‘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
Attempts at AVs Are Not New
Goals for Today

• Primer on AVs

• Planning for AVs

• Work in Toronto

• How Cities and Regions Can Prepare

Elevate the discussion about why and how cities and regions should be **SHAPING** the development of AVs
When will we see public use of AVs on our roads?

• 0-2 Years
• 2-5 Years
• 5-10 Years
• 10-15 Years
• 15+ Years
## NHTSA Levels of Automation

### Human Driver Monitors Environment

<table>
<thead>
<tr>
<th>Level</th>
<th>Description</th>
<th>Who steers, accelerates, and decelerates</th>
<th>Who monitors the driving environment</th>
<th>Who takes control when something goes wrong</th>
<th>How much driving, overall, is assisted or automated</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No Automation</td>
<td>Human driver</td>
<td>Human driver</td>
<td>Human driver</td>
<td>None</td>
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<tr>
<td>1</td>
<td>Driver Assistance</td>
<td>Human driver and system</td>
<td>System</td>
<td>System</td>
<td>Some driving modes</td>
</tr>
<tr>
<td>2</td>
<td>Partial Automation</td>
<td>System</td>
<td>System</td>
<td>System</td>
<td>Some driving modes</td>
</tr>
<tr>
<td>3</td>
<td>Conditional Automation</td>
<td>System</td>
<td>System</td>
<td>System</td>
<td>Some driving modes</td>
</tr>
<tr>
<td>4</td>
<td>High Automation</td>
<td>System</td>
<td>System</td>
<td>System</td>
<td>Some driving modes</td>
</tr>
<tr>
<td>5</td>
<td>Full Automation</td>
<td>System</td>
<td>System</td>
<td>System</td>
<td>All driving modes</td>
</tr>
</tbody>
</table>

### System Monitors Environment

<table>
<thead>
<tr>
<th>Level</th>
<th>Description</th>
<th>Who steers, accelerates, and decelerates</th>
<th>Who monitors the driving environment</th>
<th>Who takes control when something goes wrong</th>
<th>How much driving, overall, is assisted or automated</th>
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<tbody>
<tr>
<td>3</td>
<td>Conditional Automation</td>
<td>System</td>
<td>System</td>
<td>System</td>
<td>Some driving modes</td>
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<tr>
<td>4</td>
<td>High Automation</td>
<td>System</td>
<td>System</td>
<td>System</td>
<td>Some driving modes</td>
</tr>
<tr>
<td>5</td>
<td>Full Automation</td>
<td>System</td>
<td>System</td>
<td>System</td>
<td>All driving modes</td>
</tr>
</tbody>
</table>
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

- Technology
- Standards
- Ethics
- Liability
- Data
- Planning
- Impact to Jobs
- Security
- Safety
- Economics

Communications Systems
- Infrastructure
- Managing the Transition
- Consumer Preference
- Privacy
- Enforcement
- Human Factors
- Regulation
- Business Models
Complexities of AVs

Planning
Planning for AVs

• It’s no longer “if”, but “when”

• 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

• Will they increase or decrease trip-making?
• Will they increase or decrease the distance of trip-making?
• What will be their impact to transit?
• Will it be complementary or supplementary?
• Will we see more VMT or less VMT?
• Will we see more congestion or less congestion?
• Will they support or undermine land use polices?
• Will they impact locational choices of residents and employers?
• How will they impact the economy, industries and goods movement?
Key Unknowns

• Speed of Technological Advancement
• Economics
• Public Acceptance/Public Interest/Willingness
• Political Support
• Market for a Shared Model
  – Economics, Public Acceptance, Political Support
Speed of Technological Advancement

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

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# Speed of Technological Advancement

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Audi</td>
<td>2</td>
<td>3</td>
<td></td>
<td>3+</td>
<td>4/5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BMW</td>
<td>2</td>
<td></td>
<td></td>
<td>4/5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ford</td>
<td></td>
<td>2</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>3</td>
<td></td>
<td></td>
<td>3-4</td>
<td></td>
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<tr>
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<td></td>
<td></td>
<td></td>
<td>3</td>
<td></td>
<td></td>
<td>4/5</td>
<td></td>
<td></td>
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<tr>
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<td>4/5</td>
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<tr>
<td>Volvo</td>
<td>2</td>
<td></td>
<td></td>
<td>4/5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Mashable
Economics

Cost per Mile

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

Taxi

Shared AV

Source: ARK Investment Management
Economics

Cost per Mile: Shared vs. Owned

Source: Morgan Stanley (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

<table>
<thead>
<tr>
<th>Price</th>
<th>Shared AV</th>
<th>Cycling</th>
<th>Walk</th>
<th>Transit</th>
<th>Private Auto</th>
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<tr>
<td>$3.00</td>
<td>30%</td>
<td>10%</td>
<td>10%</td>
<td>10%</td>
<td>50%</td>
</tr>
<tr>
<td>$2.00</td>
<td>40%</td>
<td>20%</td>
<td>10%</td>
<td>10%</td>
<td>30%</td>
</tr>
<tr>
<td>$1.00</td>
<td>50%</td>
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<td>10%</td>
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</tr>
<tr>
<td>$0.50</td>
<td>60%</td>
<td>40%</td>
<td>10%</td>
<td>10%</td>
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</table>
## Public Acceptance – Trust of AVs

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

<table>
<thead>
<tr>
<th>Country</th>
<th>Very likely</th>
<th>Likely</th>
<th>Neutral</th>
<th>Unlikely</th>
<th>Very unlikely</th>
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</thead>
<tbody>
<tr>
<td>Global</td>
<td>29%</td>
<td>29%</td>
<td>19%</td>
<td>11%</td>
<td>12%</td>
</tr>
<tr>
<td>China</td>
<td>32%</td>
<td>43%</td>
<td>16%</td>
<td>6%</td>
<td>2%</td>
</tr>
<tr>
<td>France</td>
<td>31%</td>
<td>27%</td>
<td>17%</td>
<td>10%</td>
<td>15%</td>
</tr>
<tr>
<td>Germany</td>
<td>21%</td>
<td>23%</td>
<td>20%</td>
<td>15%</td>
<td>21%</td>
</tr>
<tr>
<td>India</td>
<td>56%</td>
<td>29%</td>
<td>10%</td>
<td>2%</td>
<td>3%</td>
</tr>
<tr>
<td>Japan</td>
<td>12%</td>
<td>24%</td>
<td>24%</td>
<td>19%</td>
<td>22%</td>
</tr>
<tr>
<td>Netherlands</td>
<td>19%</td>
<td>22%</td>
<td>25%</td>
<td>16%</td>
<td>19%</td>
</tr>
<tr>
<td>Singapore</td>
<td>31%</td>
<td>31%</td>
<td>24%</td>
<td>9%</td>
<td>7%</td>
</tr>
<tr>
<td>UAE</td>
<td>38%</td>
<td>32%</td>
<td>18%</td>
<td>7%</td>
<td>6%</td>
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<tr>
<td>UK</td>
<td>25%</td>
<td>24%</td>
<td>20%</td>
<td>14%</td>
<td>17%</td>
</tr>
<tr>
<td>US</td>
<td>27%</td>
<td>25%</td>
<td>17%</td>
<td>12%</td>
<td>18%</td>
</tr>
</tbody>
</table>

### ... but only 35% of parents would let their children ride alone in one

<table>
<thead>
<tr>
<th>Country</th>
<th>Very likely</th>
<th>Likely</th>
<th>Neutral</th>
<th>Unlikely</th>
<th>Very unlikely</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global</td>
<td>13%</td>
<td>22%</td>
<td>20%</td>
<td>23%</td>
<td>22%</td>
</tr>
<tr>
<td>China</td>
<td>16%</td>
<td>30%</td>
<td>14%</td>
<td>26%</td>
<td>14%</td>
</tr>
<tr>
<td>France</td>
<td>8%</td>
<td>19%</td>
<td>24%</td>
<td>24%</td>
<td>25%</td>
</tr>
<tr>
<td>Germany</td>
<td>3%</td>
<td>21%</td>
<td>23%</td>
<td>21%</td>
<td>32%</td>
</tr>
<tr>
<td>India</td>
<td>27%</td>
<td>31%</td>
<td>23%</td>
<td>11%</td>
<td>7%</td>
</tr>
<tr>
<td>Japan</td>
<td>7%</td>
<td>19%</td>
<td>20%</td>
<td>29%</td>
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</tr>
<tr>
<td>Netherlands</td>
<td>10%</td>
<td>19%</td>
<td>28%</td>
<td>40%</td>
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</tr>
<tr>
<td>Singapore</td>
<td>5%</td>
<td>16%</td>
<td>25%</td>
<td>30%</td>
<td>23%</td>
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<tr>
<td>UAE</td>
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<td>19%</td>
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</tr>
<tr>
<td>UK</td>
<td>7%</td>
<td>10%</td>
<td>23%</td>
<td>19%</td>
<td>40%</td>
</tr>
<tr>
<td>US</td>
<td>12%</td>
<td>15%</td>
<td>22%</td>
<td>21%</td>
<td>30%</td>
</tr>
</tbody>
</table>

Public Acceptance – Shared Use

In % of respondents per country

China: 21, 22, 25, 25, 20, 9, 5
France: 23, 22, 20, 25, 21, 25, 16, 22, 35
Germany: 42, 22, 25, 21, 20, 9, 5
India: 6, 10, 18, 35, 22, 25, 25, 32
Japan: 29, 22, 25, 16, 11, 4, 1
NL: 29, 25, 23, 30, 11, 7, 7
Singapore: 14, 14, 22, 25, 35, 32, 16, 13, 5
UAE: 13, 14, 22, 25, 25, 27, 16, 13, 5
UK: 29, 22, 25, 23, 27, 26, 29, 17, 10
US: 12, 10, 17, 26, 17, 10, 10

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

Regulations Force Uber, Lyft out of Austin…

May 15, 2016 Cointelegraph.com
Key Unknowns

• Speed of Technological Advancement

• Economics

• Public Acceptance/Public Interest/Willingness

• Political Support

• Market for a Shared Model
  – Economics, Public Acceptance, Political Support
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
Three Scenarios

Ownership Leads

Mixed

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

<table>
<thead>
<tr>
<th>Impact</th>
<th>Private</th>
<th>Mixed</th>
<th>Shared</th>
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</thead>
<tbody>
<tr>
<td>Collisions</td>
<td>↓</td>
<td>↓</td>
<td>↓</td>
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<tr>
<td>Congestion</td>
<td>↓</td>
<td>?</td>
<td>↓</td>
</tr>
<tr>
<td>Vehicular Mobility</td>
<td>↑</td>
<td>↑</td>
<td>↑</td>
</tr>
<tr>
<td>Equitable Mobility</td>
<td>?</td>
<td>↑</td>
<td>?</td>
</tr>
<tr>
<td>Cost of Private/Semi-private Vehicular Travel</td>
<td>?</td>
<td>↓</td>
<td>↓</td>
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<tr>
<td>Carpooling</td>
<td>?</td>
<td>↑</td>
<td>↑</td>
</tr>
<tr>
<td>Passenger Kilometers Travelled</td>
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<td>↑</td>
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<tr>
<td>Vehicle Kilometers Travelled</td>
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<td>?</td>
<td>?</td>
</tr>
<tr>
<td>Fixed Route Transit Demand</td>
<td>↓</td>
<td>↓</td>
<td>↓</td>
</tr>
<tr>
<td>Active Transportation</td>
<td>↓</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>Trend of Intensification</td>
<td>↓</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>Parking Demand</td>
<td>?</td>
<td>↓</td>
<td>↓</td>
</tr>
<tr>
<td>Right-of-way allocated for vehicles</td>
<td>↓</td>
<td>↓</td>
<td>↓</td>
</tr>
<tr>
<td>Residential Building/Lot Size</td>
<td>?</td>
<td>↓</td>
<td>↓</td>
</tr>
<tr>
<td>Impervious Areas</td>
<td>?</td>
<td>↓</td>
<td>↓</td>
</tr>
</tbody>
</table>
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’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
Scenarios – Shared Leads

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

Year: 2017, 2019, 2021, 2023, 2025, 2027, 2029, 2031, 2033, 2035, 2037, 2039, 2041, 2043, 2045, 2047, 2049, 2051, 2053, 2055, 2057

Legend:
- Non-AV
- Private AV
- Shared AV
- Transit
- Walking
- Cycling

Source: WSP

Page 38
Takeaways

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

• Cities and regions 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
Tesla Video

→ https://electrek.co/2016/11/18/tesla-self-driving-demonstration-video-real-time-tesla-vision/
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 mobility, reducing congestion and improving access in underserved communities. (p5)