Why Shared Autonomous Vehicles are Coming - Fast

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The change will happen faster than you think
A big driver of this change: cost of driving

Despite high costs and fast depreciation, substantial utilization can make shared, high-tech “mobility vehicles” economically compelling.

Today’s car:
- 21¢

Future mobility car:
- 17¢
- 26¢

Cost per mile:
- 0¢
- 20¢
- 40¢
- 60¢
- 80¢
- 100¢

The “mobility vehicle” is based on a small sedan that costs $25,000 and is completely replaced every three years with no residual value. It is shared and, therefore, driven 40,000 miles per year. The average NYC cab is driven an average of 70,000 miles per year.

Sources: AAA, NYC Taxi and Limousine Commission, “KPMG ULP’s Me, my vehicle, my life...in the ultra connected age.”

- Fixed Costs (per mile): Depreciation, insurance, finance, and registration-related costs.
- Operating Costs (per mile): Gas, maintenance, and tires.
A second driver: safety

U.S. Fatality Reduction Expected with Autonomous Vehicles
(Units in deaths per 100 million vehicle miles traveled)

- 2013 National Average: 1.1
- Autonomous Vehicle: 0.2
A third driver: reduced pollution

### Three Revolutions in Urban Transportation

**Business-as-Usual Scenario**

- 21st Century Technology
- Through 2050, we continue to use vehicles with internal combustion engines at an increased rate, and use transit and shared vehicles at the current rate, as population and income grow over time.

**2 Revolutions (2R) Scenario**

- Electrification + Automation
- We embrace more technology. Electric vehicles become common by 2030, and automated electric vehicles become dominant by 2040. However, we continue our current embrace of single-occupancy vehicles, with even more car travel than in the BAU.

**3 Revolutions (3R) Scenario**

- Electrification + Automation + Sharing
- We take the embrace of technology in the 2R scenario and then maximize the use of shared vehicle trips. By 2030, there is widespread ride sharing, increased transit performance—with on-demand availability—and strengthened infrastructure for walking and cycling, allowing maximum energy efficiency.

### Number of Vehicles on the Road by 2050

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Number of Vehicles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Business-as-Usual</td>
<td>2.1 billion</td>
</tr>
<tr>
<td>2 Revolutions (2R)</td>
<td>2.1 billion</td>
</tr>
<tr>
<td>3 Revolutions (3R)</td>
<td>0.5 billion</td>
</tr>
</tbody>
</table>

### CO2 Emissions by 2050

<table>
<thead>
<tr>
<th>Scenario</th>
<th>CO2 Emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Business-as-Usual</td>
<td>4,600 megatonnes</td>
</tr>
<tr>
<td>2 Revolutions (2R)</td>
<td>1,700 megatonnes</td>
</tr>
<tr>
<td>3 Revolutions (3R)</td>
<td>700 megatonnes</td>
</tr>
</tbody>
</table>
The big stick driving the change: insurance

![Figure 2. Stakeholders and insurance products in the future of mobility](image)

<table>
<thead>
<tr>
<th>Future state</th>
<th>Stakeholder model</th>
<th>Stakeholder</th>
<th>Primary coverages</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Personally owned driver-driven</td>
<td>Personally owned personal auto insurance</td>
<td>Vehicle owner (individual)</td>
<td>Driver liability, collision, comprehensive</td>
</tr>
<tr>
<td>2 Shared driver-driven</td>
<td>Fleet (e.g., yellow cab, limo)</td>
<td>Vehicle owner (commercial)</td>
<td>Driver liability, collision, comprehensive</td>
</tr>
<tr>
<td>2 Shared driver-driven</td>
<td>Owner/operator (e.g., black car)</td>
<td>Vehicle owner (individual)</td>
<td>Driver liability, collision, comprehensive</td>
</tr>
<tr>
<td>3 Personally owned autonomous</td>
<td>Rental</td>
<td>Vehicle owner (commercial)</td>
<td>Comprehensive, liability (e.g., road worthiness)</td>
</tr>
<tr>
<td>3 Personally owned autonomous</td>
<td>Personal autonomous vehicle insurance</td>
<td>Vehicle owner (individual)</td>
<td>Comprehensive, liability (e.g., road worthiness)</td>
</tr>
<tr>
<td>4 Shared autonomous</td>
<td>Autonomous vehicle insurance</td>
<td>Vehicle owner (commercial)</td>
<td>AV product liability</td>
</tr>
<tr>
<td>4 Shared autonomous</td>
<td>Commercial autonomous vehicle insurance</td>
<td>Vehicle owner (commercial)</td>
<td>AV product liability</td>
</tr>
<tr>
<td>4 Shared autonomous</td>
<td>AV system manufacturer/OS provider (commercial)</td>
<td>AV system manufacturer/OS provider (commercial)</td>
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<td>AV product liability</td>
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Today’s infrastructure will go through this change
Opportunities and Challenges

The route to the autonomous car

Advantages

- Safety: 90% of road traffic accidents are currently caused by human error.
- Driverless cars could result in approximately 36,000 lives saved each year and a potential of US$ 488 billion.
- Social: Car ownership provided to elderly or disabled people.

Economic benefits to drivers:
- Fuel costs
- Productivity gains
- Accident costs

Morgan Stanley estimates that autonomous cars will result in US$ 1.3 trillion in savings every year for the US economy, globally it's translated into US$ 5.6 trillion.

Potential obstacles

- Liability: Who accepts responsibility in the case of an accident?
- Legislation: US infrastructure deficiencies mean that US$ 10.8 billion had to be found to keep the Highway Trust Fund solvent until May 2018.

Consumer adoption

- Once people accept and trust the systems, adoption rates are expected to climb.

Welcome to the autonomous car

1. Economist Study, October 2015. Women are more in a rush than men, according to Center for Automotive Safety. (November 2015).

Note: The opinions expressed in this document are those of the author and do not necessarily reflect the views of BNY Mellon. The information is provided for educational purposes only and is not intended to provide specific investment advice or recommendations for any individual investor.
This reflects a larger value shift: sharing economy
Public rights of way will feel the change first
Creating a lot more space for other things
Cities will gain about 30% more land
Homeowners will gain land and interior space
The suburban landscape will change the most
Parking ramps will have to find other uses.
Highways will become multi-modal
Minnesota Automated and Connected Vehicles
Presentation Overview

• AV and CAV Overview
• Areas of Focus
• Why is this important
• Strategic Planning for CAV
• Automated and Connected Vehicle Pilot Projects
Connected Automation

**Autonomous Vehicle**
Operates in isolation from other vehicles using internal sensors

**Connected Vehicle**
Communicates with nearby vehicles and infrastructure

**Connected Automated Vehicle**
Leverages autonomous and connected vehicle capabilities
Society of Automotive Engineers (SAE)
Levels of Automation

<table>
<thead>
<tr>
<th>Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No Automation&lt;br&gt;Zero autonomy; the driver performs all driving tasks.</td>
</tr>
<tr>
<td>1</td>
<td>Driver Assistance&lt;br&gt;Vehicle is controlled by the driver, but some driving assist features may be included in the vehicle design.</td>
</tr>
<tr>
<td>2</td>
<td>Partial Automation&lt;br&gt;Vehicle has combined automated functions, like acceleration and steering, but the driver must remain engaged with the driving task and monitor the environment at all times.</td>
</tr>
<tr>
<td>3</td>
<td>Conditional Automation&lt;br&gt;Driver is a necessity, but is not required to monitor the environment. The driver must be ready to take control of the vehicle at all times with notice.</td>
</tr>
<tr>
<td>4</td>
<td>High Automation&lt;br&gt;The vehicle is capable of performing all driving functions under certain conditions. The driver may have the option to control the vehicle.</td>
</tr>
<tr>
<td>5</td>
<td>Full Automation&lt;br&gt;The vehicle is capable of performing all driving functions under all conditions. The driver may have the option to control the vehicle.</td>
</tr>
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Items Being Considered

Automated & Connected Vehicles

Truck Platooning

Mobility as a Service (MAAS)

Electric Vehicles

Automated Delivery Services
What are the Challenges?

Salt

Snow / Ice
Why is this important to Minnesota?

Minnesota Roadway Fatalities
Source: MnDOT 4/17/2017

Toward Zero Deaths
Established 2003

Goal for 2008: 500
Goal for 2010: 400
Goal for 2014: 350
Goal for 2020: 300

TZD Goal
Persons Killed
1995 TO 2003 Trendline

348
Other Impacts

Parking Impacts

Freight

Cyber Security

Pavement Markings

Geometric Design

Licensing Laws

Bridge Loads

Smart Signs

Pavement Impacts

Traffic Operations

Mixed Traffic (AV & Non-AV)

Revenue

Staffing

Land Use / Planning
Statewide - Jurisdictional Committee
Status of Minnesota Regulation

• Truck Platooning
  • 500 FT (152M) Spacing

• Current AV Statutes
  • Driver: “every person who drives or is in actual physical control of a vehicle.”
  • Person: “every natural person, firm, copartnership, association, or corporation.”

• Potential Legislation
MN Autonomous Bus Team
AV Bus 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>
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
MnROAD Facility and Pavement Research

MnROAD Owned and Operated by Minnesota DOT
(23-Years of Long Term Customer Service)

Pavement Research
- New and Rehabilitation
- HMA and PCC Pavements
- Granular Base / Subgrade

Test Sections
- 500 foot test sections
- Instrumentation
- Performance Monitoring
- Laboratory Testing
- Able to be bold with Designs to advance learning

A long-term accelerated pavement testing facility that gives researchers a unique, real-life laboratory to study and evaluate the performance of materials used in roadway construction.
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!
Project Photos
Lessons Learned

• Winter Weather Conditions

• Battery Life
Phase II – Downtown Minneapolis

• Free Public Rides
  • January 26 – 28th
  • 11 am – 4 pm
  • Nicollet Mall (3rd – 4th Street)
Phase III – Other Applications

• 3M Campus
• Hennepin County
• State Capitol
• Others
How to Keep Updated

• Updates on Testing
• Updates on Operating in Minneapolis (Public Rides)
• Updates on future uses in Minnesota

http://www.dot.state.mn.us/autonomous/
Connected Vehicle Applications

• 1: Signal Phase and Timing (SPaT)
• 2: Transit/Pedestrian Conflict Warning
• 3: Snow Plow Signal Priority
• 4: CV Data Exchange
• 5: Mobile Work Zone Warning System
• 6: Transit/MnPASS Lane Status Notification System
Thank you again!

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