Market Forces and Market Potential for SmartDrivingCars
(aka Autonomous Vehicles)

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Director, Program in Transportation
Faculty Chair, PAVE (Princeton Autonomous Vehicle Engineering)
Princeton University

Presented at
Institute for Pure & Applied Mathematics
UCLA
Los Angeles, CA
February 26, 2019
Outline

• What Are SmartDrivingCars (aka Autonomous Vehicles)?
  – “Safe-Driving”; “Self-Driving”; “Driverless”

• Describe Market Forces for Each
  – Attempt to Quantify/Characterize Ride-sharing Opportunities

• Say a little bit about When

• Discussion
What are SmartDrivingCars??
Lots of confusion...


Only 3 kinds:

- ‘Safe-Driving ... (Cars, Trucks or Buses)’
  - Always on Automated Emergency Braking & Lane Centering
  - Delivers: Safety

- ‘Self-Driving ... (Cars, Trucks or Buses)’
  - Safe-Driving + Sometimes Capable / User Choice: Hands-Off &/or Feet-Off
  - Delivers: User Convenience + likely Negative Environmental Benefits

- ‘Driverless ... (Cars, Trucks or Buses)’
  - Safe-Driving + Always: Hands-Off, Feet-Off
  - Delivers: Mobility for All + Enormous Environmental Benefits
‘Safe-Driving Cars... (Trucks or Buses)’

- Don’t Crash, Stay in their lane and keep us from mis-behaving
- Always on Automated Emergency Braking, Lane Centering & and Speed Limiting
- Delivers: Safety
- Consumer Play (or Regulatory Play)

Sort of works, but nor nearly well enough

And... Safety Doesn’t Sell!!!
Safe-Driving Cars
Major Market Forces ...

• Get the technology’s False-positive rate -> Zero
  – So Users don’t disable It

• Get the technology’s False-negative rate -> Zero
  – So

  Cost of the Technology
  <
  Net Present Value \{ Expected Liability Savings \text{ delivered by that technology} \}

• Then an Insurance “Amazon” will pay for it & become “Amazon” of Insurance $$$
  – This is a different business model for Personal Auto Insurance
    – (make $$$ on reducing LOSS rather than on the “Float”)
‘Self-Driving Cars... (Trucks or Buses)’

- Safe-Driving + Ability to take Hands-Off Wheel and/or Feet-Off Pedals
  - ONLY: On Some Stretches of Some Roads at Some Times
  - Requires “Adult Supervision”

- Delivers: User Comfort & Convenience + some Environmental Benefits (less speed variation)
  - New ‘Chrome & Fins’
    » Auto companies & Car Dealers know how to sell these!
Major Implications...Self-Driving Cars

• 1\textsuperscript{st} and Foremost: provides \textbf{Comfort & Convenience To the Driver}
  – VMT (Vehicle Miles Travelled) goes through the roof
  – Land ...Far away & cheap becomes more attractive
    • Acceleration of sprawl (tough to forecast!!!)
  – Driving as an occupation becomes much more attractive
  – Traditional auto companies sell more cars at higher profit
    • BMW becomes the ‘Ultimate Riding & Driving Machine”
  – “Driverless” may be the only counter force.

• \textbf{When:} Car buying has begun (Tesla, MB, Cadillac, Volvo,...)
  – Are buyers more interested in far-away cheap land??? I know one... My Oldest!

\textbf{INSIDEEVs} All Tesla Model 3 Variants In China Include Free Enhanced Autopilot
Feb 8, ‘19
Active lane-keeping

Engineers focused on two situations that challenge active lane-keeping systems — curves and hills — in tests on open roads with no other vehicles around. They also observed how the systems performed in traffic.

All five systems provide steering assistance that centers the vehicle within clearly marked lanes. They also may use a lead vehicle as a guide when traveling at lower speeds or when the lead vehicle is blocking the system’s view of the lane markers ahead.
• ‘Driverless Cars ... (Cars, Trucks or Buses)
  
  • Safe-Drivering + **Always**: Hands-Off, Feet-Off; No Steering Wheel or Pedals
    (NO Adult Supervision)
    
    – Sharing Some Streets at Some Times with Conventionally-driven vehicles
What’s the Market???

• And Implications, if Successful?
Market / Implications... Driverless Cars

• Ownership Model
  – 1. Privately owned.
• ‘Driverless Cars ... (Cars, Trucks or Buses)
  • Safe-Driving + Always: Hands-Off, Feet-Off; No Steering Wheel or Pedals (NO Adult Supervision)
    – Sharing Some Streets at Some Times with Conventionally-driven vehicles
  • These can be “Mobility Machines”
    – Delivering ~ 50 trips per day (On-demand, “24/7” to “All”:
      » Young (~12 -> 17), Old (~?? -> ???), Physically “Challenged”, Poor
    – Delivering: Substantial Environmental Benefits
‘Driverless Cars ... (Cars, Trucks or Buses)

- Safe-Driving + Always: Hands-Off, Feet-Off; No Steering Wheel or Pedals (NO Adult Supervision)
  - Sharing Some Streets at Some Times with Conventionally-driven vehicles

• These can be “Mobility Machines”

As a Fleet Play delivering Mobility as a Service; NOT a Consumer Play
You will NOT want to own one (“Can’t Drive It” Anxiety)
You are not responsible enough nor have the resources to maintain one
A year after his initial estimate that Waymo was likely a $75 billion startup, Morgan Stanley analyst Adam Jonas raised it to a staggering $175 billion, citing greater revenue potential from passenger ride services and licensing of its tech. The biggest source of future revenue, however, is likely to come from autonomous trucking and delivery services, which Jonas thinks could generate as much as $90 billion.

What Are the opportunities for Ride-sharing?
Visions of “Smart Cities”

Where are the people???
Where do people **Live** today in the US?

- Households ~ 125M
- Owner occupied ~ 64%
  - Single Family Homes ~ 75M
Where do people *Live* today in the US?
Where do people **Work** today in the US?
Essentially only way to get from home to work today is Drive Yourself

Would autonomousTaxis be a Smarter way????
Would like to...

Quantitatively Assess
the Market Opportunities for on-Demand Ride Sharing
and
the Operational Characteristics
of a Smart Communities Public Transit System
(an autonomous Taxis Fleet)
that would Capture/Serve Various Aspects of that Market

In Particular: Be Sure to Serve
the Mobility Disadvantaged
(Poor, Physically Challenged, Old & Young)
To do this ...

We’d Need to Know

Where Individuals want to
Go From & To, When

So we set out to create
the Individuals
Where they may want to go From & To, When,
and then “Play (Quantitatively Assess)”
Creating the **USA_Resident** file for “every” Traveler on a typical day Nationwide

**USA_Resident** file

Start with Publically available data:
### Bergen County @ Block Level

<table>
<thead>
<tr>
<th>County</th>
<th>Population</th>
<th>Census Blocks</th>
<th>Median Pop/ Block</th>
<th>Average Pop/Block</th>
</tr>
</thead>
<tbody>
<tr>
<td>BER</td>
<td>907,128</td>
<td>11,116</td>
<td>58</td>
<td>81.6</td>
</tr>
</tbody>
</table>

#### Bergen County Population per Census Block

![Graph showing population distribution per Census Block](image1)

#### Cumulative Population Over Census Blocks, BER

![Graph showing cumulative population over Census Blocks](image2)
For each Household

{Auto Availability/HH} Geographically, Income

% HH w/o a car: NYC 54%, DC 38%, LA 12%, Nashville 6%

Assign: {# Autos -> HH}

{Lat, Lon, Company} Transit Stop
For each Household

{Auto Availability/HH} Geographically, Income
Assign: {# Autos → HH}

{Lat, Lon, Company} Transit Stop

<table>
<thead>
<tr>
<th>HH #</th>
<th># Adults</th>
<th>Income</th>
<th>Auto Ownership</th>
<th>Distance Nearest Transit Stop</th>
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<tbody>
<tr>
<td>4,319,763</td>
<td>1</td>
<td>$24,000.</td>
<td>0</td>
<td>0.47</td>
</tr>
</tbody>
</table>
## Mobility Disadvantaged Index

$$\text{MDI} = f\{\text{HH }\#\text{, }\#\text{ Adults, Income, Auto Ownership, Transit < 5 min, Walk (Y/N)}\}$$

<table>
<thead>
<tr>
<th>HH #</th>
<th># Adults</th>
<th>Income</th>
<th>Auto Ownership</th>
<th>Transit &lt; 5 min</th>
<th>Walk (Y/N)</th>
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</thead>
<tbody>
<tr>
<td>4,319,763</td>
<td>1</td>
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<td>0</td>
<td>0.47</td>
</tr>
</tbody>
</table>
### Mobility Disadvantaged Index

The Mobility Disadvantaged Index (MDI) is calculated as follows:

\[
MDI = \begin{cases} 
\text{Auto Availability (0, 5, 10)}, & \text{if}\ \text{Transit < 5 min and Walk (Y/N)} 
\end{cases}
\]

<table>
<thead>
<tr>
<th>HH #</th>
<th># Adults</th>
<th>Income</th>
<th>Auto Ownership</th>
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<td>0</td>
<td>0.47</td>
<td></td>
</tr>
</tbody>
</table>
Mobility Disadvantaged Index

$$MDI = f\{\text{Auto Availability (0, 5, 10), Income (1,10 (percentile))}, \}$$

<table>
<thead>
<tr>
<th>HH #</th>
<th># Adults</th>
<th>Income</th>
<th>Auto Ownership</th>
<th>Transit &lt; 5 min Walk (Y/N)</th>
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<td>0</td>
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</tbody>
</table>
Mobility Disadvantaged Index

\[ \text{MDI} = \left\{ \text{Auto Availability (0, 5, 10)}, \text{Income (1,10 (percentile)), Transit Accessibility (0, 5, 10)} \right\} \]

<table>
<thead>
<tr>
<th>HH #</th>
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<td>0.47</td>
</tr>
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<td>HH #</td>
<td># Adults</td>
<td>Income</td>
<td>Auto Ownership</td>
<td>Transit &lt; 5 min Walk (Y/N)</td>
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<tr>
<td>---------</td>
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<tr>
<td>4,319,763</td>
<td>1</td>
<td>$24,000.</td>
<td>0</td>
<td>0.47</td>
</tr>
</tbody>
</table>

**Mobility Disadvantaged Index**

\[
\text{MDI} = \text{f}\{\text{Auto Availability (0, 5, 10), Income (1,10 (percentile)), Transit Accessibility (0, 5, 10)}\}
\]
Pixelization of \{\text{Longitude, Latitude}\} \rightarrow \{i,j\}:

\[
x_{\text{Pixel}} = i = \text{floor}\left(138.348 \times (\text{longitude} + 97.5) \times \cos(\text{latitude})\right)
\]

\[
y_{\text{Pixel}} = j = \text{floor}\left(138.348 \times (\text{latitude} - 37.0)\right)
\]
Where Mobility Disadvantaged Live

Pixels with transit stops

Households per pixel having lowest 10% MDI (MDI < 7)
Where Kids go to School
Public & Private Schools in the US

Assign: {Kids ➔ Schools}
Where Folks Go & Work Nation-Wide Businesses

13.6 Million Businesses
{Name, address, Sales, #employees}

Assign:  {Folks ➔ Activities}

Census County2County Worker Flow Files

Assign:  {Workers ➔ Jobs}

<table>
<thead>
<tr>
<th>Rank</th>
<th>State</th>
<th>Sales Volume</th>
<th>No. Businesses</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>California</td>
<td>$1,889</td>
<td>1,579,342</td>
</tr>
<tr>
<td>2</td>
<td>Texas</td>
<td>$2,115</td>
<td>999,331</td>
</tr>
<tr>
<td>3</td>
<td>Florida</td>
<td>$1,702</td>
<td>895,586</td>
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<tr>
<td>4</td>
<td>New York</td>
<td>$1,822</td>
<td>837,773</td>
</tr>
<tr>
<td>5</td>
<td>Pennsylvania</td>
<td>$2,134</td>
<td>550,678</td>
</tr>
<tr>
<td>9</td>
<td>New Jersey</td>
<td>$1,919</td>
<td>428,596</td>
</tr>
<tr>
<td>45</td>
<td>Washington DC</td>
<td>$1,317</td>
<td>49,488</td>
</tr>
<tr>
<td>47</td>
<td>Rhode Island</td>
<td>$1,814</td>
<td>46,503</td>
</tr>
<tr>
<td>48</td>
<td>North Dakota</td>
<td>$1,978</td>
<td>44,518</td>
</tr>
<tr>
<td>49</td>
<td>Delaware</td>
<td>$2,108</td>
<td>41,296</td>
</tr>
<tr>
<td>50</td>
<td>Vermont</td>
<td>$1,554</td>
<td>39,230</td>
</tr>
<tr>
<td>51</td>
<td>Wyoming</td>
<td>$1,679</td>
<td>35,881</td>
</tr>
</tbody>
</table>
US_PersonTrip file has ...

- **308,745,538** records
  - One for each person in US_Resident file
- Specifying **1,009,332,835** Daily Person Trips
  - Each characterized by a precise
    - \{oLat, oLon, oTime, dLat, dLon, Est_dTime\}
<table>
<thead>
<tr>
<th>State</th>
<th>Trip Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alabama</td>
<td>15,825,280</td>
</tr>
<tr>
<td>Alaska</td>
<td>2,397,128</td>
</tr>
<tr>
<td>Arizona</td>
<td>20,903,632</td>
</tr>
<tr>
<td>Arkansas</td>
<td>9,554,065</td>
</tr>
<tr>
<td>California</td>
<td>123,852,078</td>
</tr>
<tr>
<td>Colorado</td>
<td>16,839,860</td>
</tr>
<tr>
<td>Connecticut</td>
<td>11,850,814</td>
</tr>
<tr>
<td>DC</td>
<td>2,040,597</td>
</tr>
<tr>
<td>Delaware</td>
<td>2,970,506</td>
</tr>
<tr>
<td>Florida</td>
<td>61,275,215</td>
</tr>
<tr>
<td>Georgia</td>
<td>32,302,424</td>
</tr>
<tr>
<td>Hawaii</td>
<td>4,437,926</td>
</tr>
<tr>
<td>Idaho</td>
<td>5,141,420</td>
</tr>
<tr>
<td>Illinois</td>
<td>42,657,513</td>
</tr>
<tr>
<td>Indiana</td>
<td>21,431,504</td>
</tr>
<tr>
<td>Iowa</td>
<td>9,943,451</td>
</tr>
<tr>
<td>Kansas</td>
<td>9,227,226</td>
</tr>
<tr>
<td>Total</td>
<td>1,009,322,835</td>
</tr>
</tbody>
</table>

{\text{oLat}, \text{oLon}, \text{oTime}, \text{dLat}, \text{dLon}, \text{Est\_dTime}}
What are the Ride-sharing Opportunities?

- \( \{O_i, oT_i, D_i\} = \{O_j, oT_j, D_j\} \)
  
  \( \sim \) Zero

- \( \{O_i, oT_i, D_i\} = \{O_j + \alpha, oT_j + \beta, D_j + \gamma\} \)
  
  \( \alpha \) Spatial Aggregation

  \( \beta \) Departure Delay

  \( \gamma \) Along the Way
α Spatial Aggregation
Pixelation of New Jersey

Pixelization of \( \{ \text{Longitude}, \text{Latitude} \} \rightarrow \{i,j\} : \\
\text{xPixel} = i = \text{floor}\ (138.348 \times (\text{longitude} + 97.5) \times \cos(\text{latitude})) \\
\text{yPixel} = j = \text{floor}\ (138.348 \times (\text{latitude} - 37.0))
An aTaxiTrip

\{oYpixel, oXpixel, oTime (Hr:Min:Sec), dYpixel, dXpixel, Exected: dTime\}
Common Destination (CD)
CD=1p: Pixel -> Pixel (p->p) Ride-sharing

TripMiles = 3L
PersonMiles = 3L
aTaxiMiles = L
AVO = PersonMiles/aTaxiMiles = 3
Along the Way
Transit (aTaxi) Level-of-Service: Use Elevator Analogy...

- Walk < 5 minutes to aTaxi Stand
- 1st Arrival for a Destination Sector starts Timer (~ 5 minutes)
- Any other arrivals to that sector Join In
- Timer hits zero
  - door close
  - aTaxi departs with customer(s).
3 trips to common Sector

O → P → P2 → P3
CD= 3p: Pixel -> 3Pixels Ride-sharing; P₃ New
An aTaxiTrip
{oYpixel, oXpixel, TrainArrivalTime, dYpixel, dXpixel, Exected: dTime}
Transit (aTaxi) Level-of-Service: Use Elevator Analogy...

• Walk <5 minutes to aTaxi Stand
• 1\textsuperscript{st} Arrival for a Destination Sector starts Timer (~5 minutes)
• Any other arrivals to that sector Join In
• Timer hits zero
  – door close
  – aTaxi departs with customer(s).

• Can readily compute..
  – Departure Occupancy, PMT, VMT
  – Made Empty Location, Time, Fleet Size, Empty Repo....
## Orf 467F18 Symposium

Saturday, January 12, 2019, 101 Sherrerd Hall

### Ride-Share Potential and Operational Characteristics of Nation-wide aTaxi Mobility for All

<table>
<thead>
<tr>
<th>Time</th>
<th>Team</th>
<th>Name #1</th>
<th>Name #2</th>
<th>Name #3</th>
<th>Name #4</th>
<th>Name #5</th>
<th>Region</th>
<th>States</th>
</tr>
</thead>
<tbody>
<tr>
<td>9:00</td>
<td>4</td>
<td>Kara Dowling</td>
<td>Victoria Hayek</td>
<td>Ashley Willingham</td>
<td>Jackson Cressy</td>
<td></td>
<td>SouthEast (SE)</td>
<td>North Carolina, South Carolina, Georgia, Florida</td>
</tr>
<tr>
<td>9:20</td>
<td>2</td>
<td>Michael Weissman</td>
<td>Nicholas Veo</td>
<td>Shehab Thabet</td>
<td></td>
<td></td>
<td>NY Metro (NM)</td>
<td>New York, New Jersey, Pennsylvania</td>
</tr>
<tr>
<td>9:40</td>
<td>3</td>
<td>Austin Stiefeleier</td>
<td>Mashad Arora</td>
<td>Vanessa Moore</td>
<td></td>
<td></td>
<td>Mid-Atlantic (MA)</td>
<td>Delaware, Maryland, District of Columbia, Virginia, West Virginia</td>
</tr>
<tr>
<td>10:00</td>
<td>1</td>
<td>Benji Rosenblatt</td>
<td>Carrie Hildebrand</td>
<td>Michael Retoff</td>
<td>Preeti Iyer</td>
<td>Megahn Slatteri</td>
<td>NorthEast (NE)</td>
<td>Maine, Vermont, New Hampshire, Mass, CT, Rhode Island</td>
</tr>
<tr>
<td>10:20</td>
<td>5</td>
<td>Rui De Oliveira</td>
<td>Aly Bouchard</td>
<td>John Anderson</td>
<td>Alexandra Bolanos</td>
<td></td>
<td>East/Midwest (EM)</td>
<td>Kentucky, Ohio, Michigan, Indiana</td>
</tr>
<tr>
<td>10:40</td>
<td>6</td>
<td>Tan Shanker</td>
<td>Chris Dragomir</td>
<td>Dee-Dee Huang</td>
<td>Nitish Jindal</td>
<td></td>
<td>West/Midwest (WM)</td>
<td>Illinois, Wisconsin, Minnesota, Iowa, Missouri</td>
</tr>
<tr>
<td>11:00</td>
<td>7</td>
<td>Katherine Xiao</td>
<td>Chris Murphy</td>
<td>Annie Xie</td>
<td></td>
<td></td>
<td>South/MidWest (SM)</td>
<td>Tennessee, Alabama, Mississippi, Arkansas, Louisiana</td>
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<tr>
<td>11:20</td>
<td>8</td>
<td>Larry Bao</td>
<td>Jarret Stowe</td>
<td>Parker Dixon</td>
<td></td>
<td></td>
<td>Upper Mountain (UM)</td>
<td>North Dakota, South Dakota, Nebraska, Wyoming, Montana</td>
</tr>
<tr>
<td>11:40</td>
<td>9</td>
<td>David Zhou</td>
<td>Stewart Stroebel</td>
<td>Jasmine Young</td>
<td>Emily Yin</td>
<td></td>
<td>Greater Texas (GT)</td>
<td>Texas, Oklahoma, New Mexico, Colorado, Kansas</td>
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<tr>
<td>12:20</td>
<td>11</td>
<td>Millian Gehrer</td>
<td>Drey Tengan</td>
<td>TJ Floyd</td>
<td>Zach Kelly</td>
<td></td>
<td>California (CA)</td>
<td>Hawaii, California, Nevada, Utah, Arizona</td>
</tr>
<tr>
<td>12:40</td>
<td>12</td>
<td>Millian Gehrer</td>
<td>Drey Tengan</td>
<td>TJ Floyd</td>
<td>Zach Kelly</td>
<td>David Zhou</td>
<td>Bottom Line (BL)</td>
<td>NationWide Summary</td>
</tr>
</tbody>
</table>
Person Trips Served by aTaxis

- **Arizona**: 19,129,619
- **California**: 30,403,951
- **Hawaii**: 3,873,079
- **Nevada**: 5,635,506
- **Utah**: 8,006,535

**PersonTrips Served By aTaxis/Day**

**aTaxi Departures/Day**
Comparison of ADO vs. AVO for each State

- Illinois
- Iowa
- Minnesota
- Missouri
- Wisconsin
- Region

Average Departure Occupancy
Average Vehicle Occupancy
aTaxiDepartures for Region

Point color by County
- IA
- IL
- MN
- MO
- WI

>= 50

>= 100
## New Jersey - True Average Vehicle Occupancy

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<thead>
<tr>
<th>DD</th>
<th>CD = 0</th>
<th>CD = 1</th>
<th>CD = 2</th>
<th>CD = 3</th>
<th>CD = 4</th>
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<td>1.06</td>
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<td>1.04</td>
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<td>2.93</td>
<td></td>
</tr>
</tbody>
</table>

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**Results**

![3D Plot Image](image-url)

**NJ State True AVO 3D Plot**

- X-axis: CD
- Y-axis: DD
- Z-axis: True Average Vehicle Occupancy
When will aTaxis be more than a Novelty???
Have You Noticed???

Google/Waymo’s Buying Spree

Google/Waymo Purchase of Driverless Cars

Cars “Purchased”

Year

2009
Have You Noticed???

Google/Waymo’s Buying Spree

Google/Waymo Purchase of Driverless Cars

Cars “Purchased”

Year

2009  2012

Have You Noticed???
Google/Waymo’s Buying Spree

Google/Waymo Purchase of Driverless Cars

Cars “Purchased”

Year

Have You Noticed???
Google/Waymo’s Buying Spree

Google/Waymo Purchase of Driverless Cars

Cars “Purchased”

Year

2009 2012 2015 2017
Have You Noticed???

Google/Waymo’s Buying Spree

Google/Waymo Purchase of Driverless Cars

Cars “Purchased”

Year

2009  2012  2015  2017  2018.2
Have You Noticed???

Google/Waymo’s Buying Spree

Google/Waymo Purchase of Driverless Cars

Cars "Purchased"

Year


> 10X every 2 years
(Waymo’s Kornhauser Law)
WHAT WILL WAYMO DO WITH 20,000 JAGUARS?

JAGUARS

WAYMO

HHMMM!...
WAYMO
HUNGRY!

YOU CAN'T EAT THEM!

+ 60,000
Chrysler Minivans
What will Waymo do with 20,000 Jaguars?

Provide housing for the homeless in San Francisco?
Where will Waymo Deploy 20,000 + 60,000 autonomous Taxis

• Maybe they’ll “Geographically Market Test the aTaxi Mobility Experience”
  – Start by operating 1K in 20 different “cities”
    • Geo-fenced “communities of ~ 300,000” (serve 5% of personTrips)
  – Add 2K to 1st 20 (grow to 15% personTrip share) + 1K in 20 more “Communities of 300k
Maybe they’ll “Spread the Mobility Experience”
  – operate 1K in 20 different “cities”

How about “Central New Jersey”?
  – Microcosm of USA

Pop: ~300K

Intra-area Trips/day: ~ 1.0M/day

1K aTaxis would serve ~ 5% personTrips
  – Focused initially on Mobility Disadvantaged
    • whose quality-of-life would be improved substantially!
    • Provide mobility to the 90% of trips not served by walking, biking or Conventional Mass Transit.
Where will Waymo Deploy
20,000 + 60,000 autonomous Taxis

• Maybe they’ll “Spread the Mobility Experience”
  – operate 1K in 20 different “cities”
• How about “Central New Jersey”?
  – Microcosm of USA
• Initial ~ 10 Waymos...
  – Provide Priority Service to Mobility Disadvantaged working at “Robbinsville Amazon Facility and other Warehouse facilities along the NJ Turnpike, plus ...
Where will Waymo Deploy
20,000 + 60,000 autonomous Taxis

- Maybe they’ll “Spread the Mobility Experience”
  - operate 1K in 20 different “cities”
- How about “Central New Jersey”? 
  - Microcosm of USA
- Initial ~ 11 - 100 Waymos...
  - Provide Priority Service to Mobility Disadvantaged working at other places, plus...
Where will Waymo Deploy
20,000 + 60,000 autonomous Taxis

• Maybe they’ll “Spread the Mobility Experience”
  – operate 1K in 20 different “cities”

• How about “Central New Jersey”?
  – Microcosm of USA

• Biggest challenge...
  – Creating a welcoming environment for aTaxis
  – By each and every street segment/community that is being served and whose streets are being used by these aTaxis.
  – Listening, Understanding and Learning what it is that will make
    • Make the Community happy
    • Serve their needs
    • Earn their appreciation and respect
  – All above is an Open Research Question!!!!!
Discussion!

Thank You

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www.SmartDrivingCar.com
~40+ years ago...

• Personal Rapid Transit (PRT)
  – Morgantown (circa 1976)
Along the way...

• Nothing much...
And Today...

- There a 2: Masdar (2GetThere) & Heathrow (Ultra) are operational
- Morgantown has been “perfect” for 40 years
Many Studies w/Students

- ~10,000 stations
- ~10,000 miles of guideway
- < 0.25 mile walk to/from any station
- Serve Essentially all Person Trips
- > $0.25 Trillion for Infrastructure
- Went by way too many Bedroom windows
How about Just automating the Vehicle??? (use existing roadways)

2005

2007

Link to Presentation Not Easy Old House 2005 2007