

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




Alain L. Kornhauser
Professor, Operations Research & Financial Engineering
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??

Making Sure We Are Using the Same Terminology...

(one always must start with terminology)

- Lots of confusion...
- ‘Connected’; ‘Autonomous’, ‘Automated’, ‘4 NHTSA Levels’ ‘5 SAE Levels’...
 - **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**

Major Market Forces ...

– ‘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!!!

[Lexus and Toyota: Automated Braking is Standard on Nearly Every Model and Trim Level by End of 2017z](#)



Safe-Driving Cars

Major Market Forces ...

- Get the technology's **False-positive** rate -> Zero

- So Users don't disable It

IIHS faults Uber for deactivating Volvo's automatic emergency braking in fatal crash



by Andrew Ganz, special from The Car Connection | Wednesday, August 8th 2018

- Get the technology's **False-negative** rate -> Zero

- So

Cost of the Technology

<

Net Present Value { Expected Liability Savings 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”

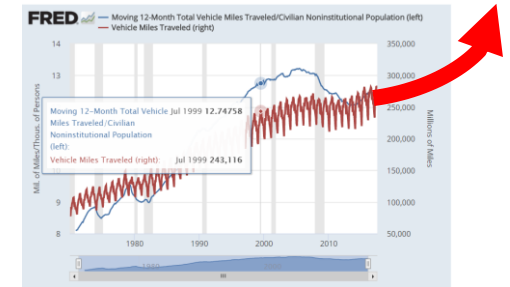


– ‘Self-Driving Cars... (Trucks or Buses)’

- 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

- 1st and Foremost: provides **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.
- **When:** Car buying has begun (Tesla, MB, Cadillac, Volvo,...)
 - Are buyers more interested in far-away cheap land??? I know one... My Oldest!



INSIDEEVs Feb 8, '19 [All Tesla Model 3 Variants In China Include Free Enhanced Autopilot](#)

When...Self-Driving Cars

August 7, 2018



EVALUATING AUTONOMY

IIHS examines driver assistance features in road, track tests

<http://m.iihs.org/mobile/news/mobilenews/evaluating-autonomy-iihs-examines-driver-assistance-features-in-road-track-tests>

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.



Number of times vehicle went over line

	on curves	on hills
BMW 5 series	3	6
Mercedes-Benz E-Class	2	1
Tesla Model 3	0	0
Tesla Model S	1	12
Volvo S90	8	2



Number of times vehicle system disengaged

	on curves	on hills
BMW 5 series	9	7
Mercedes-Benz E-Class	1	1
Tesla Model 3	0	0
Tesla Model S	0	0
Volvo S90	0	4



Number of times vehicle touched line

	on curves	on hills
BMW 5 series	1	1
Mercedes-Benz E-Class	5	1
Tesla Model 3	0	1
Tesla Model S	0	1
Volvo S90	0	1



Number of times vehicle stayed within lane

	on curves	on hills
BMW 5 series	3	0
Mercedes-Benz E-Class	9	15
Tesla Model 3	18	17
Tesla Model S	17	5
Volvo S90	9	9

Driverless



- ‘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

What's the Market???

- And **Implications**, if Successful?

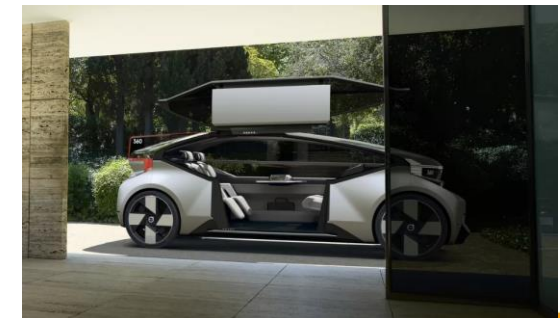
Market / Implications...**Driverless Cars**

- Ownership Model
 - 1. Privately owned..

Seems just
WRONG!



Entitled Elitists Toy



Driverless



- **‘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



- **‘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

Driverless



Forbes



Why Waymo Is Worth A Staggering \$175 Billion Even Before Launching Its Self-Driving Cars



Alan Ohnsman Forbes Staff
I write about technology-driven changes reshaping mobility

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”



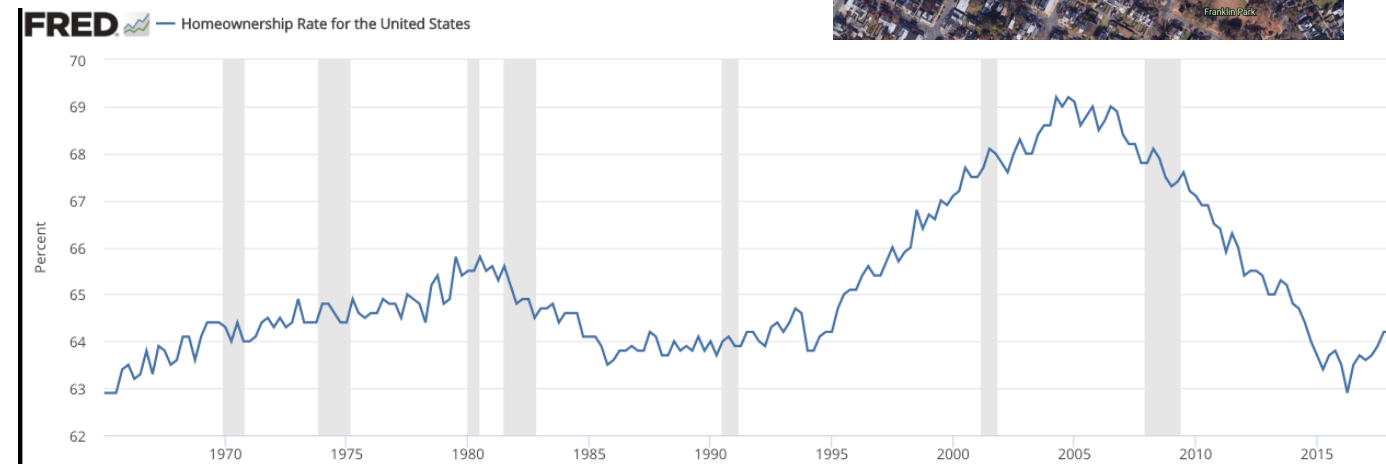
Where are the
people???



Slide from a plenary presentation from 1st morning of 2018 AV Conf.

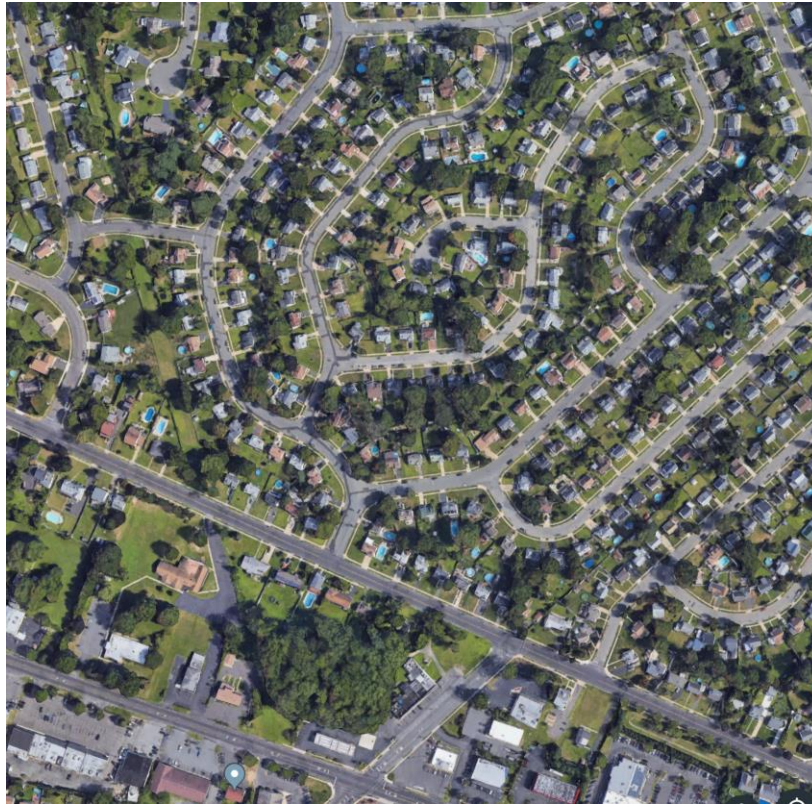
Where do people **Live** today in the US?

- Households ~ 125M
- Owner occupied ~ 64%
 - Single Family Homes ~ 75M



Country	Austria	Belgium	Denmark	France	Germany	Ireland	Norway	Spain	Portugal	UK	US	Slovenia	Israel	Canada
Home ownership rate ^[4]	56%	71%	51%	55%	42%	77%	77%	85%	64%	69%	68%	82%	71%	67%

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

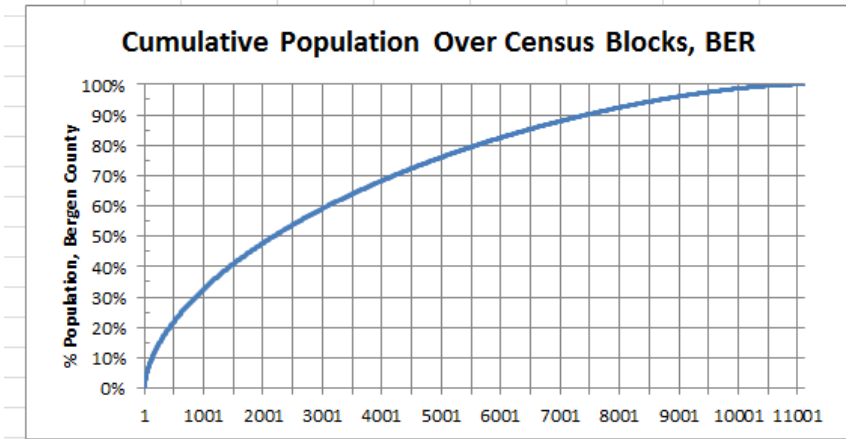
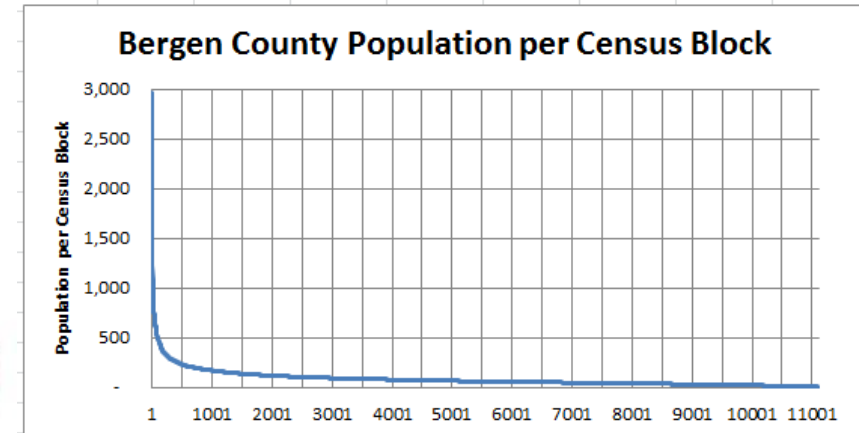
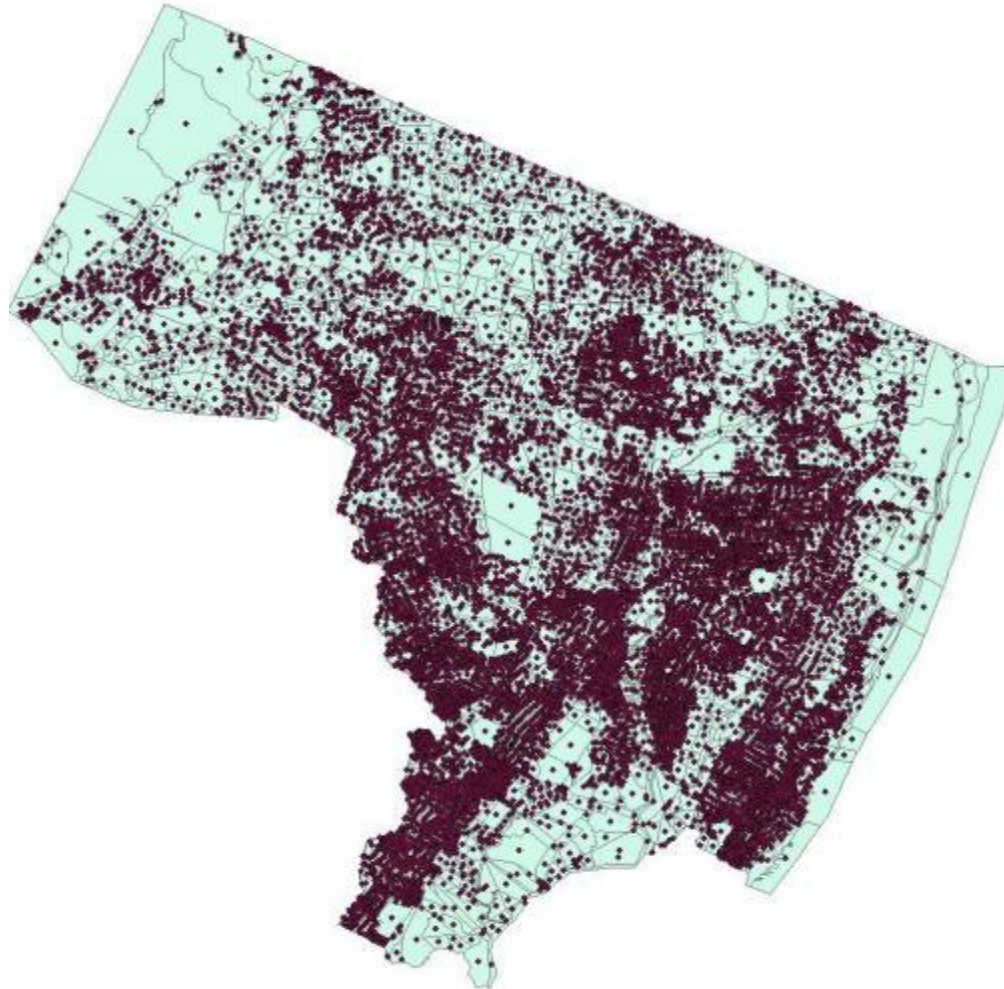
Start with Publically available data:



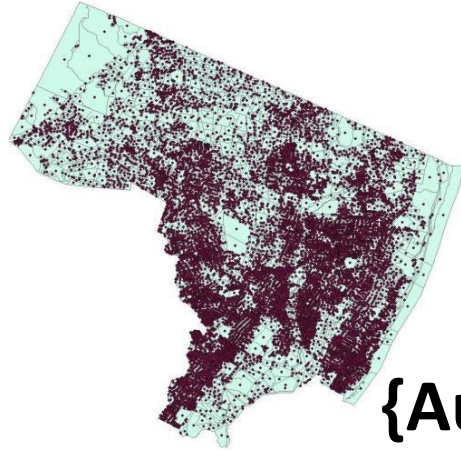
Bergen County @ Block Level



County	Population	Census Blocks	Median Pop/Block	Average Pop/Block
BER	907,128	11,116	58	81.6



For each Household



{Auto Availability/HH} Geographically, Income

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

Assign: {# Autos \rightarrow HH}



{Lat, Lon, Company} Transit Stop

For each Household



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



→ {Lat, Lon, Company} Transit Stop



HH #	# Adults	Income	Auto Ownership	Distance Nearest Transit Stop
4,319,763	1	\$24,000.	0	0.47

HH #	# Adults	Income	Auto Ownership	Transit < 5 min Walk (Y/N)
4,319,763	1	\$24,000.	0	0.47

Mobility Disadvantaged Index

MDI =

{ , , }

HH #	# Adults	Income	Auto Ownership	Transit < 5 min Walk (Y/N)
4,319,763	1	\$24,000.	0	0.47

Mobility Disadvantaged Index

MDI =

f{Auto Availability (0, 5, 10), , }

HH #	# Adults	Income	Auto Ownership	Transit < 5 min Walk (Y/N)
4,319,763	1	\$24,000.	0	0.47

Mobility Disadvantaged Index

MDI =

f{Auto Availability (0, 5, 10), **Income (1,10 (percentile))**, }

HH #	# Adults	Income	Auto Ownership	Transit < 5 min Walk (Y/N)
4,319,763	1	\$24,000.	0	0.47

Mobility Disadvantaged Index

MDI =

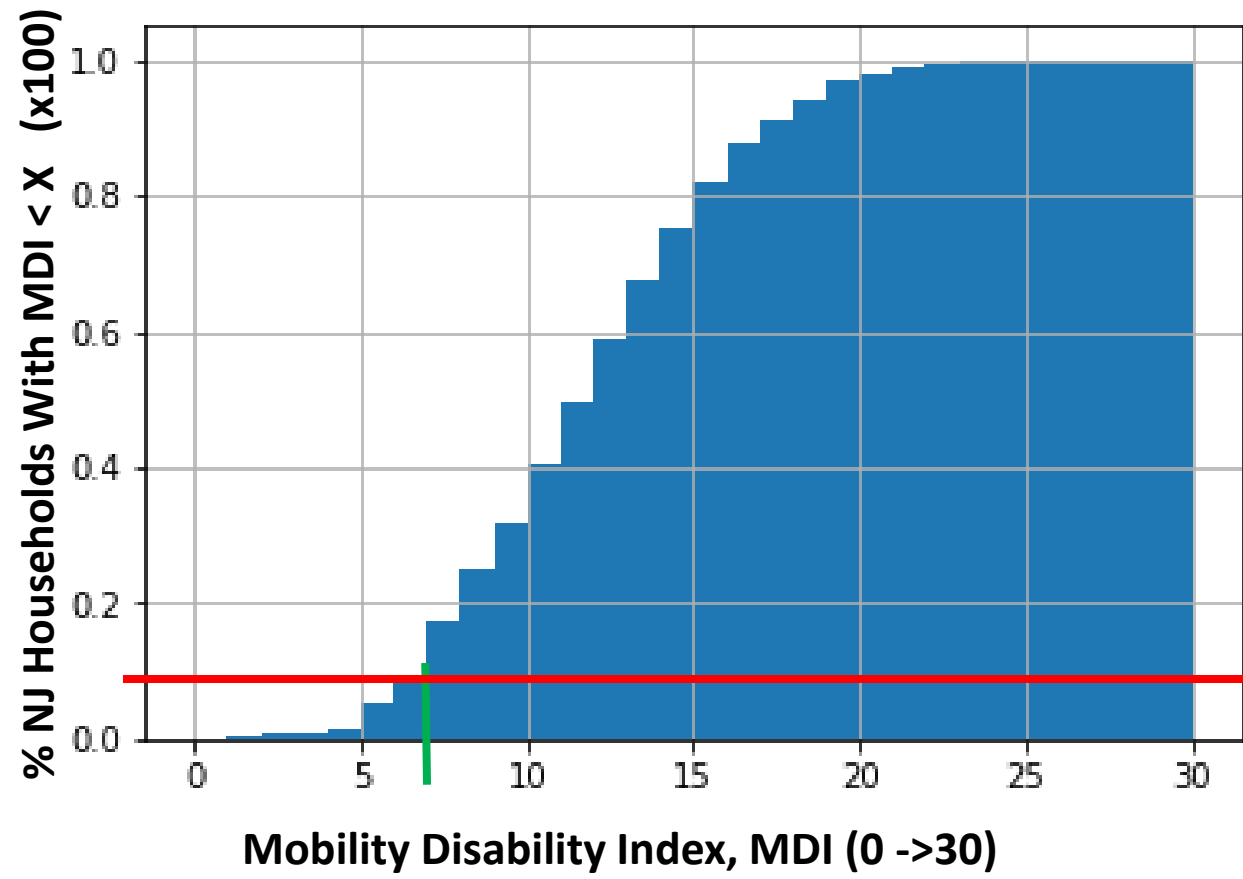
f{Auto Availability (0, 5, 10), Income (1,10 (percentile)), Transit Accessibility (0, 5, 10)}

HH #	# Adults	Income	Auto Ownership	Transit < 5 min Walk (Y/N)
4,319,763	1	\$24,000.	0	0.47

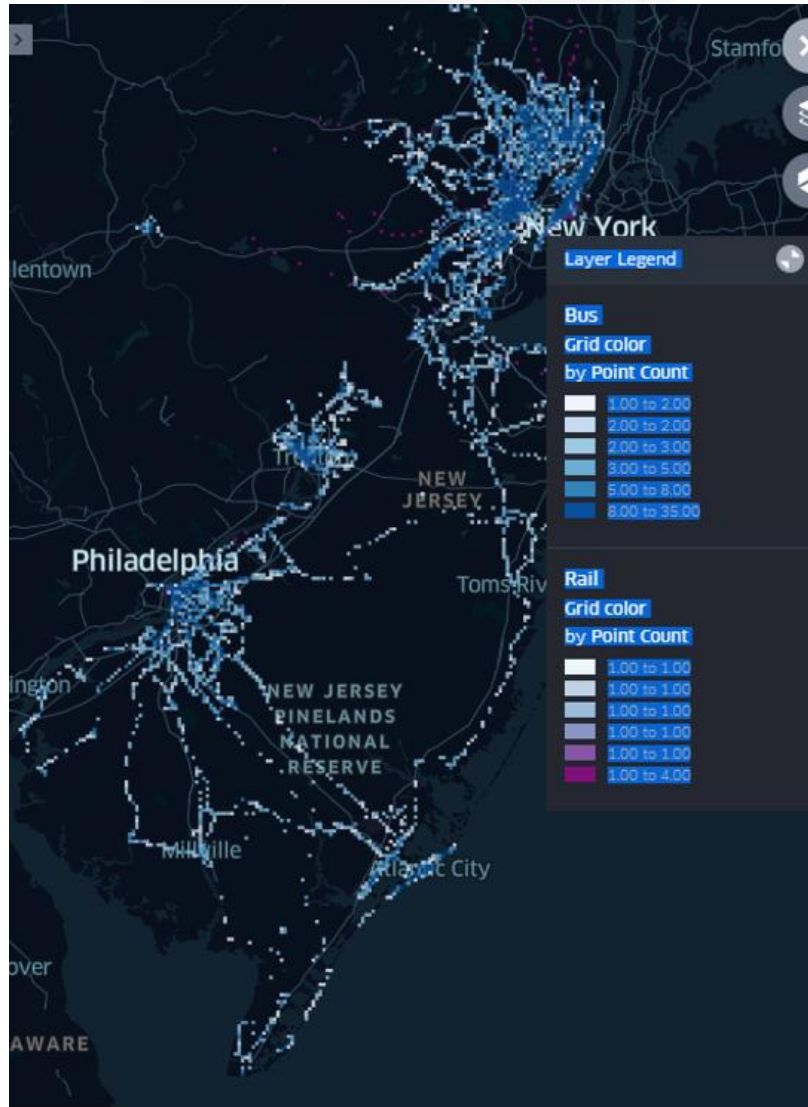
Mobility Disadvantaged Index

MDI =

f{Auto Availability (0, 5, 10), Income (1,10 (percentile)), Transit Accessibility (0, 5, 10)}



NJ Transit Stops



Pixelization of { Longitude, Latitude } -> { i,j } :

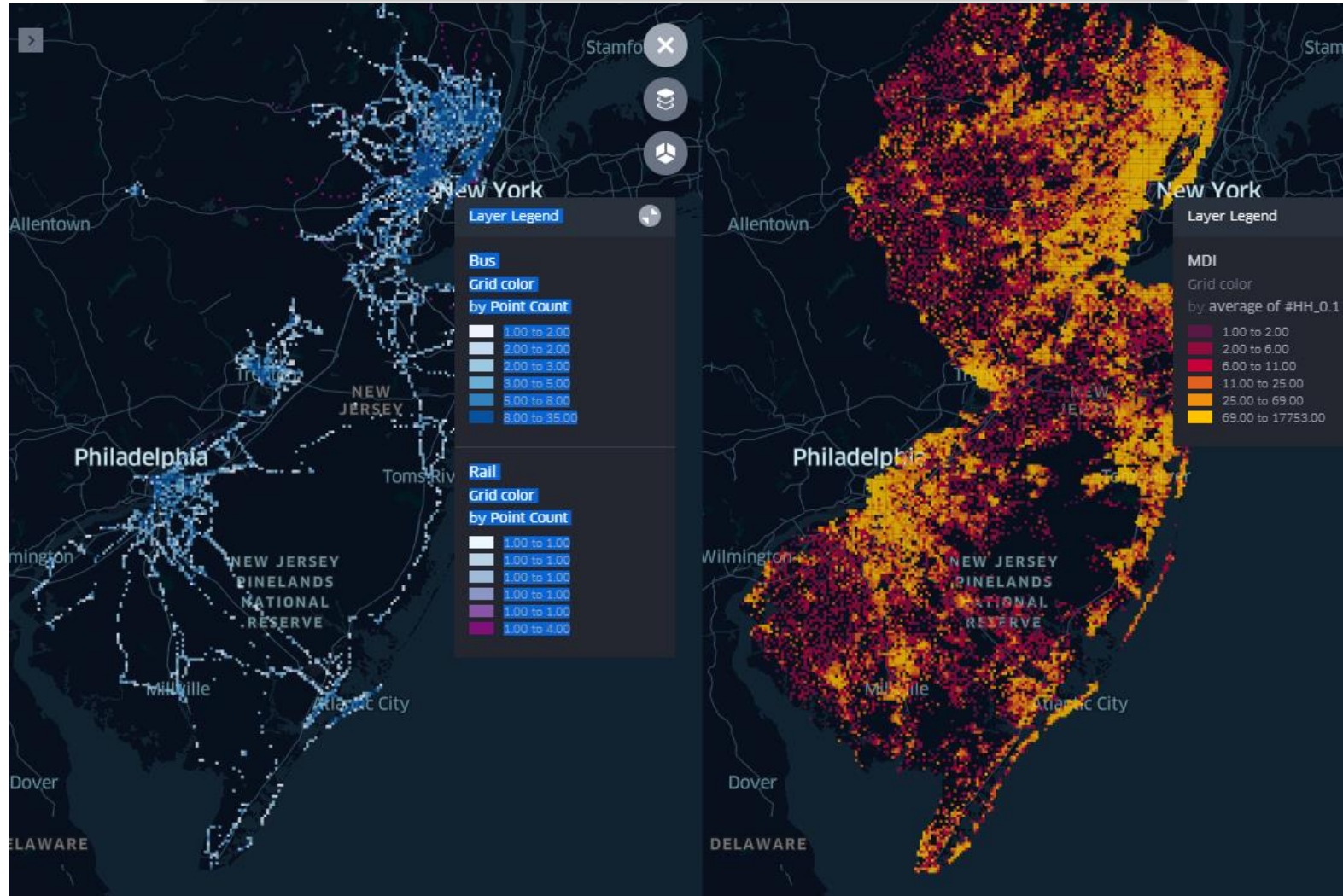
$$xPixel = i = \text{floor} \{ 138.348 * (\text{longitude} + 97.5) * \text{Cos}(\text{latitude}) \}$$

$$yPixel = j = \text{floor} \{ 138.348 * (\text{latitude} - 37.0) \}$$



Zoomed-In Grid of Mercer

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}

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

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}

State	Trip Count	State	Trip Count	State	Trip Count
Alabama	15,825,280	Kentucky	14,349,637	North Dakota	2,196,072
Alaska	2,397,128	Louisiana	8,148,094	Ohio	38,087,870
Arizona	20,903,632	Maine	4,429,255	Oklahoma	12,262,687
Arkansas	9,554,065	Maryland	19,316,346	Oregon	12,730,747
California	123,852,078	Massachusetts	21,866,204	Pennsylvania	41,709,485
Colorado	16,839,860	Michigan	32,833,666	Rhode Island	3,489,284
Connecticut	11,850,814	Minnesota	11,167,667	South Carolina	15,262,810
DC	2,040,597	Mississippi	9,717,958	South Dakota	2,627,648
Delaware	2,970,506	Missouri	19,699,659	Tennessee	21,096,931
Florida	61,275,215	Montana	3,261,369	Texas	83,584,971
Georgia	32,302,424	Nebraska	5,979,671	Utah	9,047,267
Hawaii	4,437,926	Nevada	9,048,868	Vermont	2,104,664
Idaho	5,141,420	New Hampshire	4,444,770	Virginia	26,646,786
Illinois	42,657,513	New Jersey	29,237,285	Washington	22,475,312
Indiana	21,431,504	New Mexico	6,779,308	West Virginia	6,106,765
Iowa	9,943,451	New York	64,529,719	Wisconsin	18,824,313
Kansas	9,327,336	North Carolina	31,638,807	Wyoming	1,870,191
Total	1,009,322,835				

{oLat, oLon, oTime, dLat, dLon, Est_dTime}

What are the Ride-sharing Opportunities?

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

$$\{O_i, oT_i, D_i\} = \{O_j + \alpha, oT_j + \beta, D_j + \gamma\}$$

α Spatial Aggregation

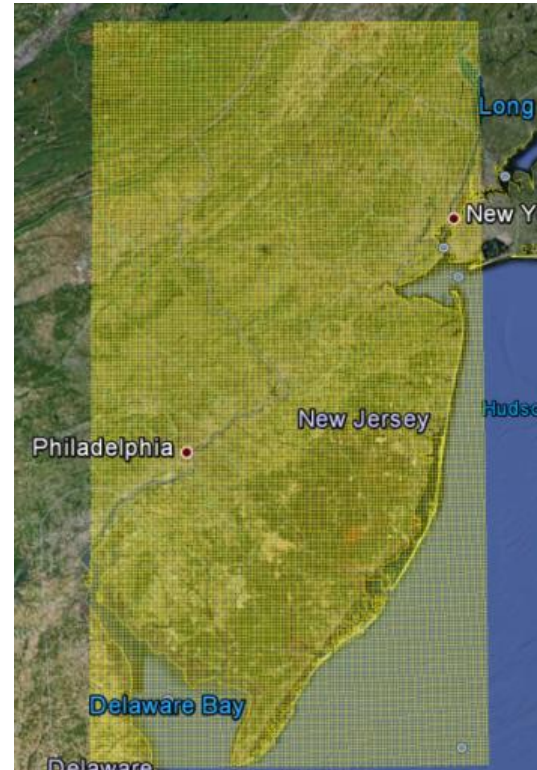
β Departure Delay

γ Along the Way



α Spatial Aggregation

Pixelation of New Jersey



NJ State Grid



Zoomed-In Grid of Mercer

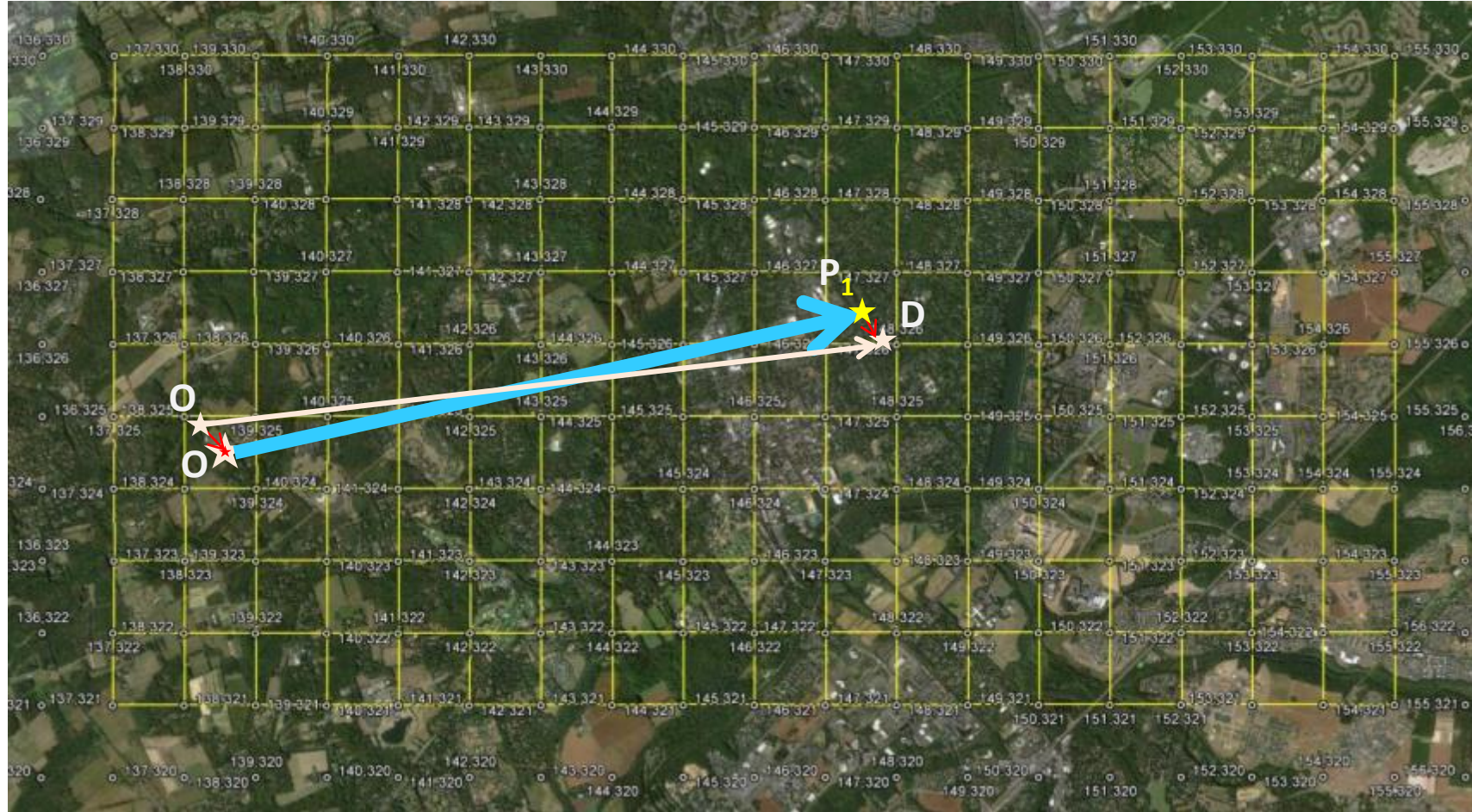
Pixelization of { Longitude, Latitude } \rightarrow {i,j} :

$$xPixel = i = \text{floor} \{ 138.348 * (\text{longitude} + 97.5) * \text{Cos}(\text{latitude}) \}$$

$$yPixel = j = \text{floor} \{ 138.348 * (\text{latitude} - 37.0) \}$$

An aTaxiTrip

{oYpixel, oXpixel, oTime (Hr:Min:Sec) ,dYpixel, dXpixel, Exected: dTime}

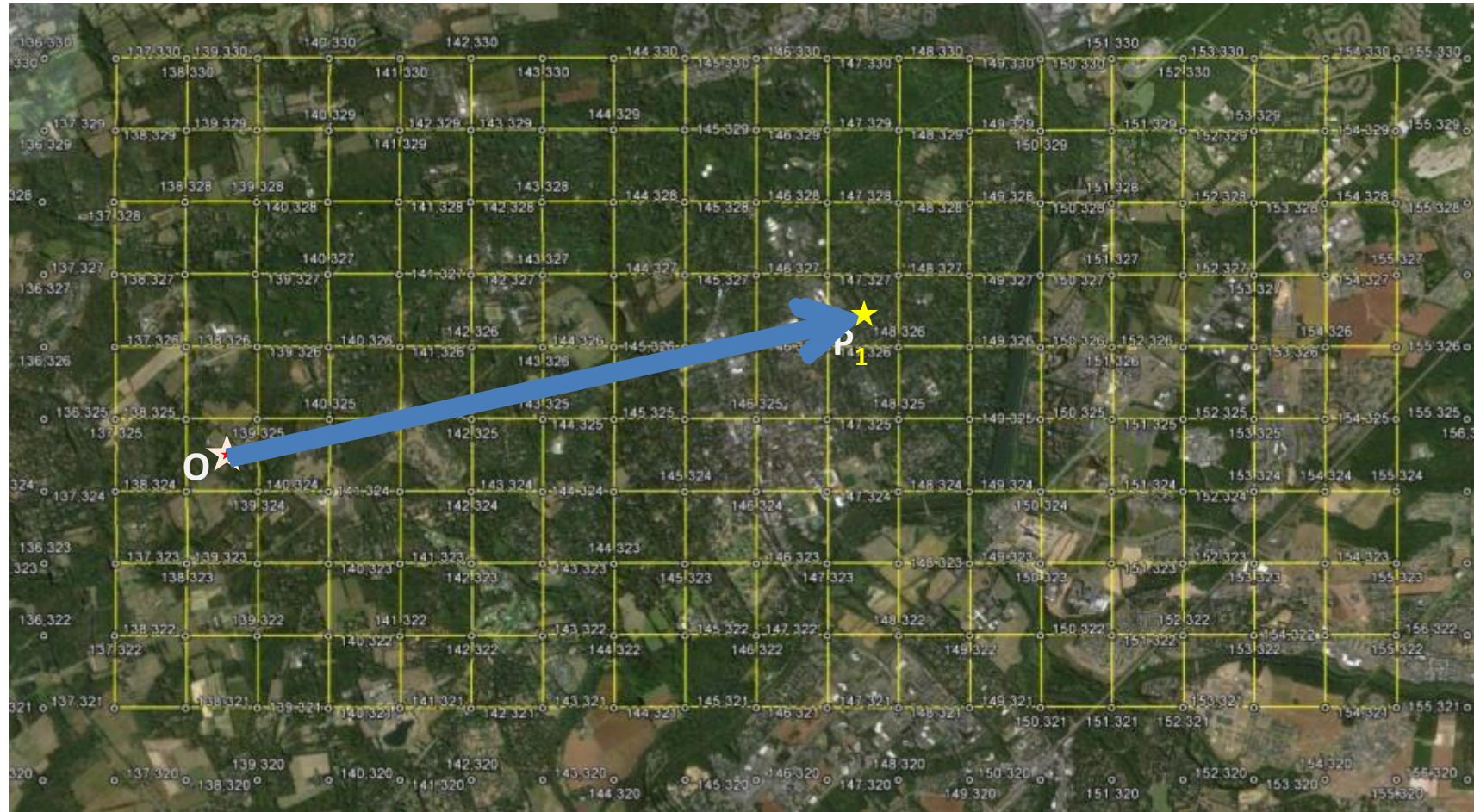


Common Destination (CD)

CD=1p: Pixel -> Pixel (p->p) Ride-sharing

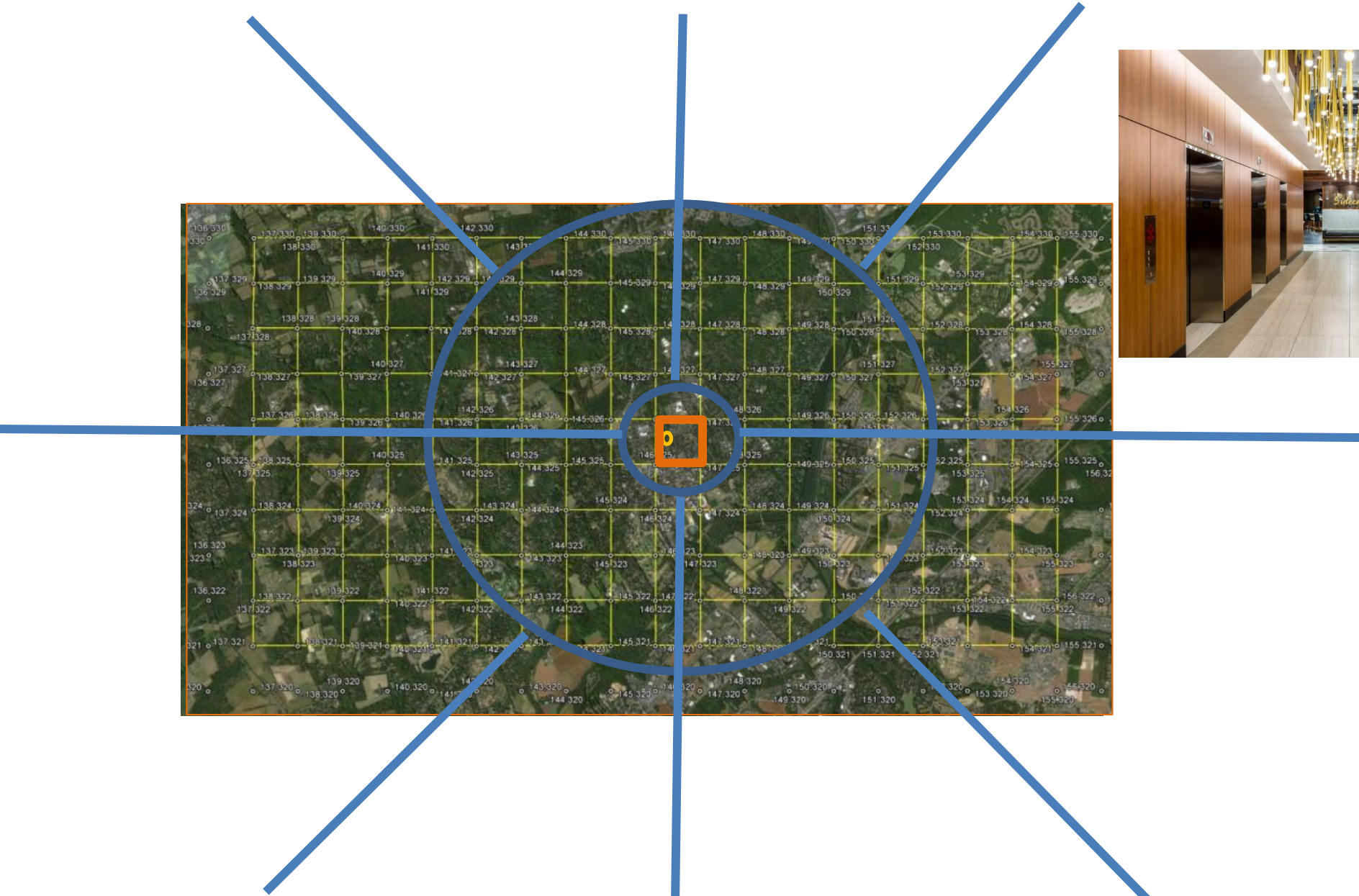


TripMiles = $3L$



PersonMiles = 3L
aTaxiMiles = L
AVO = PersonMiles/aTaxiMiles = 3

γ Along the Way

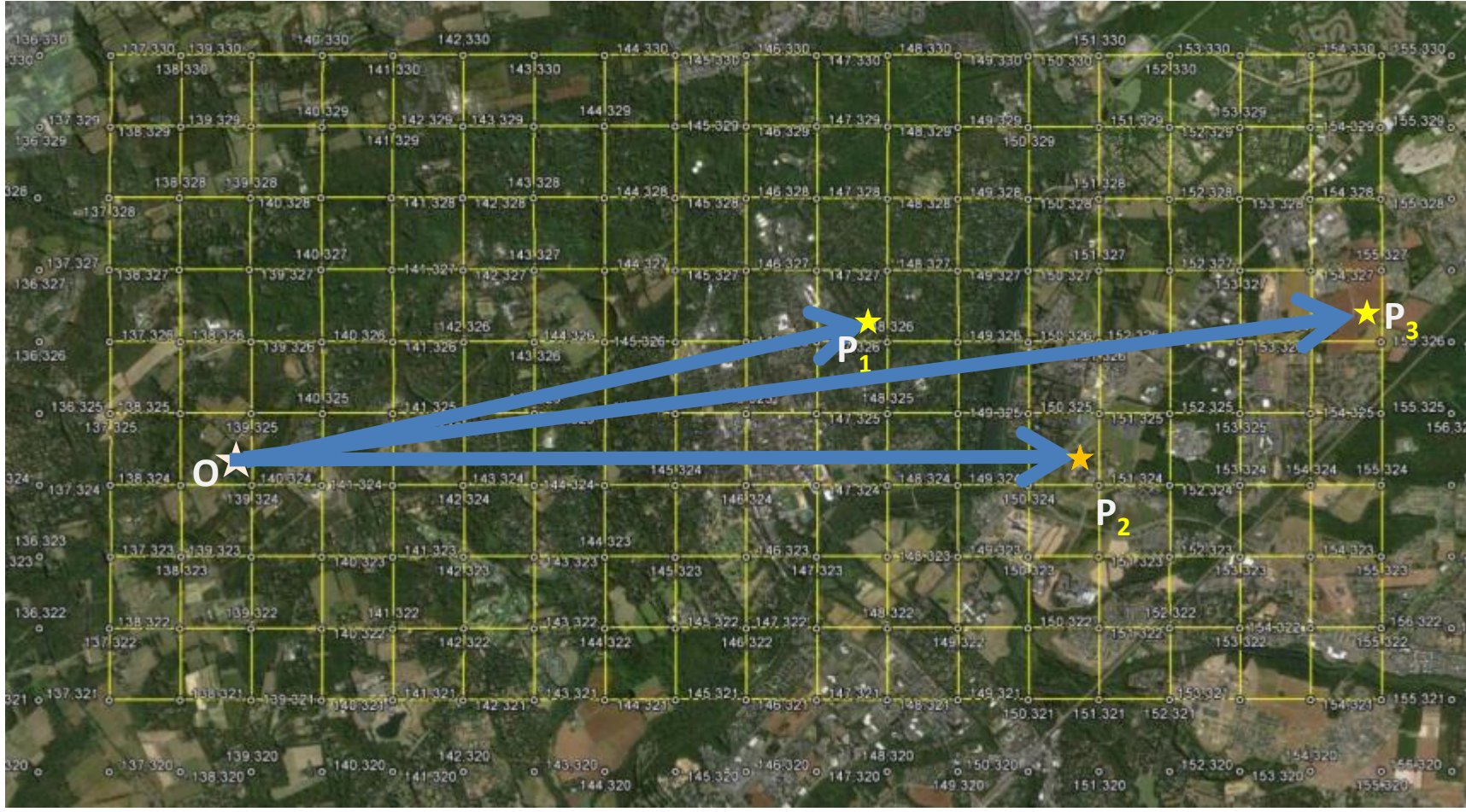


Transit (aTaxi) Level-of-Service: Use Elevator Analogy...

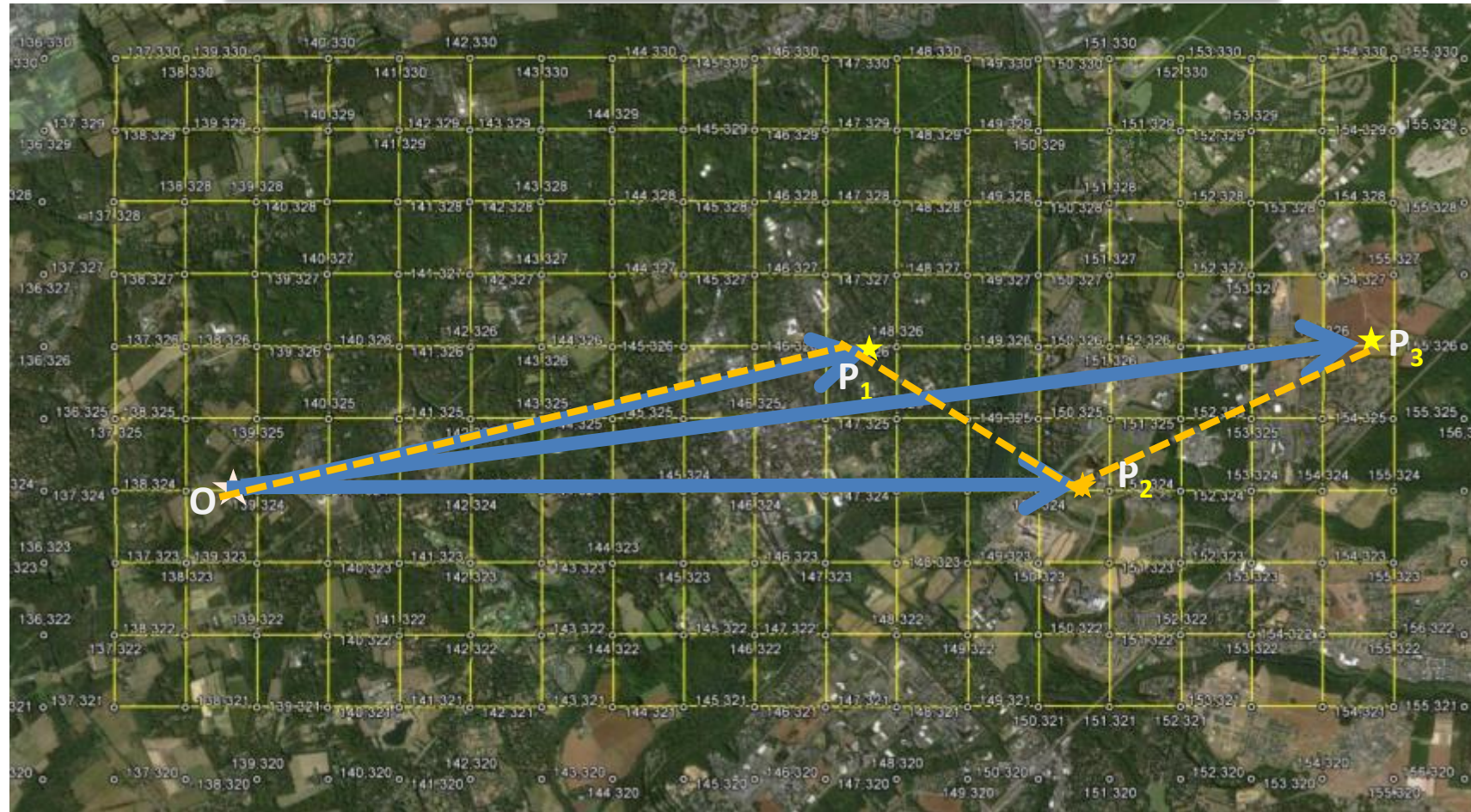
- Walk < 5 minutes to a Taxi Stand
- 1st Arrival for a Destination Sector starts Timer (~ 5 minutes)
- Any other arrivals to that sector Join In
- Timer hits zero
 - door close
 - aTaxi departs with customer(s).



3 trips to common Sector



CD= 3p: Pixel ->3Pixels Ride-sharing; P₃ New



An aTaxiTrip
{oYpixel, oXpixel, TrainArrivalTime, dYpixel, dXpixel, Exected: dTime}

★ NYC



Transit (aTaxi) Level-of-Service: Use Elevator Analogy...

- Walk < 5 minutes to a Taxi 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).
- **Can readily compute..**
 - Departure Occupancy, PMT, VMT
 - Made Empty Location, Time, Fleet Size, Empty Repo....



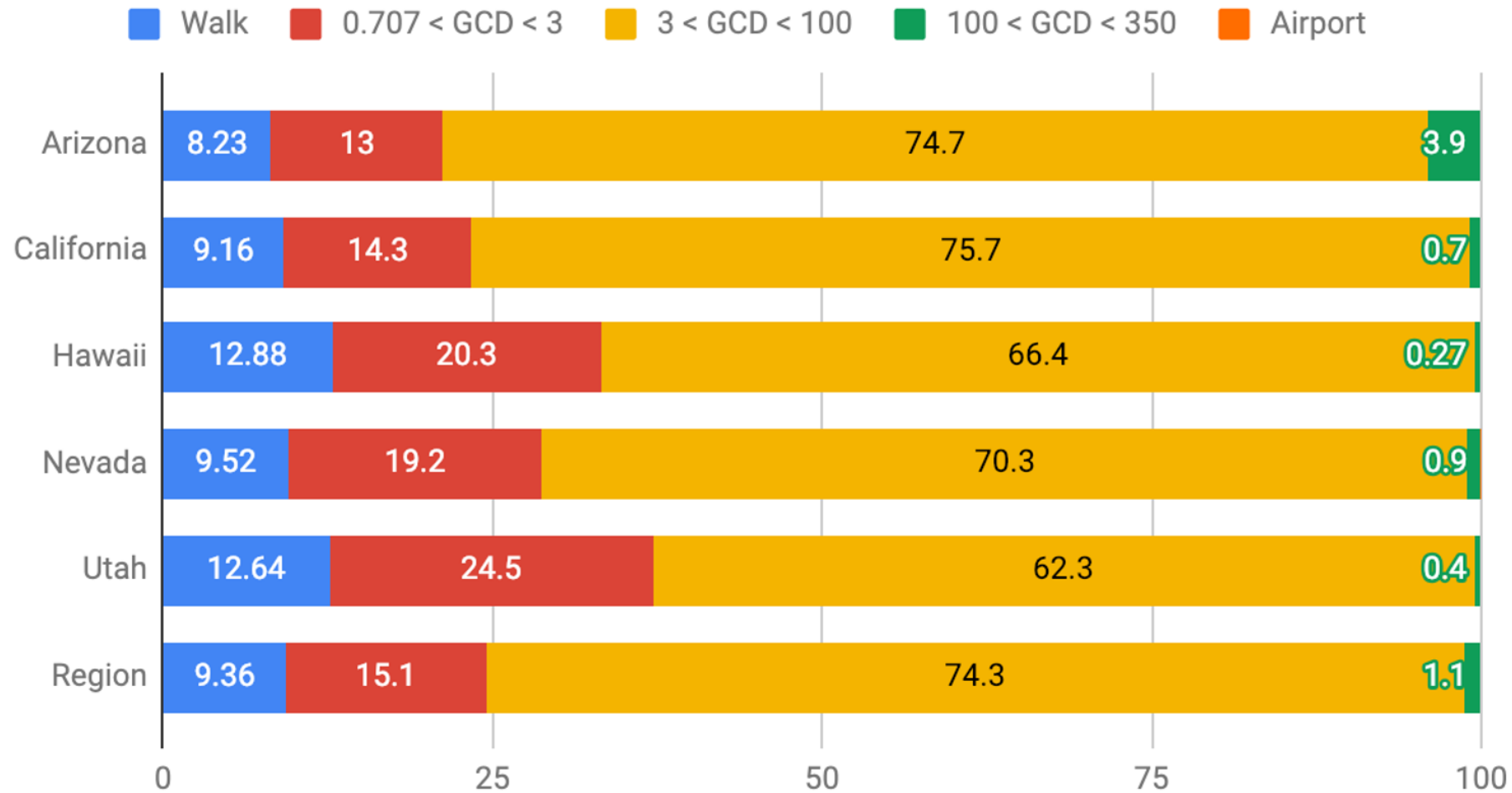
Orf 467F18 Symposium v 01/11/19

Saturday, January 12, 2019, 101 Sherrerd Hall

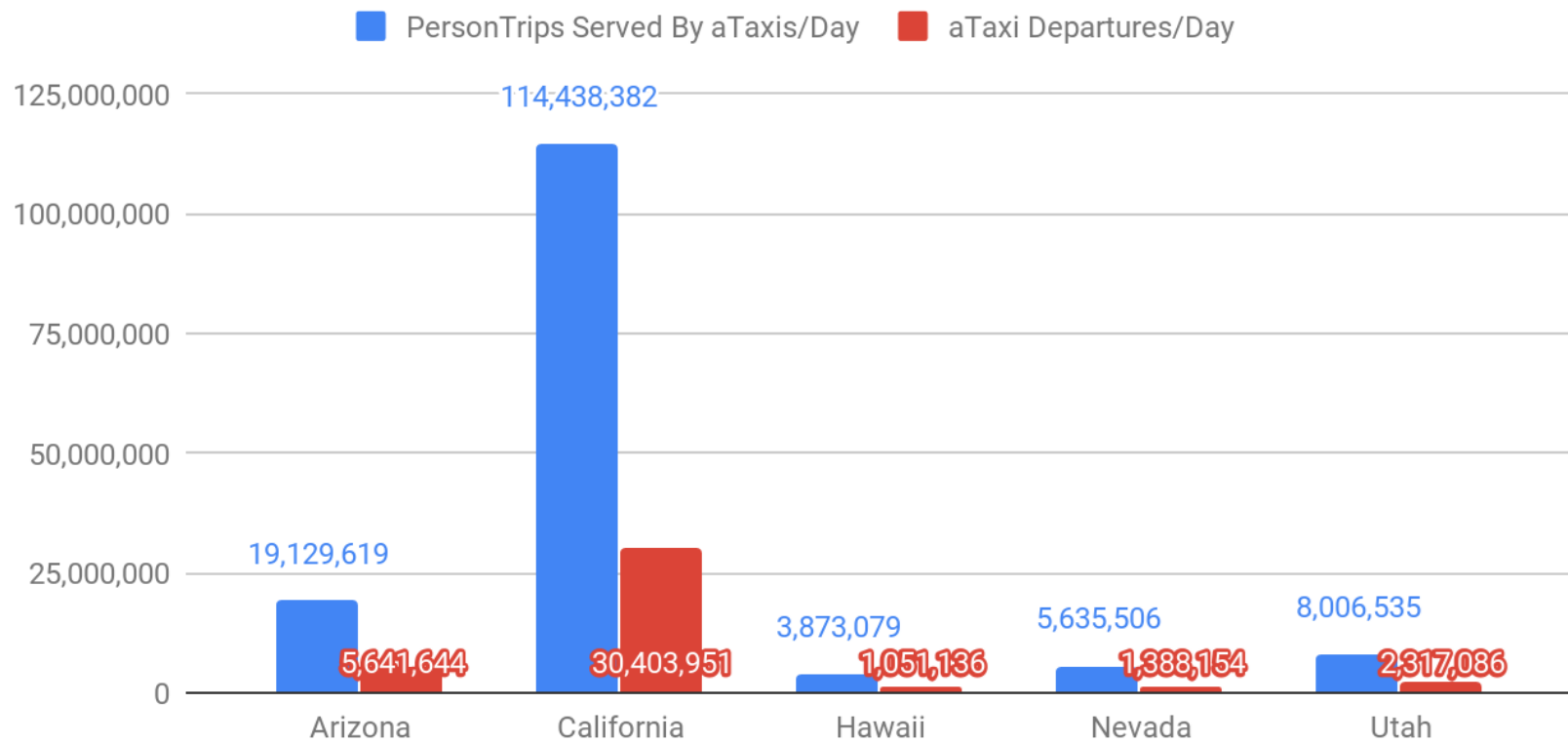
Ride-Share Potential and Operational Characteristics of Nation-wide aTaxi Mobility for All

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

% of Trips by GCD



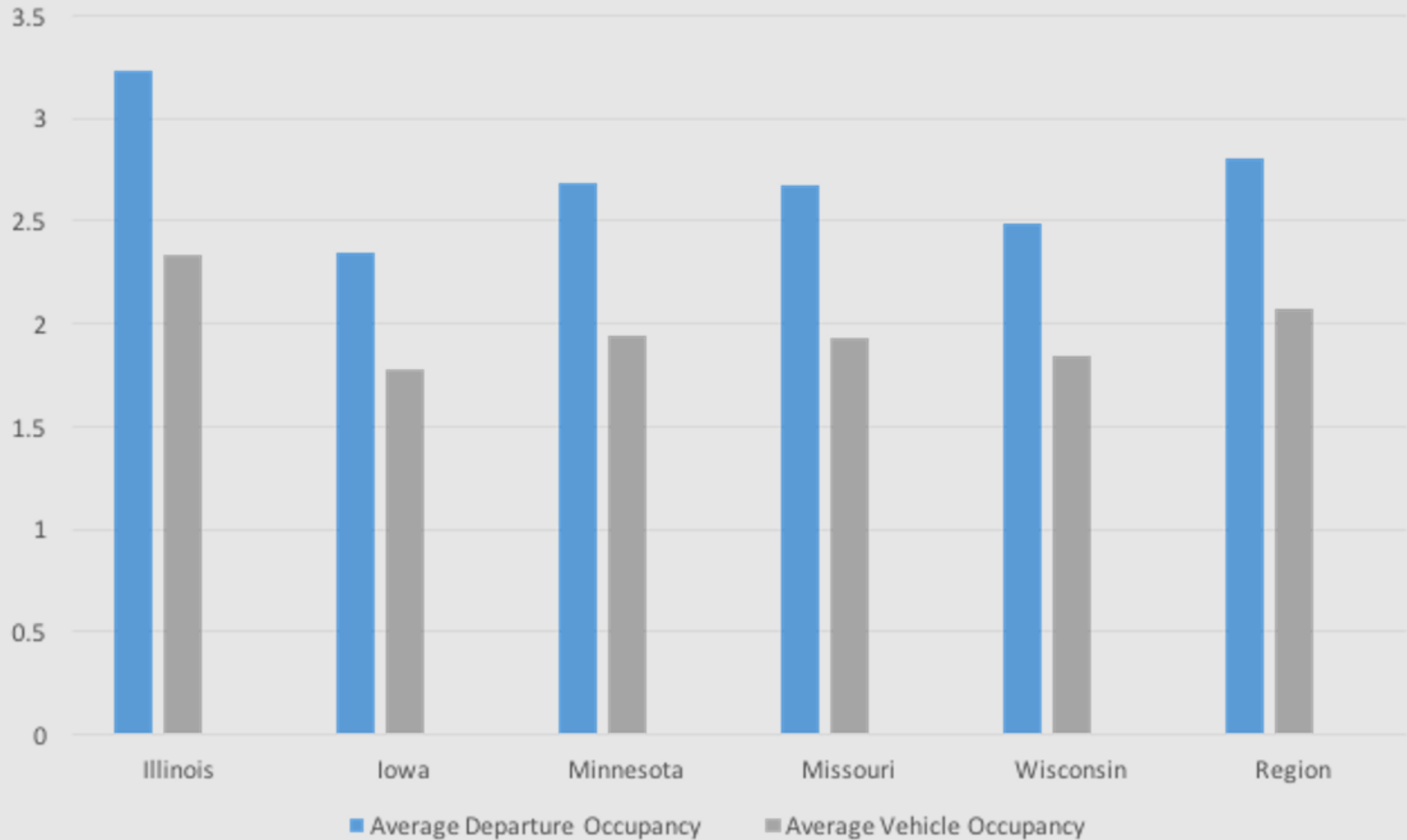
Person Trips Served by aTaxis



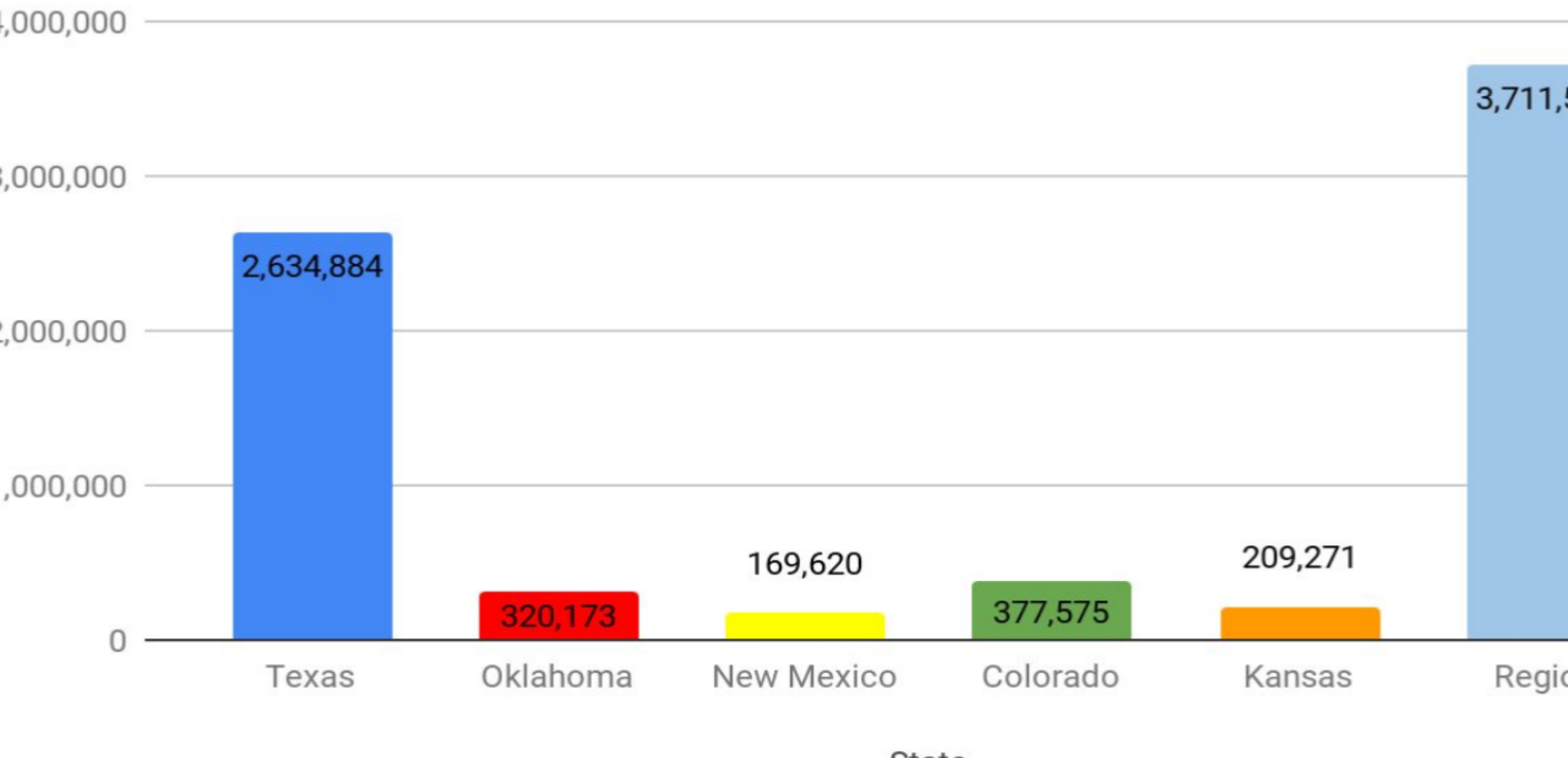
ADO and AVO



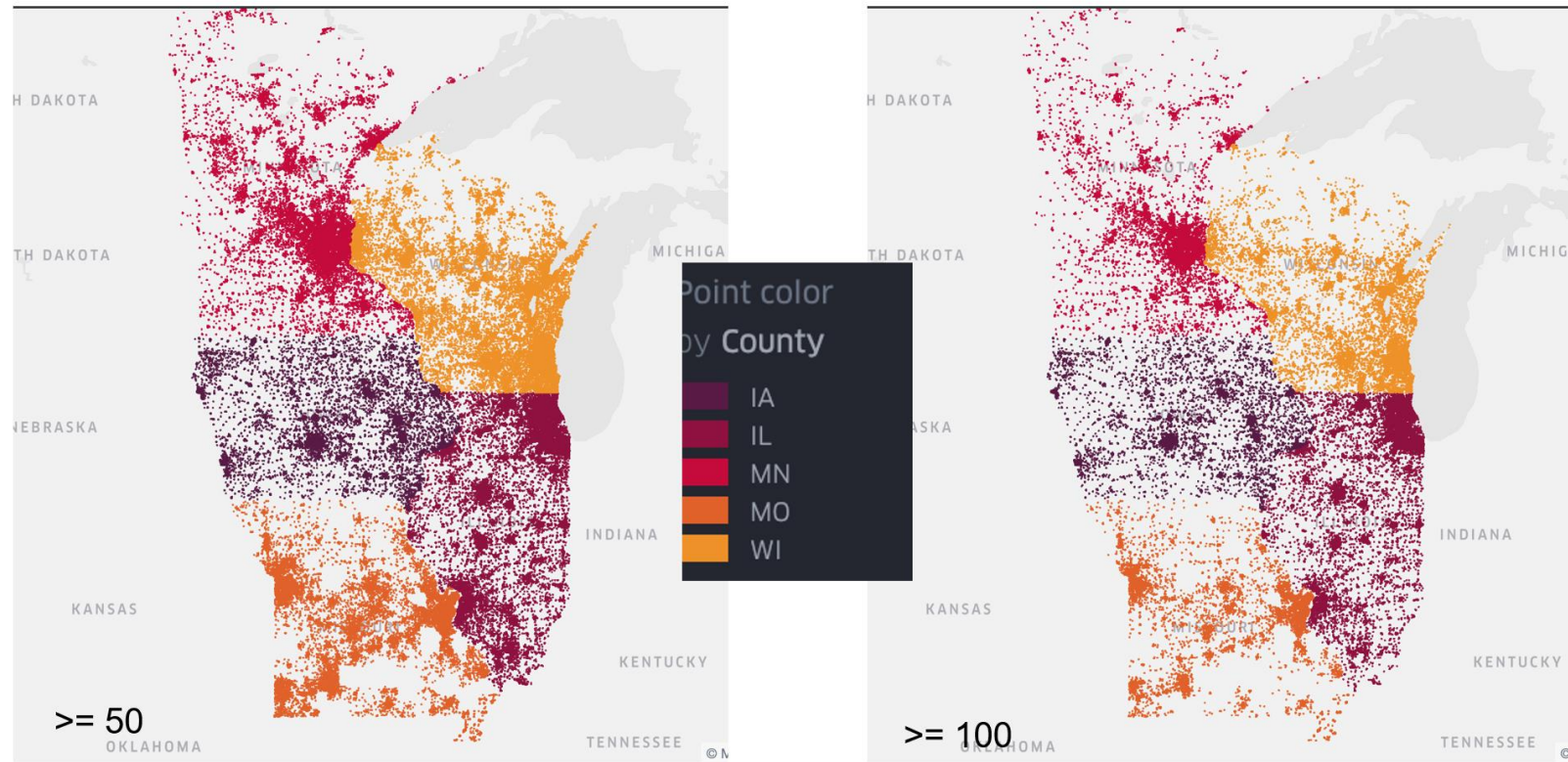
Comparison of ADO vs. AVO for each State



1.1*Minimum Fleet Size

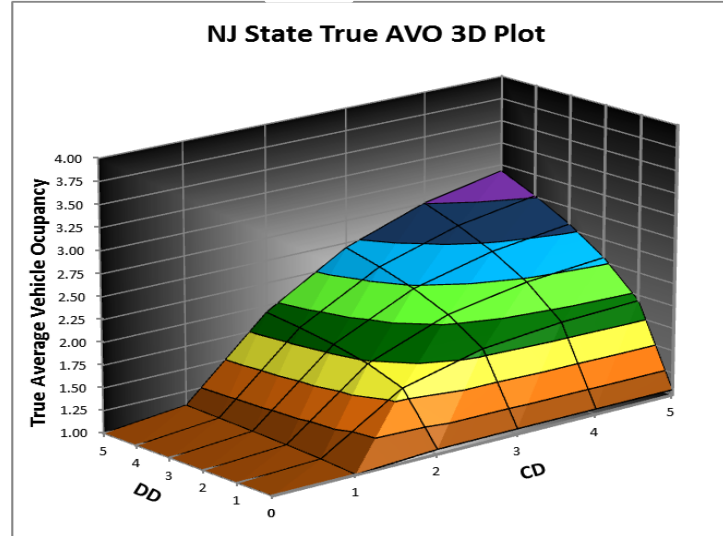


aTaxiDepartures for Region



Results

New Jersey - True Average Vehicle Occupancy						
	CD = 0	CD = 1	CD = 2	CD = 3	CD = 4	CD = 5
DD = 0	1.00	1.05	1.06	1.06	1.06	1.06
DD = 1	1.04	1.59	1.81	1.90	1.94	1.94
DD = 2	1.06	1.73	2.07	2.23	2.23	2.30
DD = 3	1.07	1.82	2.23	2.45	2.56	2.56
DD = 4	1.08	1.88	2.35	2.62	2.76	2.76
DD = 5	1.10	1.92	2.45	2.76	2.93	2.93

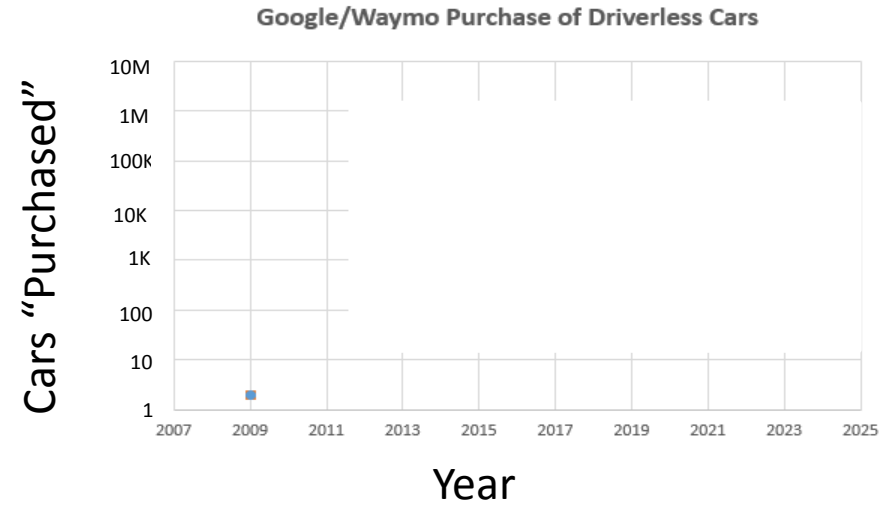


When will a Taxis
be more
than a Novelty ???



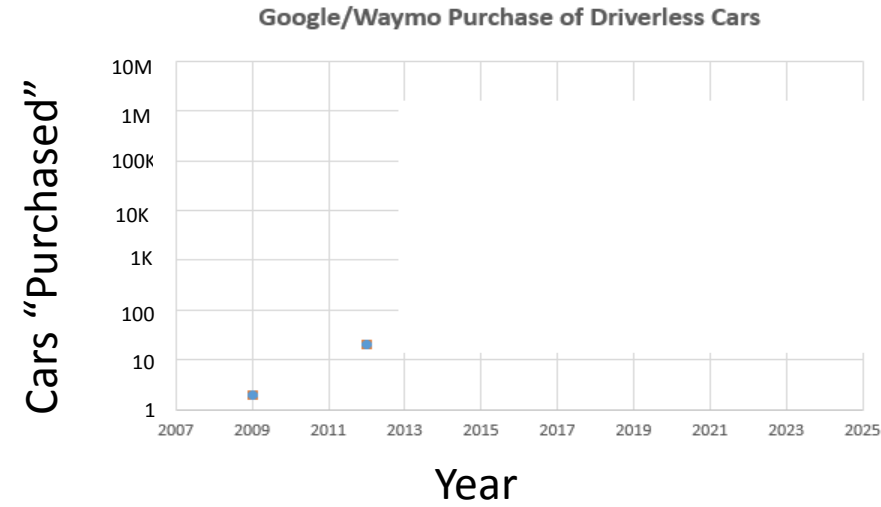
Have You Noticed???

Google/Waymo's Buying Spree



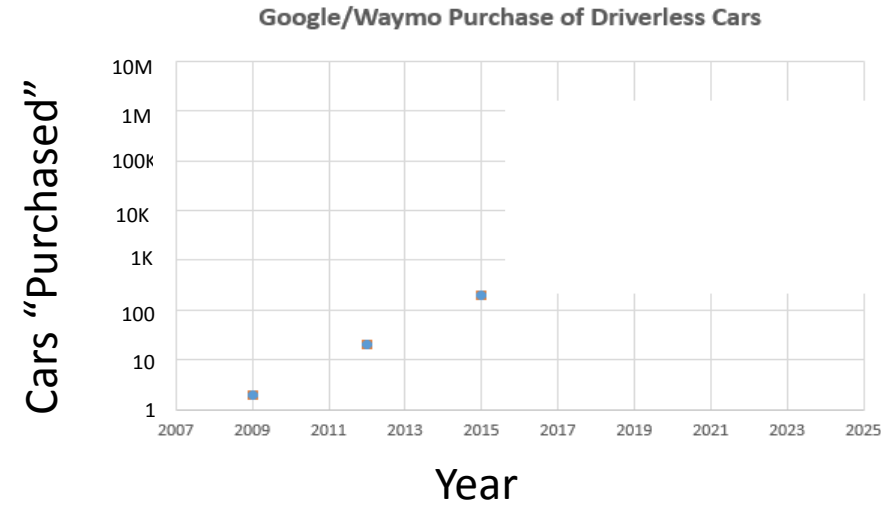
Have You Noticed???

Google/Waymo's Buying Spree



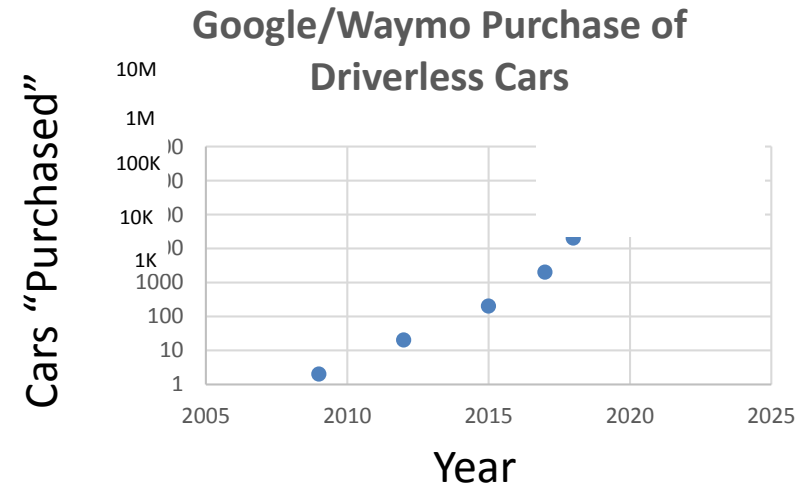
Have You Noticed???

Google/Waymo's Buying Spree



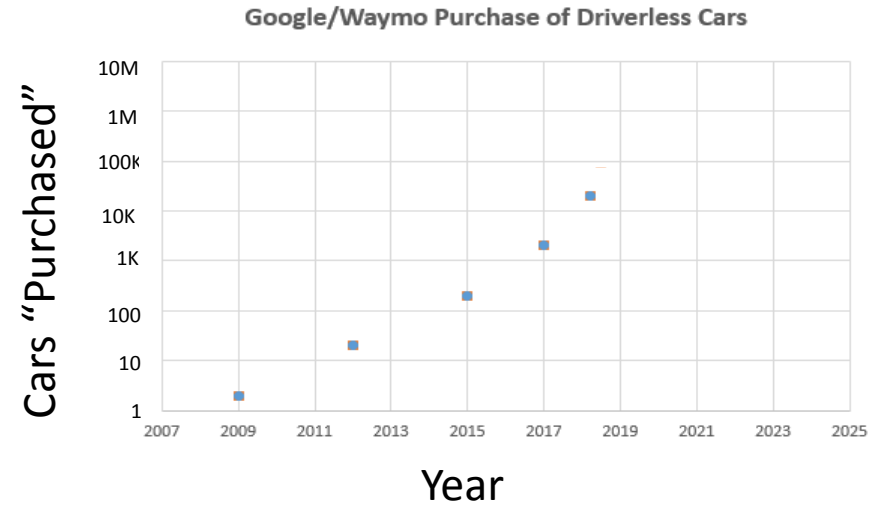
Have You Noticed???

Google/Waymo's Buying Spree



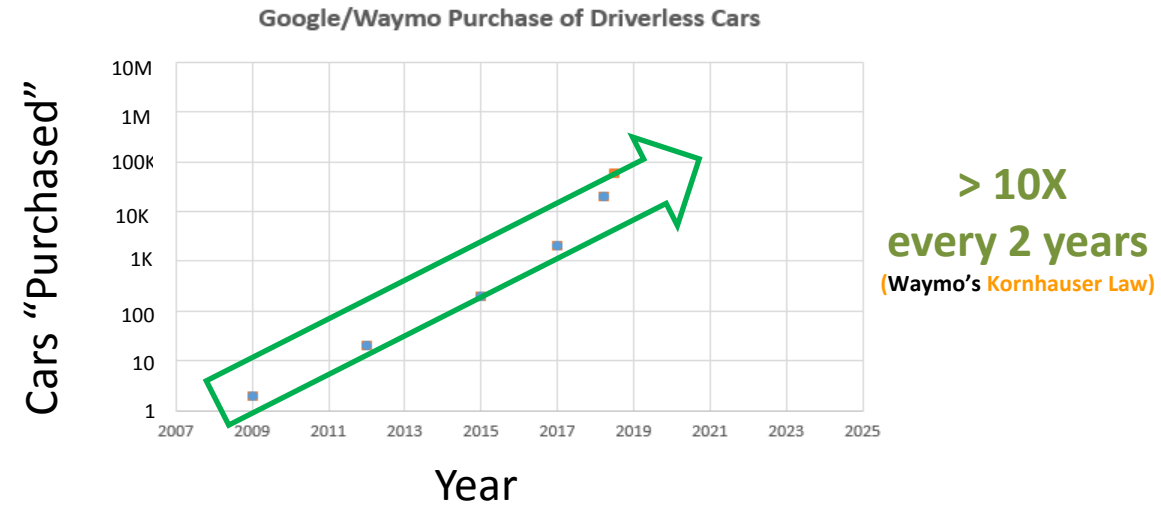
Have You Noticed???

Google/Waymo's Buying Spree



Have You Noticed???

Google/Waymo's Buying Spree



WHAT WILL WAYMO DO WITH 20,000 JAGUARS?



WHAT WILL WAYMO DO WITH 20,000 JAGUARS?



PROVIDE HOUSING FOR THE HOMELESS IN SAN FRANCISCO?

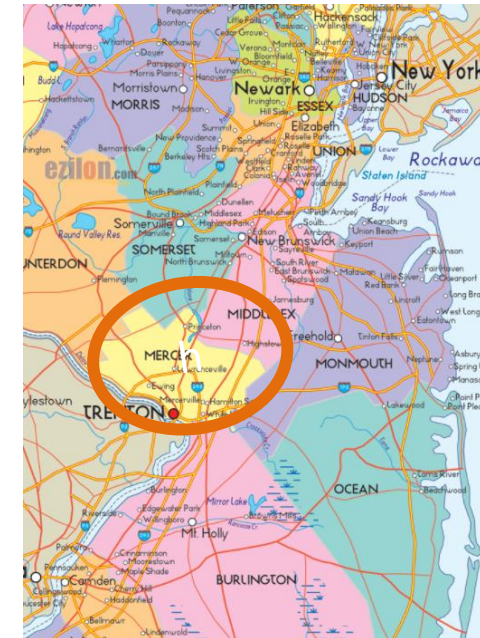
Where will Waymo Deploy 20,000 + 60,000 autonomousTaxis

- 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"



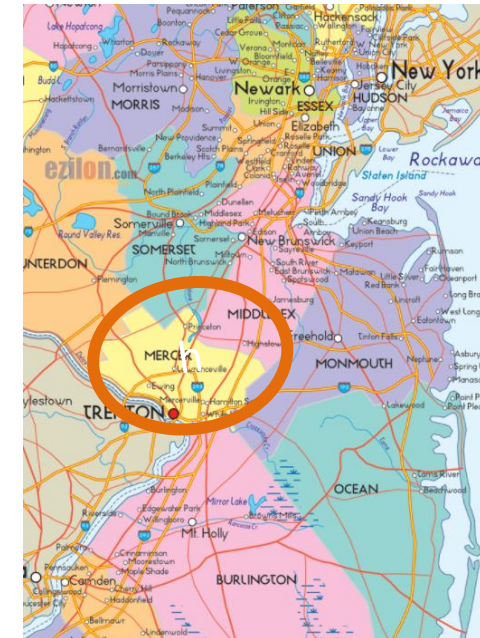
Where will Waymo Deploy 20,000 + 60,000 autonomousTaxis

- 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.



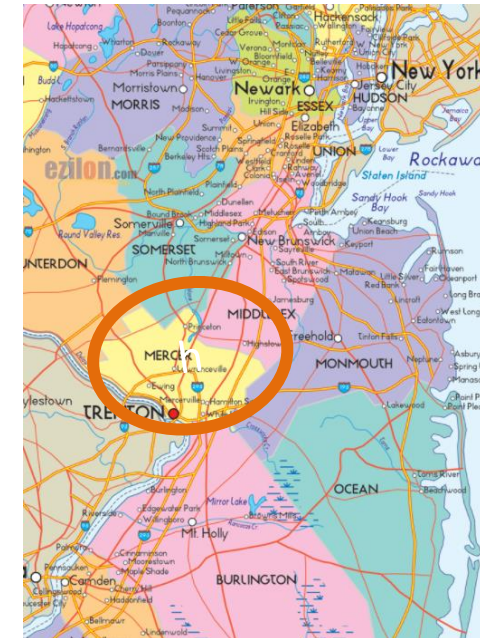
Where will Waymo Deploy 20,000 + 60,000 autonomousTaxis

- 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 ...**



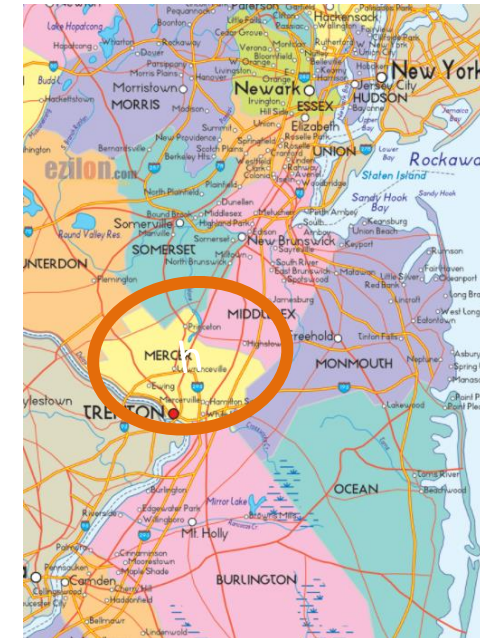
Where will Waymo Deploy 20,000 + 60,000 autonomousTaxis

- 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 a, plus ...



Where will Waymo Deploy 20,000 + 60,000 autonomousTaxis

- 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

alaink@princeton.edu

www.SmartDrivingCar.com

~40+ years ago...

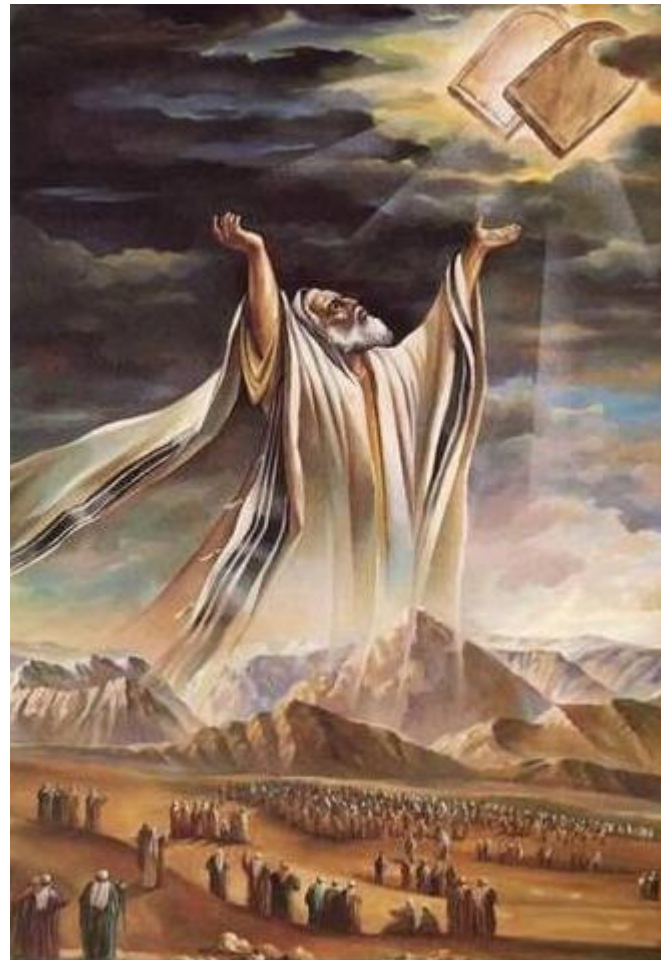
- Personal Rapid Transit (PRT)
 - Morgantown (circa 1976)





Along the way...

- Nothing much...



And Today...

- There are 2: Masdar (2GetThere) & Heathrow (Ultra) are operational
- Morgantown has been “perfect” for 40 years

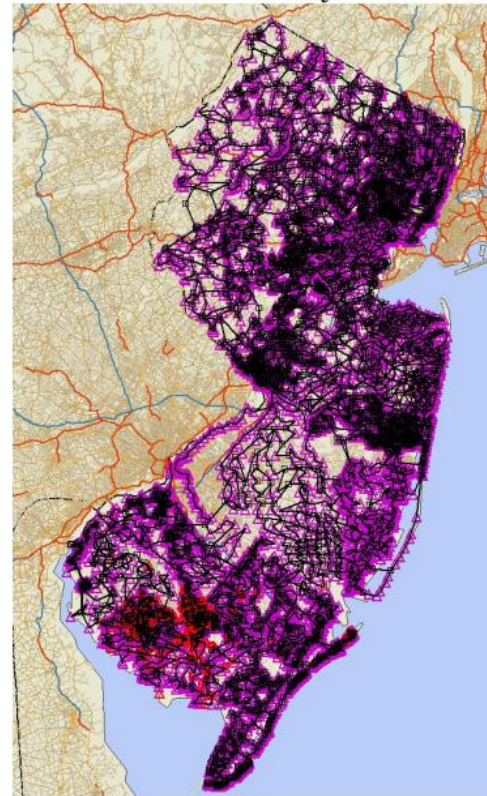


[Video](#)



Many Studies w/Students

Personal Rapid Transit (PRT)
for
New Jersey



By
Orf 467 Transportation Systems Analysis, Fall 2004/5
Princeton University
Prof. Alain L. Kornhauser

Nkonye Okoh	Mathe Y. Mosny	Shawn Woodruff	Rachel M. Blair	Jeffery R Jones
James H. Cong	Jessica Blankshain	Mike Daylamani	Diana M. Zakem	Darius A Craton
Michael R Eber	Matthew M Lauria	Bradford Lyman	M Martin-Easton	Robert M Bauer
Neset I Pirkul	Megan L. Bernard	Eugene Gokhvat	Nike Lawrence	Charles Wiggins

- ~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](#)

