Attempts at AVs Are Not New
Agenda

• Brief Primer on AVs

• Planning for AVs

• Work in Toronto

• Moving Forward
## NHTSA Levels of Automation

<table>
<thead>
<tr>
<th>Level</th>
<th>Automation</th>
<th>Human Driver Monitors Environment</th>
<th>System Monitors Environment</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No Automation</td>
<td>The absence of any assistive features such as adaptive cruise control.</td>
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</tr>
<tr>
<td>1</td>
<td>Driver Assistance</td>
<td>Systems that help drivers maintain speed or stay in lane but leave the driver in control.</td>
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<tr>
<td>2</td>
<td>Partial Automation</td>
<td>The combination of automatic speed and steering control—for example, cruise control and lane keeping.</td>
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<td>3</td>
<td>Conditional Automation</td>
<td>Automated systems that drive and monitor the environment but rely on a human driver for backup.</td>
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<tr>
<td>4</td>
<td>High Automation</td>
<td>Automated systems that do everything—no human backup required—but only in limited circumstances.</td>
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<tr>
<td>5</td>
<td>Full Automation</td>
<td>The true electronic chauffeur: retains full vehicle control, needs no human backup and drives in all conditions.</td>
<td></td>
</tr>
</tbody>
</table>

**Who steers, accelerates and decelerates:**
- 0: Human driver
- 1: Human driver
- 2: System
- 3: System
- 4: System
- 5: System

**Who monitors the driving environment:**
- 0: Human driver
- 1: Human driver
- 2: Human driver
- 3: System
- 4: System
- 5: System

**Who takes control when something goes wrong:**
- 0: Human driver
- 1: Human driver
- 2: Human driver
- 3: System
- 4: System
- 5: System

**How much driving, overall, is assisted or automated:**
- 0: None
- 1: Some driving modes
- 2: Some driving modes
- 3: Some driving modes
- 4: Some driving modes
- 5: All driving modes
Self-Contained “Seeing”
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
- In the future, greater throughput, reducing 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

Planning
Planning for AVs

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

• It will likely be very, very disruptive

• Over time, will likely 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
Questions on Planning for AVs

With “cost” of travel coming down, this will likely:

• increase trip-making
• increase the distance of trip-making
• increase PMT
• increase VMT

In addition, it:

• MAY decrease transit and AT trip-making
• COULD increase OR decrease congestion
• MAY undermine land use polices
• MAY impact locational choices of residents and employers
• MAY impact the economy, industries and goods movement
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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<td>Ford</td>
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Source: Mashable
Economics

Cost per Mile

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

Total cost per passenger mile in New York City ($)\textsuperscript{a}

<table>
<thead>
<tr>
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<th>Cost per Mile</th>
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<tr>
<td>Public transport</td>
<td>1.0</td>
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<tr>
<td>Vehicle ownership</td>
<td>1.2</td>
</tr>
<tr>
<td>Taxi</td>
<td>2.8</td>
</tr>
<tr>
<td>Robo-taxi</td>
<td>1.1</td>
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</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.

Average number of people per vehicle

- Public transport: NA
- Vehicle ownership: 1.6
- Taxi: 1.2
- Robo-taxi: 1.2
- Other: 1

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

\textsuperscript{a}Does not consider the impact of convenience and shorter wait and commute times.

\textsuperscript{b}Non-fare-based operating funds received from New York City transit; local, state, and federal sources; and other sources.

\textsuperscript{c}Annual fare revenues per passenger mile traveled.

Source: Boston Consulting Group (2016)
Economics

Figure 3: Average Unlinked Passenger Trip Length, 2011

Source: APTA 2011 Fact Book
Economics

Illustrative Mode Share at Various per Mile Prices

- Shared AV
- Cycling
- Walk
- Transit
- Private Auto

$3.00 $2.00 $1.00 $0.50

$3.00
$2.00
$1.00
$0.50
Public Acceptance – Trust of AVs

58% say they would take a ride in a fully self-driving car

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<th>Very likely</th>
<th>Likely</th>
<th>Neutral - Neither likely nor unlikely</th>
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... but only 35% of parents would let their children ride alone in one

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<td>22%</td>
<td>21%</td>
<td>30%</td>
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</tbody>
</table>

Public Acceptance – Shared Use

In % of respondents per country

China | France | Germany | India | Japan | NL | Singapore | UAE | UK | US

Political Support

Helsinki “announced 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

L.A. Mayor Eric Garcetti:
We Will Be the First City to Do Autonomous Vehicles Right

− September 29, 2014 • citylab.com

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

− December 21, 2016 Techcrunch.com
Political Support
Will a Shared Model Work?

The Economics need to create a market

- This will influence speed of privates and extent of coverage

There Needs to be a Willing Client Base

- If for cultural, demographic purposes there is reluctance
  - Likely wealthy, tech-supportive, tech-savvy, public-transit friendly cities and regions

Political Support

- Barriers could be created if opposed
- Economics will improve if vehicle size and weight can come down. This will likely only happen in AV-only environments – facilities or zones
Key Unknowns

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

Without a clear understanding of the future, how do we plan?
Driving Changes: Automated Vehicles in Toronto

Discussion paper

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

October 15, 2015

― David Ticoll, University of Toronto
Three Scenarios

Ownership Leads

Mixed

Shared Leads
### Impacts of Private vs. Mixed vs. Shared

<table>
<thead>
<tr>
<th></th>
<th>Private</th>
<th>Mixed</th>
<th>Shared</th>
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<tbody>
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<td>Collisions</td>
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<td>Vehicular Mobility</td>
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<td>Equitable Mobility</td>
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<td>Cost of Private/Semi-private Vehicular Travel</td>
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<td>Vehicle Kilometers Travelled</td>
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<td>Fixed Route Transit Demand</td>
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<td>Active Transportation</td>
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<tr>
<td>Trend of Intensification</td>
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<td>Parking Demand</td>
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<td>Right-of-way allocated for vehicles</td>
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<td>Residential Building/Lot Size</td>
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<td>![down]</td>
<td>![down]</td>
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<tr>
<td>Impervious Areas</td>
<td>![question]</td>
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How is this Unfolding?

- Discussions are happening primarily at the federal and state levels

- Economic development considerations have seemed to be a significant driver of the policy discussions

- Because of the potential “winner take all”, stakes are high, companies are moving fast…. 
Goals of Cities and Regions

- Safety
- Accessibility
- Mobility
- Economic Opportunity
- Quality of Life
- High-Quality Natural and Built Form
- Environmental Sustainability
- Social Inclusion
- Financial Sustainability
Toronto Working Group

- Transportation
- Economic Development
- City Planning
- Toronto Transit Commission
- Licensing & Standards
- Police Services
- Parking Authority
- Parking Enforcement
- Revenue
- Employment Services
- Fleet
- Budget
- City IT
- Privacy Commission
Approaches Cities Could Take

Actively Discourage
- Prohibit or Restrict AVs or TaaS

Passive
- Wait and See

Actively Encourage
- Outfit signals with transmitters
- Map curbside regulations
- Conduct a pilot or demonstration
- Tax credits
- Create AV-only zones
- Create AV-only facilities
Toronto’s Draft Vision Statement

Toronto needs to harness the potential of AVs to help us create the City that we want.
Toronto Transportation Services Work Plan

PREPARING FOR AUTONOMOUS VEHICLES

Divisional Workplan 2016-2018
GOAL 2

PREPARATION

To prepare for the arrival of AVs no matter when and how they are introduced and adopted.

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<th>Objectives</th>
<th>2016</th>
<th>2017</th>
<th>2018</th>
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<tbody>
<tr>
<td>2.1 Improve Understanding and Clarity</td>
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<tr>
<td>2.1.1 Create and maintain a common lexicon of terms and concepts for consistent understanding.</td>
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<td>2.1.2 Identify and understand the broad range of potential implications of AVs.</td>
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<td>2.1.3 Define the interests of Transportation Services in vehicle automation across all sections and districts.</td>
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<td>2.1.4 Undertake public opinion research to assess and establish baseline attitudes toward AVs, expectations of government, and how AVs may influence travel behaviour and modal choice in the Greater Toronto and Hamilton Area.</td>
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<td>2.1.5 Develop detailed scenarios – ranging from no change, to a completely new transportation paradigm – for consistent forecasting and planning pathways; use these scenarios on a scale of possible to probable.</td>
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<td>2.1.5.1 In partnership with the Organization for Economic Cooperation and Development’s International Transportation Forum, undertake a modelling exercise to further develop and refine potential scenarios.</td>
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<td>2.2 Prepare a Foundation</td>
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<td>2.2.1 Improve the management and current function of traffic control devices, particularly signage and pavement markings.</td>
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<tr>
<td>2.2.1.1 Increase asset management and lifecycle analysis of traffic control devices, particularly signage and pavement markings.</td>
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<td>2.2.1.2 Review and consider the need for pavement markings on local streets.</td>
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<tr>
<td>2.2.1.3 Improve the visibility of traffic control devices under all weather conditions.</td>
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<tr>
<td>2.2.2 Work with mapping providers to investigate the potential for AV-supportive mapping to be conducted in Toronto, and determine the appropriate role for Transportation Services and the City.</td>
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<tr>
<td>2.2.3 Begin to engage with technology providers, automobile manufacturers, and transportation network companies to discuss municipal preparations and potential pathways.</td>
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</table>
Are GTHA Residents Ready for Autonomous Vehicles?

Survey Overview
November 24, 2016

Sweet, Matthias; Laidlaw, Kailey; Olsen, Tyler
Learning Objectives

• How likely are individuals to adopt Driverless Cars?

• How are individuals likely to change their travel behavior?

• How are different neighborhoods and demographic groups likely to respond differently?

• What role can public policy play in managing the future of driverless cars?
Population and Geographic Location

- 3,201 individuals surveyed, aged 18-75

- Greater Toronto-Hamilton Area Residences:
  - Toronto
    - Downtown
    - Etobicoke
    - Scarborough
    - North York
  - Hamilton
  - Peel Region
  - York Region
  - Durham Region
  - Halton Region
Challenges in Shaping Policy

• Companies don’t want to deal with municipalities, and are engaging at the only the most superficial level....

• Complex issue, lots of moving unknowns, we don’t have a clear understanding, so it’s difficult to advise our elected officials and boards

• Currently lacking the methods and tools to help us better inform the discussion
Scenario Planning

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

Walking

Transit

Shared AV

Non-AV

Private AV

Non-AV  Private AV  Shared AV  Transit  Walk  Cycling

2017 2019 2021 2023 2025 2027 2029 2031 2033 2035 2037 2039 2041 2043 2045 2047 2049 2051 2053 2055 2057
Scenarios – Private Leads

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

Timeline from 2017 to 2057.
Potential MaaS Markets

Highly Viable MaaS Service
Viable MaaS Service
Transit-Supportive MaaS Service
Wildcards

Catastrophic Event

Public Backlash Regarding Data and Privacy
Takeaways

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

• Cities, regions and transit agencies have a chance to shape this, but need to move

• While still many unknowns, we need to start factoring AVs into long-range planning

• Don’t let the unknowns and complexities paralyze us
“The best way to predict the future is to create it.”
Resources

DRIVING TOWARDS DRIVERLESS:
A GUIDE FOR GOVERNMENT AGENCIES

LAUREN ISAAC

WSP
PARSONS BRINKERHOFF
Resources

http://smartdrivingcar.com/GreenLight-092316

Friday, September 23, 2016

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
Resources

AV Update

nuTonomy is testing its vehicles in Michigan and UK
January 2017

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
Richard Voith

The Future of Transportation

February 8, 2017

ECONSULT SOLUTIONS
economics | policy | strategy
February 8, 2017
Transportation in the Digital Age: A Changing Landscape

- Digital reframing in personal and public transportation
- Ride sharing
- Autonomous vehicles
Transportation in the Digital Age: A Changing Landscape

**Data Driven Transportation**
- Optimization
- Customer Expectations and Communities

**Ridesharing Disruption**
- Ridesharing & Transit as Substitutes
- Ridesharing & Transit as Complements

**Automation Disruption**
- Automation substituting for labor
- Changing spatial needs
Transportation in the Digital Age: The Big Picture

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Transportation in the Digital Age: 3 Main Players

1. Increased Options

2. Mobiles

3. Cashless Transactions
Transportation in the Digital Age: Increased Options for Consumers

From Binary transportation modes (car or transit)

Private Car

OR

Public Transit

To Multi-modal (transit and rideshare and bike and car share and...)

Private Car

Public Transit

Rideshare

Bike

Car Share
Transportation in the Digital Age: Mobiles & Cashless Transactions

Southeastern Pennsylvania Transportation Authority (SEPTA)
Transportation in the Digital Age: Cashless Transactions

2013
- Overall pass usage: 25% decrease
- Pay per use: 20% increase

2014
- Bus users: 30% decrease
- Pay per use: 24% increase

2015
- First 9 months: $55 M

Introducing the Ventra App.
A better way to Ventra has arrived.
Transportation in the Digital Age: Turmoil for Agencies

- Overdue / Poor-Quality Repairs
- Reduced Service Hours
- Decreasing Consumer Confidence
Transportation in the Digital Age: Loss of Public Benefits

- Greater Options
- Decreased Service Rates
- Longer Wait Times
- Less Usage
Transportation in the Digital Age: Loss of Public Benefits

- Less Transit
- Less Density
- Loss of "Agglomeration" Benefits
Future Automation: Wide Ranging Impacts

- Cost of Transportation
- Infrastructure Needs
- Funding Mechanisms
- Personal Privacy
- Land and Development Patterns
• Autos more expensive, but shared so costs fall
• Travel time can be redirected toward productivity or leisure
• Parking costs can be lower
• Safety risks reduced
Automation: Costs of Passenger Transport (Transit)

- Last mile transit could fall
- Reduced service levels could raise time costs
- Less dense development could exacerbate transit problems
Infrastructure
Infrastructure: Automation

- Less need for parking
- Changing road design
- Multiple passengers in shared cares
- Roadways more densely used

- **May** reduce infrastructure needs

Transit Seriously Challenged

- Need sophisticated automation to compete
- **May** change transit investments
Infrastructure: Automation

- Infrastructure Savings Depends in Part on
  - Future Land Use Patterns
  - Status of Transit
    - Congestion increase if transit uncompetitive -> more infrastructure
Infrastructure Needs: Freight and Logistics

- Reduced need for cars to carry packages
  - Need for shared delivery locations
  - Changing nature of retail
- Need public and private infrastructure to support new delivery logistics
Funding Mechanisms
Gas Tax based funding of infrastructure should work well into the near future

BUT:

The world and transportation landscape is changing
• Current pattern of vehicle ownership may change
  – Corporate fleets of shared and automated vehicles
Funding & Connected Vehicles:

- Infrastructure charges by vehicle mile traveled by vehicle and time of day
  - Completely feasible at a low cost
  - Coordinated with land use decisions
Personal Privacy:
Travel pattern can be tracked
Spending can be tracked
Common carrier transportation may be an alternative
Personal Privacy

Ridership Data

Spending Data

= Targeted Marketing Strategy
Land Use & Development Patterns:
Automation: Land Use & Development

- Remote parking
- Denser centers (maybe)
- Lower travel costs -> More travel, greater decentralization
• Potential agglomeration loss
• Access for lower income citizens could be adversely impacted
May reduce infrastructure needs

- Roadways more densely used
  - Multiple passengers in shared cars
  - Closer spacing with connected vehicles
  - Changing road design
- Less need for parking
Personal Privacy

• **Sharing industry = ridership data**
  – Provider companies know your locations & destinations

• **Cashless transactions = spending data**
Development Patterns:
More changes for the ridesharing landscape

‘Ownership’ an emerging gray area

New implications for public transportation

The Next Big Digital Implication: Autonomous Vehicles
The Next Big Digital Implication: Autonomous Vehicles

- Cannot satisfy demand for large scale transportation
Impact of Autonomous Vehicles on Land Use

• Autonomous vehicles solve the parking related density issues – Constantly in use
Data-driven Transportation Services
  • Optimization
  • Customer Expectations and Communication
Ridesharing Disruption
  • Ridesharing & Transit as substitutes
  • Ridesharing & Transit as complements
Automation Disruption
  • Automation substituting for labor
  • Changing spatial needs
• Cities have less of a need for parking in central areas
• More efficient use of roads will lead to greater density
  – Lower cost transit
  – Less need for cars
  – Increased sharing, less need for urban personal ownership
• Time costs may be lowered if not shared
• Lower cost implies more travel
  – More travel = decentralization
  – Time costs don’t fall = decentralization of lower income people
What These Changes Mean For:

• Automated transit vehicles
• Cost and frequency of services
  – Implications for workforce needs and training
  – Have the ability to flexibly change routes
Infrastructure: Automation

- **May** change transit investments
  - Need sophisticated automation to compete
  - Implications depend on land use
Pennsylvania Autonomous Vehicle Testing Policy Task Force

Highly Automated Vehicles
The Coming Revolution
Background: *Innovation Unleashed*

- **PA leadership**
  - Academic: Carnegie Mellon; UPenn; Penn State
  - AAMVA, AASHTO, TRB
- **City of Pittsburgh**
  - CMU Autonomous Vehicle
  - GM
  - Uber
- **2016 USDOT Smart Cities Finalist**
  - Awarded $10.9 million by USDOT to implement a component of their original smart city application
PennDOT HAV Goals

1. Promote and encourage HAV R&D, innovation and testing in Pennsylvania
2. Ensure public safety on Pennsylvania roadways

*Safety is PennDOT’s paramount mission*
Our Approach

• Current law: legal, but limited

• Proposed legislation (SB 1412; HB 2203)
  - Advance AV testing on public roads
  - Testing to be overseen by PennDOT; PA Turnpike

• Regulations versus Policy
  – Flexibility to keep pace with innovation
  - Readiness to address safety issues promptly
Stakeholder Collaboration: Participating Members

**Federal Government**
- U.S. Department of Transportation
- Federal Highway Administration

**State Government**
- Pennsylvania Department of Transportation
- Pennsylvania Turnpike
- Pennsylvania State Police
- Pennsylvania Insurance Department
- Pennsylvania Department of Community & Economic Development

**Academia**
- Carnegie Mellon University
- Penn University

**Local Government**
- City of Pittsburgh

**Private Sector Organizations**
- SAE International
- AAA
- ATA
- Pennsylvania Motor Truck Association

**Private Sector Business**
- GM
- Uber
AV Task Force Mission

- Develop testing policy recommendations in anticipation of legislation
- Consensus seeking effort
- Alternate views and opinions recorded
1. Establishing the minimum levels that HAVs must achieve to begin testing


3. Defining “Who is the Driver?”


5. Determining what data do we want/need to collect, and what do we do with it?

6. Examining how we approve and govern testing now and in the future
Task Force Report Accepted – Nov. 2016
• **PennDOT AV webpage:**
  [http://www.penndot.gov/ProjectAndPrograms/ResearchandTesting/Pages/Autonomous-Vehicle-Testing.aspx](http://www.penndot.gov/ProjectAndPrograms/ResearchandTesting/Pages/Autonomous-Vehicle-Testing.aspx)

• **Task Force report:**

• **Town Hall webinar:**

•
Next Steps

• Enact legislation

• Expand Task Force representation and mission

• Foster and promote citizen engagement

• Identify and address critical issues
  – Trial and error
  – Human/automated driver transition
  – Workforce/business impacts
  – Cyber security, data privacy, and ownership