Attempts at AVs Are Not New

Source: PATH, 1997
Source: Google, 2014.
Agenda

• Primer on AVs
• Planning for AVs
• Key Unknowns
• Toronto Experience
• Action Agenda
Primer on AVs
NHTSA Levels of Automation

<table>
<thead>
<tr>
<th>Level</th>
<th>Description</th>
<th>Steering and acceleration/ deceleration</th>
<th>Monitoring of driving environment</th>
<th>Fallback when automation fails</th>
<th>Automated system is in control</th>
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<tbody>
<tr>
<td>0</td>
<td>NO AUTOMATION</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
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<td>2</td>
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<td>SOME DRIVING MODES</td>
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<tr>
<td>3</td>
<td>CONDITIONAL AUTOMATION</td>
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<tr>
<td>4</td>
<td>HIGH AUTOMATION</td>
<td>SOME DRIVING MODES</td>
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<td>SOME DRIVING MODES</td>
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<tr>
<td>5</td>
<td>FULL AUTOMATION</td>
<td>SOME DRIVING MODES</td>
<td>SOME DRIVING MODES</td>
<td>SOME DRIVING MODES</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Source: SAE
Self-Contained “Seeing”

Source: Google
The Promise of AVs

• Improved road safety
• Economic benefits of less lost productivity
• More equitable access for all
• Increased travel options
• Reduced stress of driving
• Reduced fuel consumption and emissions
• Reduced collisions, reducing incident-related congestion
• In the future, potentially greater capacity, reducing recurring congestion
Two Paths

Private Ownership Model
• Driven by Auto Industry
• Incremental Moves in Functionalities
• Mostly Privately Owned
• Here Today

Shared Mobility Model (MaaS/TaaS/Robo-taxis)
• Driven by Tech and TNCs
• Jump to Fully Automated
• Transportation-as-a-Service
• A few (or many, many) years away
Complexities of AVs

- Data
- Technology
- Standards
- Ethics
- Liability
- Human Factors
- Safety
- Economics
- Communications Systems
- Infrastructure
- Managing the Transition
- Planning
- Consumer Preference
- Impact to Jobs
- Privacy
- Enforcement
- Regulation
- Business Models
Complexities of AVs

Planning
Planning for AVs
Planning for AVs

• It’s no longer “if”, but “when” and “how”

• It will likely be very, very disruptive

• Over time, it will transform mobility as we know it

• Will impact how we design, build and operate not only roads, but likely all aspects of our transportation system
Implications for Planning

Changes

- Trip-making
- Distance of Trip Making
- Passenger Miles Travelled
- Vehicle Miles Travelled
- Fixed Route Transit Demand
- Active Transportation
- Parking Demand
- Curbside Demands
- Congestion
- Trend of Intensification
- Right-of-way allocated for vehicles
Key Unknowns
Key Unknowns

- Speed of Technological Advancement
- Economics
- Public Acceptance
- Political Support
- Market for a Shared Model
Speed of Technological Advancement

‘What we’ve got will blow people’s minds, it blows my mind… it’ll come sooner than people think’

- Elon Musk on Tesla Fully Autonomous Car, Electrek, August 4, 2016

Uber starts self-driving car pickups in Pittsburgh

-Tech Crunch, September 14, 2016

Google starts deploying its self-driving Chrysler Pacifica minivans: first prototypes spotted

-Electrek, October 9, 2016
# Speed of Technological Advancement

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<tr>
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<td>4/5</td>
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<td>BMW</td>
<td>2</td>
<td></td>
<td></td>
<td>4/5</td>
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<td>Ford</td>
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<td>4/5</td>
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<tr>
<td>Honda</td>
<td>2</td>
<td></td>
<td></td>
<td>3</td>
<td></td>
<td></td>
<td>3-4</td>
<td></td>
<td></td>
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<tr>
<td>KIA</td>
<td></td>
<td></td>
<td></td>
<td>3</td>
<td></td>
<td></td>
<td>4/5</td>
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<tr>
<td>Mercedes-Benz</td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Nissan</td>
<td>2</td>
<td>3</td>
<td></td>
<td>4/5</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Tesla</td>
<td>2</td>
<td></td>
<td></td>
<td>4/5</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
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<td>Volvo</td>
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<td>4/5</td>
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<tr>
<td>Uber</td>
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</tr>
</tbody>
</table>

Source: Mashable, June 2016
Speed of Technological Advancement

NVIDIA to introduce level-4 enabling system by 2018
(Source: NVIDIA, 2017-03-16)

Audi to introduce a self-driving car by 2020
(Source: IEEE Spectrum, 2017-01-05)

NuTonomy to provide self-driving taxi services in Singapore by 2018, expand to 10 cities around the world by 2020
(Source: Yahoo News, 2016-08-29)

Delphi and MobilEye to provide off-the-shelf self-(SAE Level 4) driving system by 2019
(Source: TheVerge, 2016-08-23)

Ford CEO announces fully autonomous vehicles for mobility services by 2021
(Source: Reuters, 2016-08-16)
## California Autonomous Testing Disengagements

<table>
<thead>
<tr>
<th>Company</th>
<th>Miles Driven</th>
<th>DE*</th>
<th>Miles per DE</th>
<th>Miles per DE in 2015</th>
<th>Common Causes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waymo (aka Google)</td>
<td>635,868</td>
<td>124</td>
<td>5,128</td>
<td>1,244</td>
<td>Software discrepancy; unwanted vehicle maneuver</td>
</tr>
<tr>
<td>BMW</td>
<td>638</td>
<td>1</td>
<td>638</td>
<td>N/A</td>
<td>Lane marking unclear</td>
</tr>
<tr>
<td>Nissan</td>
<td>4,099</td>
<td>28</td>
<td>247</td>
<td>14</td>
<td>AV system failure; AV is about to collide with vehicle or obstacle</td>
</tr>
<tr>
<td>Ford</td>
<td>590</td>
<td>3</td>
<td>197</td>
<td>N/A</td>
<td>Aborted lane change due to vehicle overtaking at high speed</td>
</tr>
<tr>
<td>Delphi</td>
<td>3,125</td>
<td>178</td>
<td>18</td>
<td>42</td>
<td>Completing lane change in heavy traffic; traffic light detection</td>
</tr>
<tr>
<td>Cruise (GM)</td>
<td>9,847</td>
<td>414</td>
<td>9.3</td>
<td>N/A</td>
<td>To avoid unexpected behavior</td>
</tr>
<tr>
<td>Tesla Motors</td>
<td>550</td>
<td>182</td>
<td>3</td>
<td>N/A</td>
<td>Planner output invalid; follower output invalid</td>
</tr>
<tr>
<td>Mercedes-Benz</td>
<td>673</td>
<td>336</td>
<td>2</td>
<td>1.8</td>
<td>Driver discomfort; technology evaluation management</td>
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<tr>
<td>Bosch</td>
<td>983</td>
<td>1,442</td>
<td>0.7</td>
<td>1.5</td>
<td>Planned test of technology</td>
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<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
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<tr>
<td>VW/Audi</td>
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<td>N/A</td>
<td>N/A</td>
<td>75</td>
<td>N/A</td>
</tr>
</tbody>
</table>

DE* = Disengagements

Source: The Numbers Don’t Lie: Self-Driving Cars Are Getting Good, Wired, February 1, 2017
Economics

Cost per Person per Mile

- **$0.50**
- **$1.00**
- **$1.50**
- **$2.00**
- **$2.50**
- **$3.00**
- **$3.50**
- **$4.00**

**Source:** ARK Investment Management
Economics

Cost per Mile: Shared vs. Owned

Source: Morgan Stanley (2016)
Economics

Robo-Taxis Could Replace Traditional Taxis and Cars in Megacities

New York City case study

<table>
<thead>
<tr>
<th>Average number of people per vehicle</th>
<th>Public transport</th>
<th>Vehicle ownership</th>
<th>Taxi</th>
<th>Robo-taxi</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.6</td>
<td>1.2</td>
<td>1.2</td>
<td>1.2</td>
<td>1</td>
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<tr>
<td>2</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>

Robo-taxis that accommodate at least two people could be cost-competitive with mass transit if capital budgets and government subsidies are taken into account.

Sources: BCG analysis; U.S. Department of Transportation; NYC Metropolitan Transportation Authority; NYC Taxi & Limousine Commission; Kelley Blue Book.

*Does not consider the impact of convenience and shorter wait and commute times.
*Non-fare-based operating funds received from New York City transit; local, state, and federal sources; and other sources.
*Annual fare revenues per passenger mile traveled.

Source: Boston Consulting Group (2016)
Economics

Future Rates for Shared AVs

ARK Investment - $0.35/mile

Morgan Stanley - $0.50/mile

WEF/BCG - $0.60-$1.00/mile

Source: ARK Investment Management
Economics

Figure 3: Average Unlinked Passenger Trip Length, 2011

Source: APTA 2011 Fact Book
Public Acceptance

“The technology may be ready before society is.”

- Bill Ford, Jr., Chairman, Ford Motor Company
  December, 2015
## Public Acceptance

<table>
<thead>
<tr>
<th>Country</th>
<th>Use an AV?</th>
<th>Use a shared AV?</th>
</tr>
</thead>
<tbody>
<tr>
<td>India</td>
<td>85%</td>
<td>67%</td>
</tr>
<tr>
<td>China</td>
<td>75%</td>
<td>62%</td>
</tr>
<tr>
<td>UAE</td>
<td>70%</td>
<td>48%</td>
</tr>
<tr>
<td>US</td>
<td>52%</td>
<td>27%</td>
</tr>
<tr>
<td>UK</td>
<td>49%</td>
<td>19%</td>
</tr>
<tr>
<td>Netherlands</td>
<td>41%</td>
<td>15%</td>
</tr>
<tr>
<td>Japan</td>
<td>36%</td>
<td>24%</td>
</tr>
</tbody>
</table>

Percentage of Very Likely or Likely

Political Support
Political Support

“Helsinki announces plans to transform its existing public transport network into a comprehensive, point-to-point ‘mobility on demand’ system by 2025”

– July 10, 2014 • theguardian.com

**Uber stops San Francisco self-driving pilot as DMV revoked registrations**

– December 21, 2016 Techcrunch.com

Gov. Doug Ducey welcomes Uber self-driving cars with open arms

– December 23, 2016 • The Arizona Republic
Political Support
Influencing a Shared Model

• Economics will strongly influence viability

• Unless we see quick, definitive actions by cities or transit agencies, this WILL be driven by consumer preference and pricing

• Shared use will likely not work in all areas or for all needs, so there will likely still be a strong market for privately-owned AVs

• Public acceptance will likely not only vary regionally, but even within regions

• AV-only facilities or zones will be needed to permit smaller, lighter vehicles that make a shared AV model more economical and attractive
Factors Driving Where Shared Mobility Will Land First

- Market
  - Density
  - Tech-savvy
  - Accustomed to Sharing
  - Wealthy

- Political Support
  - Infrastructure
  - Incorporation into Transit

- Weather
Influencing a Shared Model

Source: Uber website (5/22/17).
Key Unknowns

- Speed of Technological Advancement
- Economics
- Public Acceptance
- Political Support
- Market for a Shared Model
Without a clear understanding of the future, how do we plan?
Key Short-term Challenges in Shaping Policy

- This is currently being driven by the market

- Most regions, cities and transit agencies aren’t at the table

- Complex issue with lots of moving parts and unknowns, making it difficult to educate or advise leadership and elected officials

- Currently lacking the methods and tools to help us better inform the discussion
## Roles and Responsibilities

<table>
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<tr>
<th>Topic</th>
<th>Federal</th>
<th>State</th>
<th>Local</th>
<th>Industry</th>
<th>Academic</th>
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<td>![St]</td>
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<td>![Acc]</td>
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<td>![Ind]</td>
<td>![Acc]</td>
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<td>![Loc]</td>
<td>![Ind]</td>
<td>![Acc]</td>
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<td>Alignment with Planning</td>
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</table>
Approaches Regions Could Take

**Actively Discourage**
- Prohibit or Restrict AVs or TaaS

**Actively Encourage**
- Conduct a pilot or demonstration
- Create AV-only facilities
- Create AV-only zones

**Passive**
- Wait and See
- Outfit signals with transmitters
- Map system attributes
- Map curbside regulations
- Develop standards and technology for lane closures

**Outfit signals with transmitters**
Approaches Transit Agencies Could Take

Resist

• Attempt to
  Prohibit or
Restrict
  Shared AVs

Passive

• Laissez-faire

Embrace

• Partner

• Own and
  Operate

• Partner and
  Fund
Toronto Experience
Toronto Experience

2014
- Started Monitoring AV developments

2015
- Established dialogue with other municipalities
- Hosted an Interdivisional Workshop
- Presented to Toronto Senior Management Team
- Created a Transportation AV Working Group
- Commissioned White Paper
- Released “Driving Changes”

2016
- Conducted Stakeholder Workshops
- NACTO Policy Statement on AVs
- Created an Interdivisional AV Working Group
- Created a Transportation Work Plan
- Conducted Public Survey
- Ryerson Planning Studio
Driving Changes: Automated Vehicles in Toronto

Discussion paper

David Tixier
Distinguished Research Fellow
Innovation Policy Lab
Munk School of Global Affairs
University of Toronto

October 15, 2015
Three Scenarios

Ownership Leads

Mixed

Shared Leads
<table>
<thead>
<tr>
<th></th>
<th>Private</th>
<th>Mixed</th>
<th>Shared</th>
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<td>Congestion</td>
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<td>Equitable Mobility</td>
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<tr>
<td>Cost of Private Vehicular Travel</td>
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<td>Carpooling</td>
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<td>Vehicle Kilometers Travelled</td>
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<tr>
<td>Fixed Route Transit Demand</td>
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<tr>
<td>Active Transportation</td>
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<td>![Down Arrow]</td>
</tr>
<tr>
<td>Trend of Intensification</td>
<td>![Down Arrow]</td>
<td>![Down Arrow]</td>
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<td>Parking Demand</td>
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<td>![Down Arrow]</td>
<td>![Down Arrow]</td>
</tr>
<tr>
<td>Right-of-way allocated for vehicles</td>
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<tr>
<td>Residential Building/Lot Size</td>
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<td>Impervious Areas</td>
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</table>
Toronto Working Group

- Transportation
- Economic Development
- City Planning
- Toronto Transit Commission
- Licensing & Standards
- Police Services
- Parking Authority
- Parking Enforcement
- Fleet
- Revenue
- Disabilities Commission
- Employment Services
- Aging
- Budget
- City IT
- Privacy Commission
Most Common Job (2014)

Source: IPUMS-CPS/ University Of Minnesota
Credit: Quoctrung Bui/NPR
Goals of Cities

• Safety
• Accessibility
• Mobility
• Economic Opportunity
• Quality of Life
• High-Quality Natural and Built Form
• Environmental Sustainability
• Social Inclusion
• Financial Sustainability
Toronto’s Draft Vision Statement

*Toronto needs to harness the potential of AVs to help us create the City that we want.*
PREPARING FOR AUTONOMOUS VEHICLES

Divisional Workplan 2016-2018
Work Plan Goals

Leadership and Engagement
• To demonstrate leadership in guiding and influencing the arrival of AVs on Toronto's streets

Preparation
• To prepare for the arrival of AVs no matter when and how they are introduced

Integration
• To begin to integrate AV-supportive measures into the operations of Transportation Services
Are GTHA Residents Ready for Autonomous Vehicles?

Survey Overview
November 24, 2016

Matthias Sweet; Kailey Laidlaw, Kailey; Tyler Olsen

Ryerson University
Suppose using a driverless vehicle does not enable you to go faster, but enables you to now use that travel time for other activities while traveling. Would you be likely to travel further to work (e.g. for a better job or less expensive housing)?
Automated and driverless vehicles are likely to become more common in the future. How should governments respond?
Would you support investment to encourage, support, or regulate automated vehicles?

- **Support Investment**
  - Under 35: 54.8%
  - 35-55: 46.6%
  - Over 55: 46.3%
  - Total: 46.3%

- **Not support investment**
  - Under 35: 16.6%
  - 35-55: 20.2%
  - Over 55: 21.9%
  - Total: 21.9%

- **Unsure**
  - Under 35: 28.6%
  - 35-55: 33.2%
  - Over 55: 33.5%
  - Total: 31.8%
Imagining Alternative Futures
(Ryerson University)

2017-2035
Scenario Planning

- Speed of Technological Advancement
- Economics
- Public Acceptance
- Political Support
- Market for a Shared Model
Mobility as a Service

• Currently presumed to be a private model

• Often touted as a first-mile/last-mile solution

• Will cater to consumer demand

• Will deploy where they generate the most profit
Scenarios – Shared Leads

- Walking
- Transit
- Shared AV
- Non-AV
- Private AV

2017 to 2057
Scenarios – Private Leads

- Walking
- Transit
- Shared AV
- Private AV
- Non-AV
Wildcards

Catastrophic Event

Public Backlash Regarding Data and Privacy
Action Agenda
Many planners believe that this will unfold in a thoughtful and controlled way.

Unless we see quick, definitive actions by states, transit agencies, and cities this WILL be market-driven by consumer preference and pricing.

Conversation is currently being driven by politically-active industries that have HUNDREDS of BILLIONS at stake.

Some companies in this space appear to be driven entirely by profit motivations.
What This May Mean

For Planning Agencies:
• Major investments will be questioned and challenged
• There may be opportunities for new funding (and pricing) mechanisms

For Cities:
• Will “feel it” first
• Will be highly disruptive to how streets operate

For Transit Agencies:
• Investments will be questioned and challenged
• MaaS services, particularly if unregulated, will begin to cannibalize some surface transit services
Developing a Work Plan

- Leadership and Engagement
- Informing the Discussion
- Preparation
- Integration
Actions to Take - Regions

- Convene and educate your partners

- Review your regional goals, and frame discussions around those goals

- Develop scenarios that are likely for your region

- Develop tools that can help inform the conversation

- Begin to consider alternative funding and pricing models
Actions to Take - Cities

• Convene and educate your city departments

• Review your city goals, and frame discussions around those goals

• Develop principles on how you’d like this to unfold

• Develop scenarios and assess

• Develop a work plan

• Create a “Break Glass” plan
Actions to Take – Transit Agencies

- Convene and educate your divisions
- Review your Mission
- Begin to discuss and evaluate potential directions that your agency could take
- Set the ground rules, even if just in principle
Resources
Resources

DRIVING TOWARDS DRIVERLESS:
A GUIDE FOR GOVERNMENT AGENCIES

LAUREN ISAAC

WSP | BRINCKERHOFF
Resources

http://smartdrivingcar.com/GreenLight-092316
Friday, September 23, 2016

NHTSA Federal Automated Vehicles Policy: Accelerating the Next Revolution In Roadway Safety
September 2016, "Executive Summary...For DOT, the excitement around highly automated vehicles (HAVs) starts with safety. (p5)

...The development of advanced automated vehicle safety technologies, including fully self-driving cars, may prove to be the greatest personal transportation revolution since the popularization of the personal automobile nearly a century ago. (p5)

...The benefits don’t stop with safety. Innovations have the potential to transform personal
From the Editors
Wishing all our readers and AV Subscribers a very happy and prosperous New Year.

Earlier this month, the Ottawa AV Summit 2017 was held in Kanata, Ontario, hosted by the Kanata North Business Association, CAVCOE and the Conference Board of Canada. The objective was to help the local technology industry better understand the business opportunities and technologies in the AV space and to network with each other. The event was very successful and we had twice as many attendees as we expected.

The Canadian Parliamentary research report "Automated and Connected Vehicles: Status of the Technology and Key Policy Issues for Canadian Governments" reads very well for the advancements in Canada on the AV front. The report uses a significant amount of source material from the report CAVCOE and the Conference Board of Canada published a year earlier.

Here in Canada, we remain concerned that our very occasional adverse weather (our tongue firmly in cheek) will slow the deployment of AVs on our roads. However, it seems that Tesla’s Autopilot is already accomplished at steering in the snow, even without visible lane lines or a
Key Takeaways

• *This is coming fast – guide it or respond to it*

• *Regions, cities, and transit agencies have a chance to shape this, but need to move*

• *Don’t let the unknowns and complexities paralyze us*
“The best way to predict the future is to create it.”
Stephen Buckley, P.E.

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