Legislation

LEGEND
- Enacted
- Executive Order
SPaT Challenge

[Diagram showing a smart crosswalk system where a pedestrian uses a smartphone with a SmartCross app to communicate with vehicles and traffic signals, enhancing pedestrian safety and traffic efficiency.]
Minnesota Connected Vehicle Corridor
Smart Corridor Concepts

• Secure Signal Phasing and Timing (SPaT)
• Vehicle – Pedestrian Conflict Warning System
• Snow Plow Signal Priority
• Data Management
  • Basic Safety Messages (in from vehicles)
  • Traffic Signal Data (our to third party vendors)
• Mobile Work Zone
Other Concepts Being Considered

- Automated Truck at MnROAD Site
- Final Four Demonstration
- Truck Platoon Demonstration
- Innovative Ideas Funding
- Automated Truck Mounted Attenuator