Princeton University

Daily Person Trips
in New Jersey & the Whole USA:
A Synthesis

by

ALAIN L. KORNHAUSER, PHD

Professor, Operations Research & Financial Engineering
Director, Program in Transportation
Faculty Chair, PAVE (Princeton Autonomous Vehicle Engineering)
Princeton University

See also:
A National Hybrid Activity/Agent-Based Demand Model to Characterize the Mobility of the United States,
K. Marocchini, Jan 2017
Mufti: TripSynthesizer
HillWyrough'14SeniorThesis

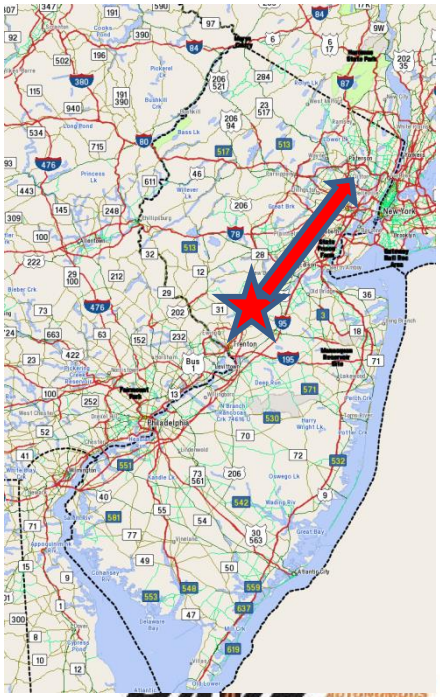
Presented at

Orf 467'F17
Oct. 23, 2017

PAVE PRINCETON AUTONOMOUS VEHICLE ENGINEERING

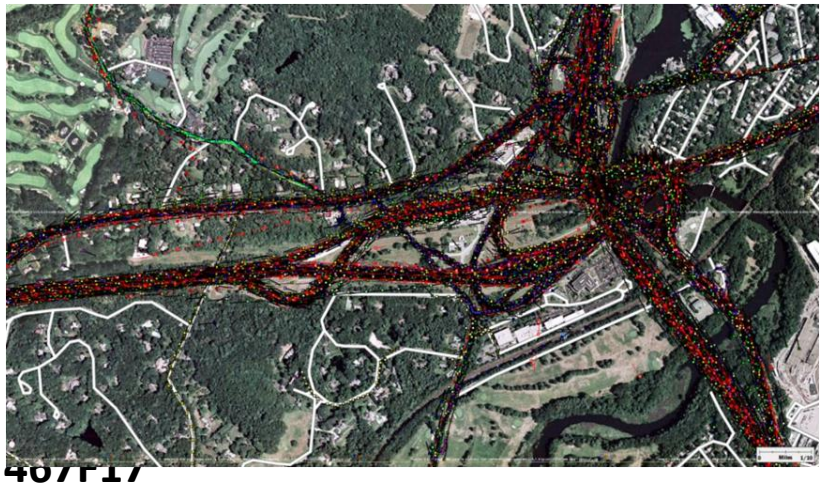
Most every day…

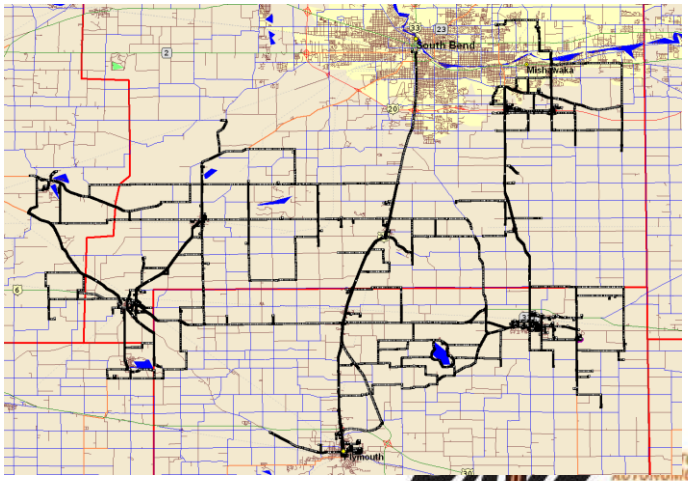
- Almost 9 Million NJ residents
- 0.25 Million of out of state commuters
- Make 30+ Million trips
- Throughout the 8,700 sq miles of NJ
- Where/when do they start?
- Where do they go?
- Does anyone know???
  - I certainly don't
    - Not to sufficient precision for credible analysis



I've Tried…

- I've harvested one of the largest troves of GPS tracks
  - Literally billions of individual trips,
  - Unfortunately, they are spread throughout the western world, throughout the last decade.
  - Consequently, I have only a very small ad hoc sample of what happens in NJ on a typical day.





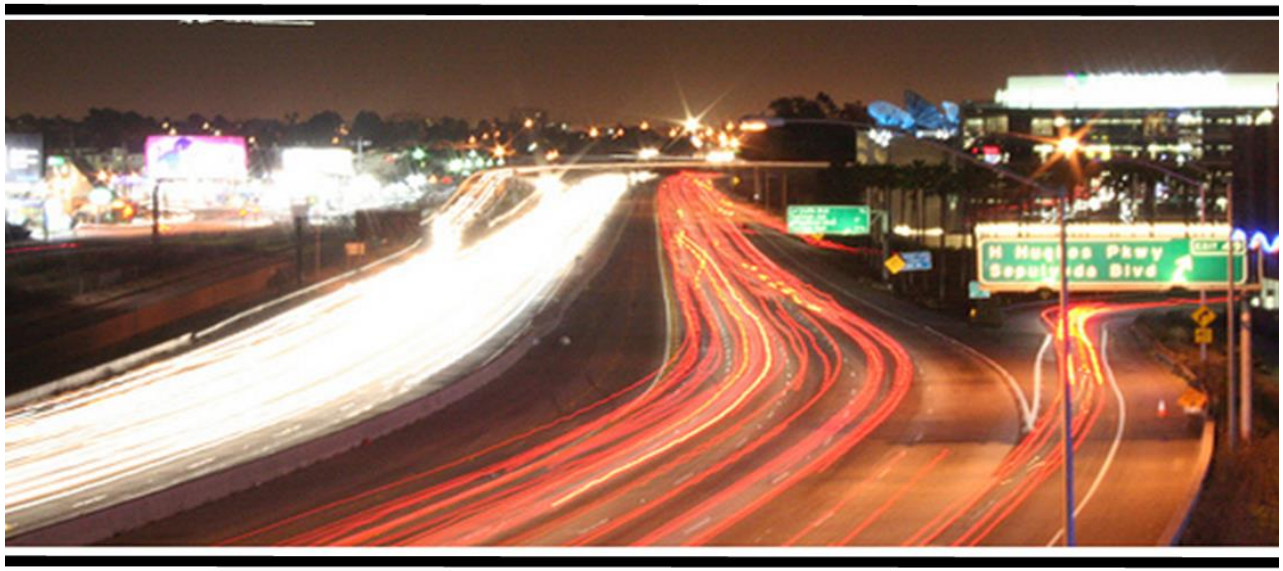
Why do I want to know **every** trip?

- Academic Curiosity
- If offered an alternative, which ones would likely "buy it" and what are the implications.
- More specifically:
  - If an alternative transport system were available, which trips would be diverted to it and what operational requirements would those trip impose on the new system?
- In the end…
  - a transport system serves **individual** decision makers. It's patronage is an **ensemble of individuals**,
  - I would prefer analyzing each individual trip patronage opportunity.

Princeton Univers

Synthesizing Individual Travel Demand in New Jersey

Trips everyone in NJ wants/needs to make on a typical day



Philip Acciarito '12
Luis Quintero '12
Spencer Stroeble '12
Natalie Webb '12
Heber Delgado-Medrano *12
Talal Mufti *12
Bharath Alamanda '13
Christopher Brownell '13
Blake Clemens '13
Charles Fox '13
Sarah Germain '13
Akshay Kumar '13
Michael Markiewicz '13
Tim Wenzlau '13

Professor Alain L. Kornhauser *71

Department of Operations Research & Financial Engineering
Princeton University

January, 2012

Orf 467F17

PAVE PRINCETON AUTONOMOUS VEHICLE ENGINEERING

Synthesize from publically available data:

- "every" NJ Traveler on a typical day **NJ_Resident file**
  - Containing appropriate demographic and spatial characteristics that reflect trip making

- "every" trip that each Traveler is likely to make on a typical day. **NJ_PersonTrip file**
  - Containing appropriate spatial and temporal characteristics for each trip

Creating the **NJ_Resident** file

for “every” NJ Traveler on a typical day

NJ_Resident file

Start with Publically available data:

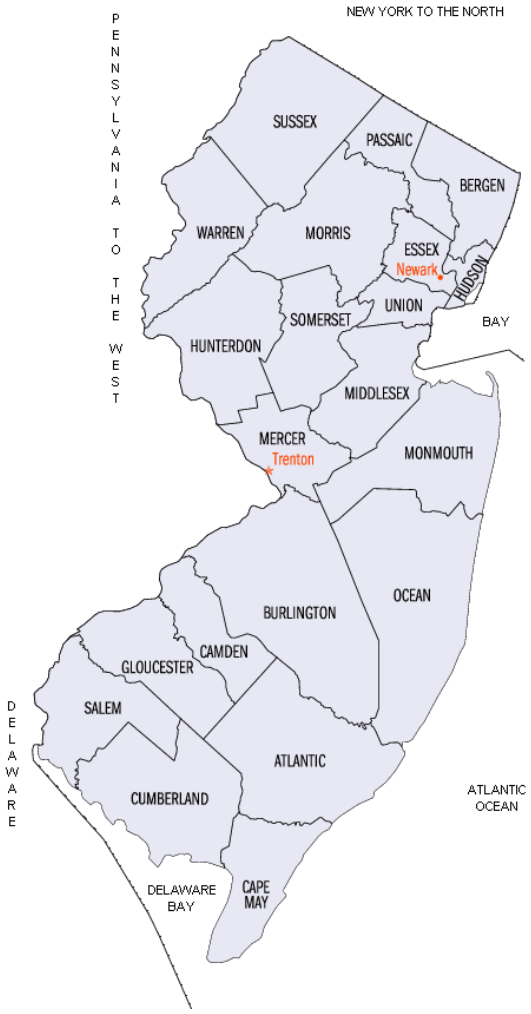
United States Census 2010

AMERICAN COMMUNITY SURVEY
U.S. CENSUS BUREAU

PAVE PRINCETON AUTONOMOUS VEHICLE ENGINEERING

2010 Population census @Block Level

– 8,791,894 individuals distributed 118,654 Blocks.

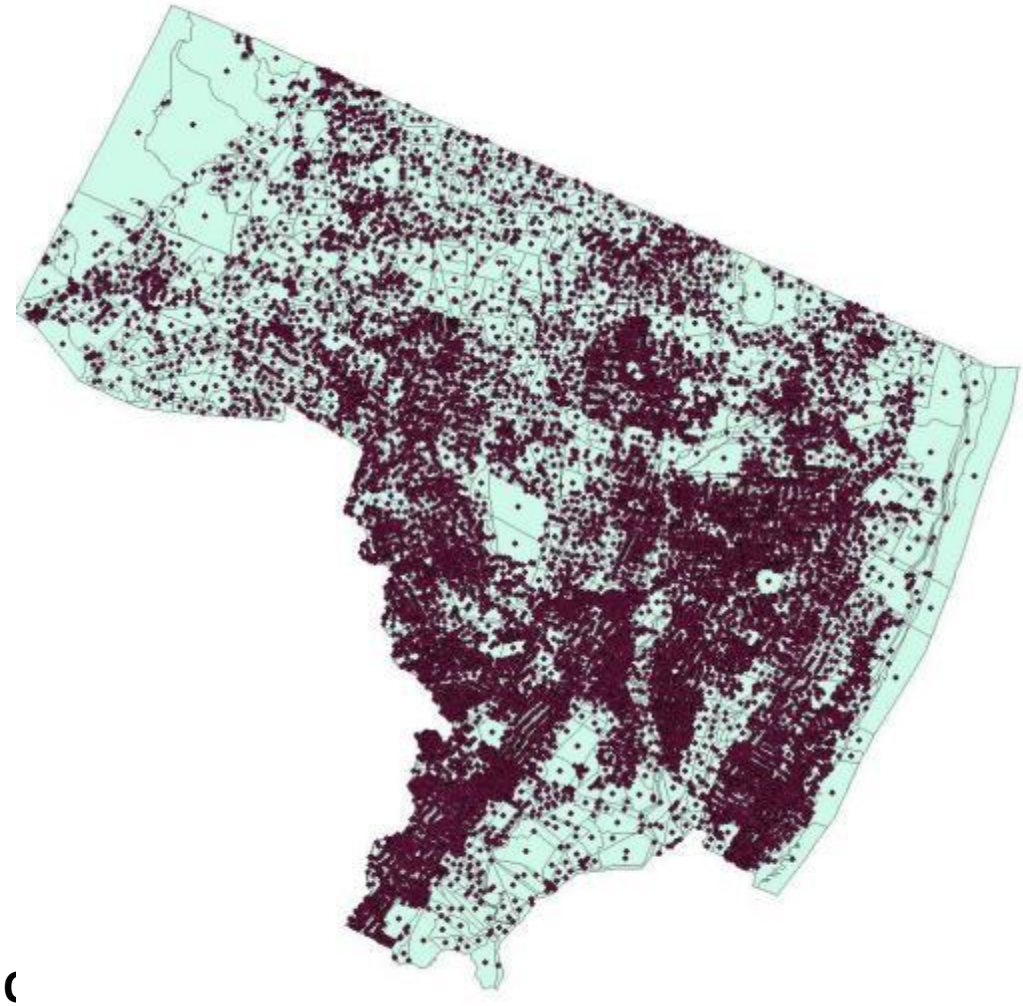


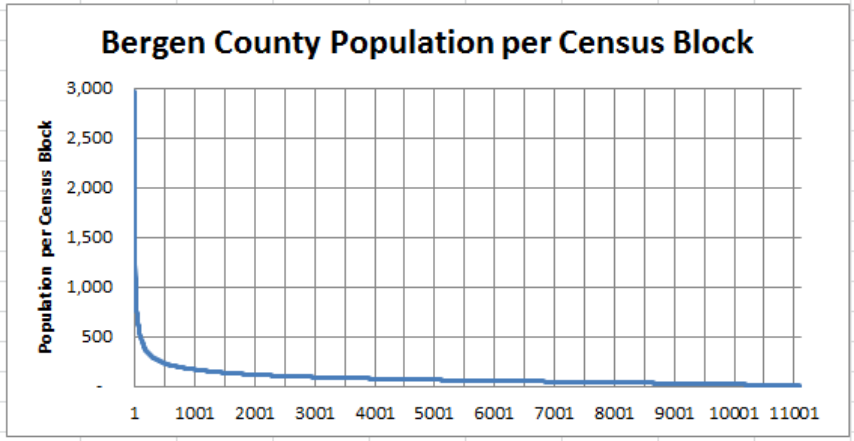
County	Population	Census Blocks	Median Pop/ Block	Average Pop/Block
ATL	274,549	5,941	26	46
BER	905,116	11,171	58	81
BUR	448,734	7,097	41	63
CAM	513,657	7,707	47	67
CAP	97,265	3,610	15	27
CUM	156,898	2,733	34	57
ESS	783,969	6,820	77	115
GLO	288,288	4,567	40	63
HUD	634,266	3,031	176	209
HUN	128,349	2,277	31	56
MER	366,513	4,611	51	79
MID	809,858	9,845	50	82
MON	630,380	10,067	39	63
MOR	492,276	6,543	45	75
OCE	576,567	10,457	31	55
PAS	501,226	4,966	65	101
SAL	66,083	1,665	26	40
SOM	323,444	3,836	51	84
SUS	149,265	2,998	28	50
UNI	536,499	6,139	61	87
WAR	108,692	2,573	23	42
Total	8,791,894	118,654		74.1

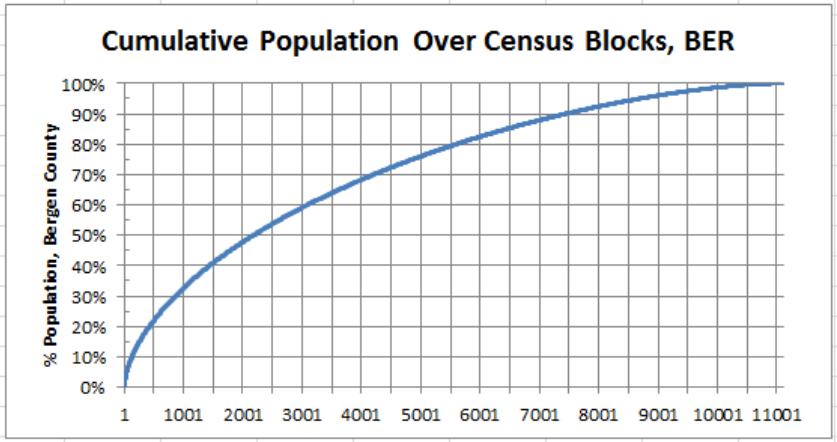
Princeton University

Bergen County @ Block Level

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







PAVE PRINCETON AUTONOMOUS VEHICLE ENGINEERING

Publically available data:

- Distributions of Demographic Characteristics
  - Age
  - Gender
  - Household size
  - Name (Last, First)

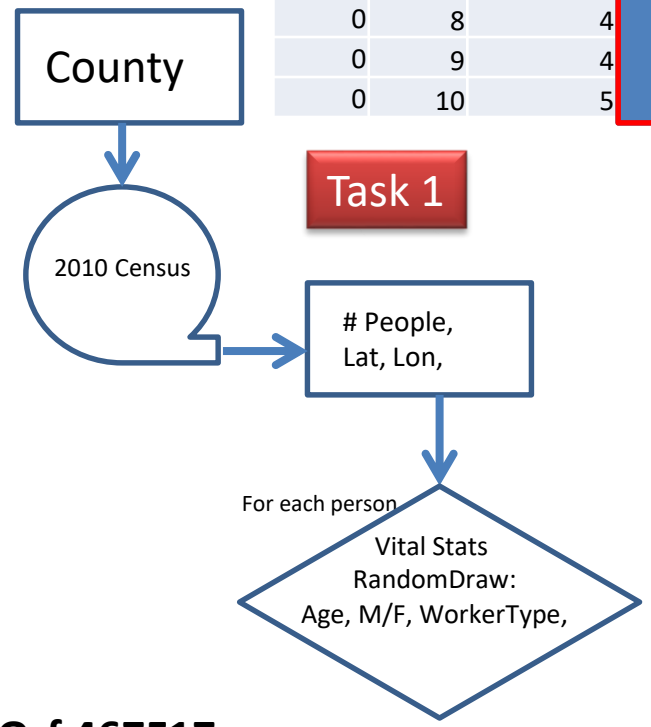
Ages (varying linearly over interval):	input:	output:
[0,49]	67.5%	67.5%
[50,64]	18.0%	17.9%
[65,79]	12.0%	12.1%
[80,100]	2.5%	2.5%

Gender:	Input:	Output:
female	51.3%	51.3%

Household:	Size:	Probability:	cdf:	Expectation:
couple	2	0.30	0.300	0.6
couple + 1	3	0.08	0.380	0.24
couple + 2	4	0.06	0.440	0.24
couple + 3	5	0.04	0.480	0.2
couple + 4	6	0.04	0.520	0.24
couple + grandparent:	3	0.01	0.525	0.015
single woman	1	0.16	0.685	0.16
single mom + 1	2	0.07	0.755	0.14
single mom + 2	3	0.05	0.805	0.15
single mom + 3	4	0.03	0.835	0.12
single mom + 4	5	0.03	0.865	0.15
single man	1	0.12	0.985	0.12
single dad + 1	2	0.01	0.990	0.01
single dad + 2	3	0.005	0.995	0.015
single dad + 3	4	0.005	1.000	0.02
				2.42

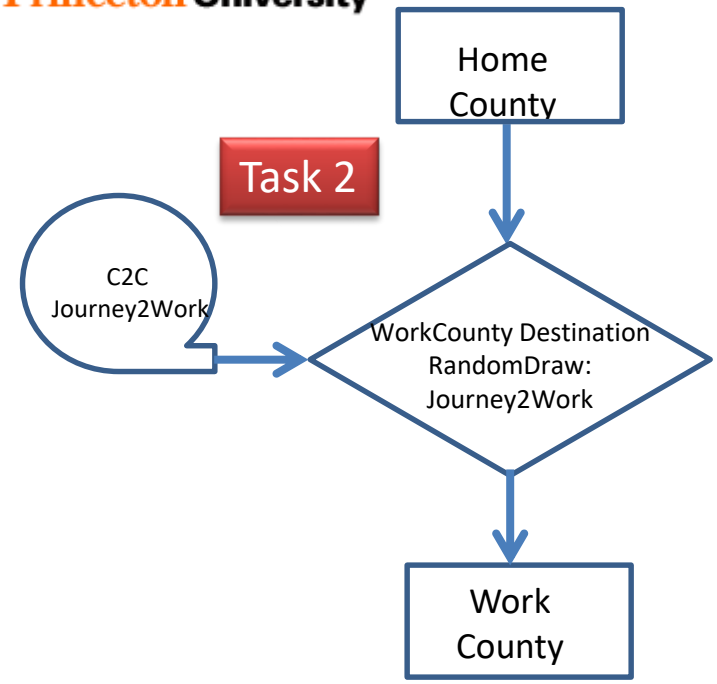
Beginnings of NJ_Resident file

County	Person Index	Household Index	Last Name	First Name	Middle Initial	Age	Gender	Worker Index	Worker Type	Home Latitude	Home Longitude
0	1	1				24	FALSE			39.43937	-74.495087
0	2	1				7	FALSE			39.43937	-74.495087
0	3	1				1	FALSE			39.43937	-74.495087
0	4	2				24	TRUE			39.43937	-74.495087
0	5	2				2	FALSE			39.43937	-74.495087
0	6	2				6	TRUE			39.43937	-74.495087
0	7	3				26	TRUE			39.43937	-74.495087
0	8	4				24	FALSE			39.43937	-74.495087
0	9	4				25	TRUE			39.43937	-74.495087
0	10	5				23	TRUE			40.85646	-74.197833



WorkerType Index	WorkerType String:	Distribution:
0	grade school	100% ages [6,10]
1	middle school	100% ages [11,14]
2	high school	100% ages [15,18]
3	college: commute	Sate-wide distribution
4	college: on campus	Sate-wide distribution
5	worker	Drawn to match J2W Stats by County
6	at-home worker and retired	Remainder + 100% ages [65,79]
7	nursing home and under 5	100% ages [0,5] and 100% ages [80,100]

Princeton University



Using Census Journey-to-Work (J2W) Tabulations to assign Employer County

Home State	Home County	County Name	Work State	Work County	County Name	Workers
34	1	Atlantic Co. NJ	6	59	Orange Co. CA	12
34	1	Atlantic Co. NJ	6	85	Santa Clara Co. CA	9
34	1	Atlantic Co. NJ	10	3	New Castle Co. DE	175
34	1	Atlantic Co. NJ	10	5	Sussex Co. DE	9
6	37	L. A. Co. CA	34	1	Atlantic Co. NJ	33
6	65	Riverside Co. CA	34	1	Atlantic Co. NJ	7
9	3	Hartford Co. CT	34	1	Atlantic Co. NJ	5
9	5	Litchfield Co. CT	34	1	Atlantic Co. NJ	4

http://www.census.gov/population/www/cen2000/commuting/files/2KRESCO_NJ

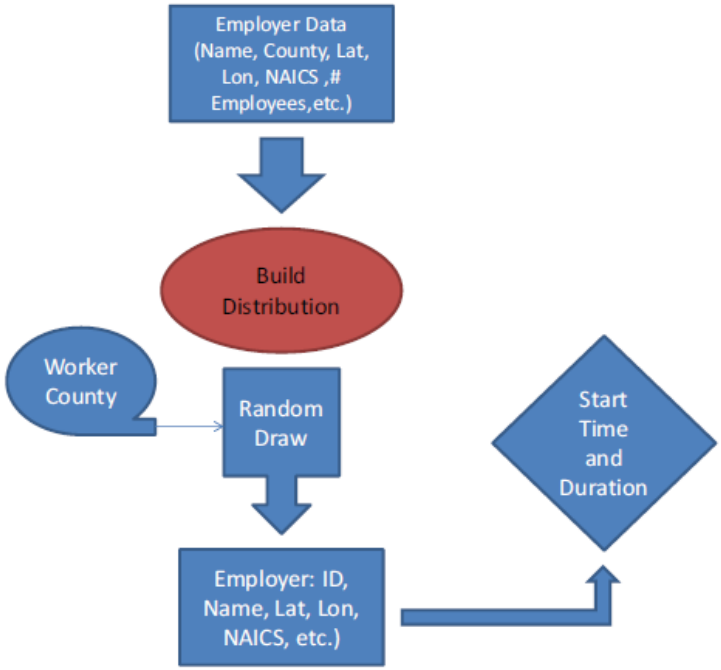
http://www.census.gov/population/www/cen2000/commuting/files/2KWRKCO_NJ.xls

County	Person Index	Household Index	Last Name	First Name	Middle Initial	Age	Gender	Worker Index	Worker Type	Home Latitude	Home Longitude	Employer County
0	1	1	PREVILLE	RICHARD	G.	24	FALSE	5	worker	39.43937	-74.495087	**22**
0	2	1	PREVILLE	JACK	J.	7	FALSE	0	grade School	39.43937	-74.495087	
0	3	1	PREVILLE	CHARLES	X.	1	FALSE	7	under 5	39.43937	-74.495087	
0	4	2	DEVEREUX	SUE	B.	24	TRUE	6	at-home-worker	39.43937	-74.495087	
0	5	2	DEVEREUX	ANTON	P.	2	FALSE	7	under 5	39.43937	-74.495087	
0	6	2	DEVEREUX	KATIE	S.	6	TRUE	0	grade School	39.43937	-74.495087	
0	7	3	WHEDBEE	LINDA	C.	26	TRUE	6	at-home-worker	39.43937	-74.495087	
0	8	4	CARVER	ROBERT	Z.	24	FALSE	5	worker	39.43937	-74.495087	**0**
0	9	4	CARVER	JENNIFER	P.	25	TRUE	6	at-home-worker	39.43937	-74.495087	
0	10	5	TINSLEY	ELLEN	U.	23	TRUE	4	college on c ampus:	40.85646	-74.197833	

Orf 4

Princeton University

Using Employer Data to assign a Workplace Characteristics



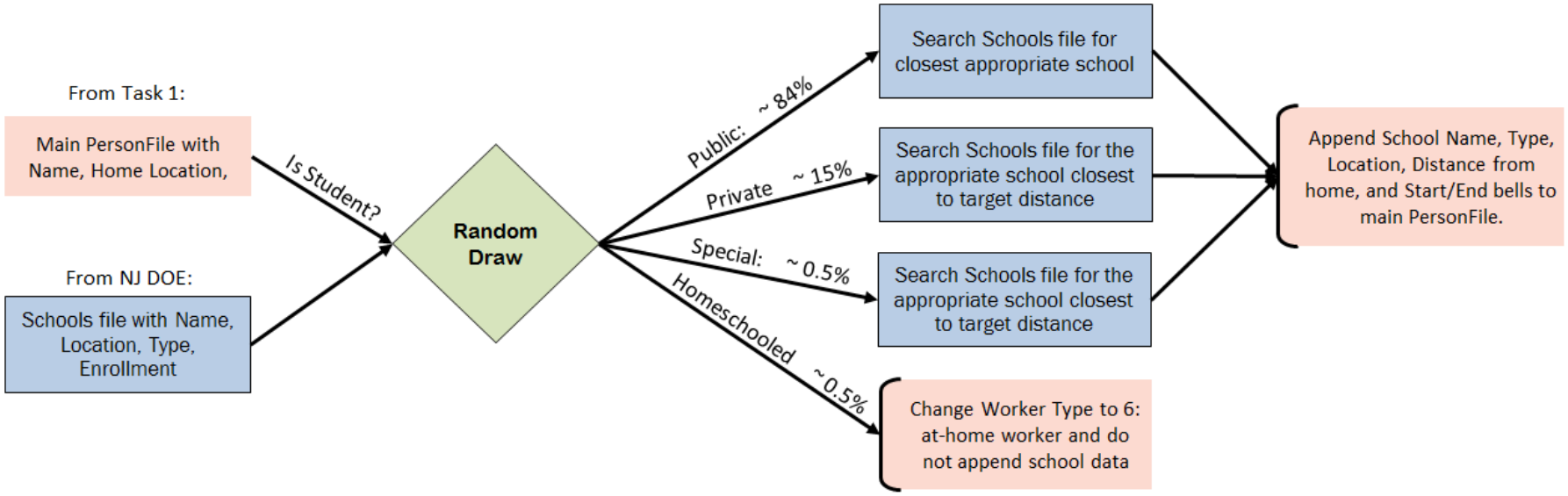
Employment-Weighted Random Draw

Name	County	NAICS Code	NAICS Description	Employment	Latitude	Longitude
1 VIP SKINDEEP	Atlantic	81219915	Other Personal Care	2	39.401104	-74.514228
10 Acres Motel	Atlantic	72111002	Hotels & Motels Ex Casino	2	39.437305	-74.485488
1001 Grand Street Investors	Atlantic	52399903	Misc Financial Inves	3	39.619732	-74.786654
1006 S Main St LLC	Atlantic	53111004	Lessors Of Res Buildg	5	39.382399	-74.530785
11th Floor Creative Group	Atlantic	51211008	Motion Picture Prod	2	39.359014	-74.430151
123 Cab Co	Atlantic	48531002	Taxi Svc	2	39.391600	-74.521715
123 Junk Car Removal	Atlantic	45331021	Used Merch Stores	2	39.361705	-74.435779
1400 Bar	Atlantic	72241001	Drinking Places	4	39.411266	-74.570083
1-800-Got-Junk?	Atlantic	56221910	Other Non-Haz Waste Disp	4	39.423954	-74.557892

Res Info	County	ID	Name	Lat	Lon	SIC	SIC Des	NAICS	NAICS Des	Dist	Start	End
*	22	0		39.95	-75.16	0	0	0	0	50.3	31162	59657
*	0	10101	Seaview Golf	39.45	-74.47	701	Resorts	721	All Other	20.1	31392	63101
*	0	11777	Univ Chimn	39.37	-74.42	174	Chimney	238	Masonry	15.2	30903	59765
*	12	6823	Shell	40.29	-74.00	435	Gasoline	567	Gasoline	48.9	30222	61295
*	14	1107	Target	39.17	-74.78	365	Retail	456	Retail	39.8	28626	57389

PRINCETON AUTONOMOUS VEHICLE ENGINEERING

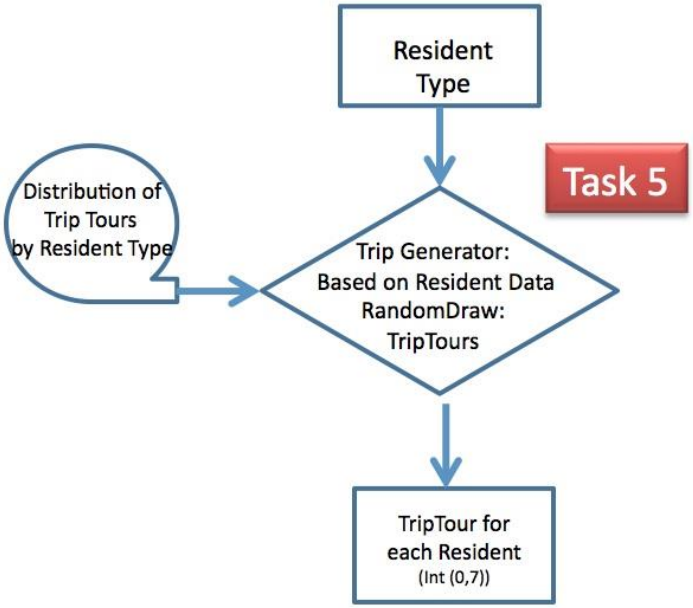
Using School Data to Assign School Characteristics



FIRST	AGE	GENDER	WORKER TYPE		LAT	LON	SCHOOL	TYPE	LAT	LON	DIST	START	END
MELISSA Y.	33	TRUE	6	at-home worker	39.28709	-74.5715							
LYDIA Y.	7	TRUE	0	grade school	39.28709	-74.5715	Upper Township Primary	PUBLIC ELEMENTARY	39.26946	-74.6442	4.08 miles	32100	55800
JOHN V.	14	FALSE	1	middle school	39.28709	-74.5715	Upper Township Middle School	PUBLIC MIDDLE	39.26137	-74.7333	8.85 miles	29700	54300
ANGELA L.	50	TRUE	6	at-home worker	39.28709	-74.5715							
CAROL C.	52	TRUE	6	at-home worker	39.28709	-74.5715							
FRANKLIN X	32	FALSE	6	at-home worker	39.28709	-74.5715							
JEFFREY D.	47	FALSE	5	worker	39.28709	-74.5715							
RUBY F.	65	TRUE	6	retired	39.28709	-74.5715							
ROBERTO F.	49	FALSE	5	worker	39.28709	-74.5715							
YVONNE E.	67	TRUE	6	retired	39.28709	-74.5715							
ANGELA D.	17	TRUE	2	high school	39.28709	-74.5715	Cape May County Tech. High School	PUBLIC HIGH	39.10147	-74.7969	17.63 miles	27600	52200
TONY G.	11	FALSE	1	middle school	39.28709	-74.5715	Upper Township Middle School	PUBLIC MIDDLE	39.26137	-74.7333	8.85 miles	29700	54300
RICHARD I.	52	FALSE	6	at-home worker	39.28709	-74.5715							
BETTY P.	68	TRUE	6	retired	39.28709	-74.5715							
WILLIAM S.	19	FALSE	4	college: on campu	40.34409	-74.6525	Princeton University	NON_COMMUTER UNIV	40.34651	-74.6595	Within Cam	36000	59400
DEANNA M.	18	TRUE	2	high school	39.28709	-74.5715	Cape May County Tech. High School	PUBLIC HIGH	39.10147	-74.7969	17.63 miles	27600	52200
DONALD Z.	57	FALSE	5	worker	39.28709	-74.5715							

Assigning a Daily Activity (Trip) Tour to Each Person

TripChainType Number	What it looks like	Number of trip ends
0	H	0
1	W H	2
2	H W	3
3	W H	4
4	W H	4
5	H W	5
6	W H	
7	H W	



	Probabilities								
Trip Chain Type	Grade School	Middle School	High School	College Commuter	College on Campus	Worker	Out of State Worker	At Home Worker	Nursing Home & Under 5
0	0.050	0.025	0.025	0.050	0.300	0.010	0.000	0.100	1.000
1	0.175	0.150	0.050	0.075	0.300	0.050	0.600	0.300	0.000
2	0.250	0.200	0.200	0.250	0.200	0.100	0.300	0.200	0.000
3	0.200	0.275	0.225	0.225	0.100	0.150	0.000	0.150	0.000
4	0.000	0.000	0.050	0.000	0.000	0.150	0.100	0.000	0.000
5	0.200	0.200	0.250	0.150	0.040	0.250	0.000	0.100	0.000
6	0.075	0.100	0.150	0.150	0.040	0.200	0.000	0.100	0.000
7	0.050	0.050	0.050	0.100	0.020	0.090	0.000	0.050	0.000
AVG	**3.625**	**3.850**	**4.150**	**4.000**	**2.140**	**4.480**	**2.500**	**3.150**	**0.000**

Final NJ_Resident file

- Home County
- Person Index
- Household Index
- Full Name
- Age
- Gender
- Worker Type Index
- Worker Type String
- Home lat, lon
- Work or School lat,lon
- Work County
- Work or School Index
- NAICS code
- Work or School start/end time

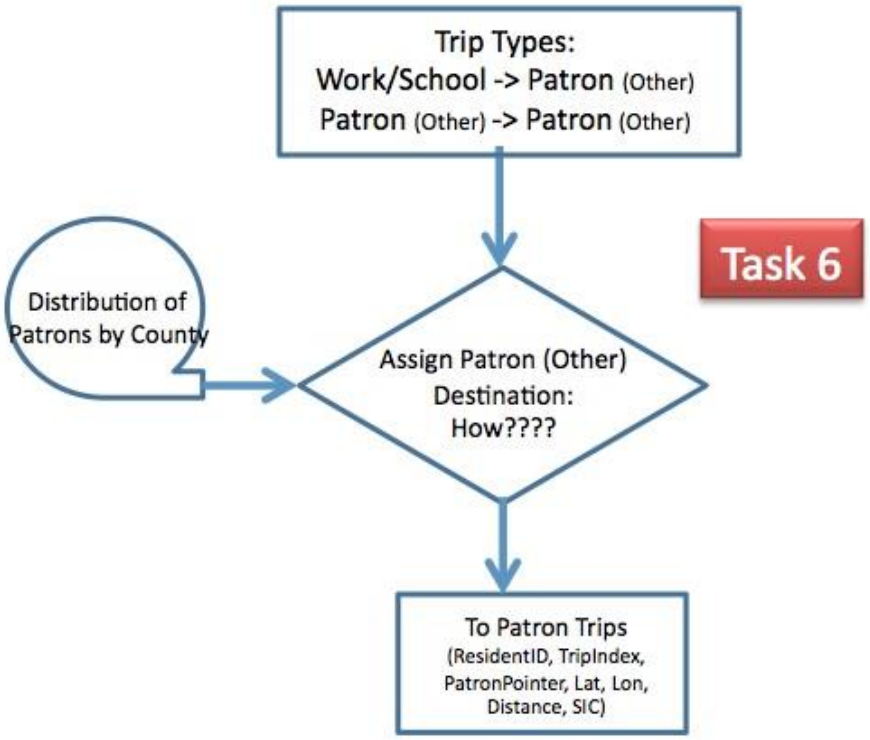
0	1	1	PREVILLE	RICHARD	24	FALSE	5	worker	39.43937	-74.4951							22	0	39.95234	-75.1638	0	31162.18	28494.57
0	2	1	PREVILLE	JACK J.	7	FALSE	0	grade sch	39.43937	-74.4951	H. Ashton	PUBLIC E	39.43596	-74.4953	0.24 miles	32100	55800	7	0	0	0	0	0	0
0	3	1	PREVILLE	CHARLES	1	FALSE	7	under 5	39.43937	-74.4951								0	0	0	0	0	0	0
0	4	2	DEVEREU	SUE B.	24	TRUE	6	at-home w	39.43937	-74.4951								0	0	0	0	0	0	0
0	5	2	DEVEREU	ANTON F	2	FALSE	7	under 5	39.43937	-74.4951								0	0	0	0	0	0	0
0	6	2	DEVEREU	KATIE S.	6	TRUE	0	grade sch	39.43937	-74.4951	H. Ashton	PUBLIC E	39.43596	-74.4953	0.24 miles	32100	55800	0	0	0	0	0	0	0
0	7	3	WHEDBE	LINDA C.	26	TRUE	6	at-home w	39.43937	-74.4951								0	0	0	0	0	0	0
0	8	4	CARVER	ROBERT	24	FALSE	5	worker	39.43937	-74.4951								0	10101	39.44931	-74.4742	721	31392.93	31707.57
0	9	4	CARVER	JENNIFEF	25	TRUE	6	at-home w	39.43937	-74.4951								9	0	0	0	0	0	0
0	10	5	TINSLEY	ELLEN U	23	TRUE	4	college; o	40.85646	-74.1978	Montclair	NON_COL	40.8538	-74.2003	Within Ca	36000	59400	0	0	0	0	0	0	0

ATL	274,549
BER	905,116
BUR	448,734
CAM	513,657
CAP	97,265
CUM	156,898
ESS	783,969
GLO	288,288
HUD	634,266
HUN	128,349
MER	366,513
MID	809,858
MON	630,380
MOR	492,276
OCE	576,567
PAS	501,226
SAL	66,083
SOM	323,444
SUS	149,265
UNI	536,499
WAR	108,692
NYC	86,418
PHL	18,586
BUC	99,865
SOU	13,772
NOR	5,046
WES	6,531
ROC	32,737
Total:	9,054,849

Creating the **NJ_PersonTrip** file

- "every" trip that each Traveler is likely to make on a typical day. **NJ_PersonTrip file**
  - Containing appropriate spatial and temporal characteristics for each trip
- Start with
  - **NJ_ResidentTrip file**
  - **NJ_Employment file**
- Readily assign trips between Home and Work/School
  - Trip Activity -> Stop Sequence
    - Home, Work, School characteristics synthesized in NJ_Resident file

Assigning "Other" Locations



Task 6

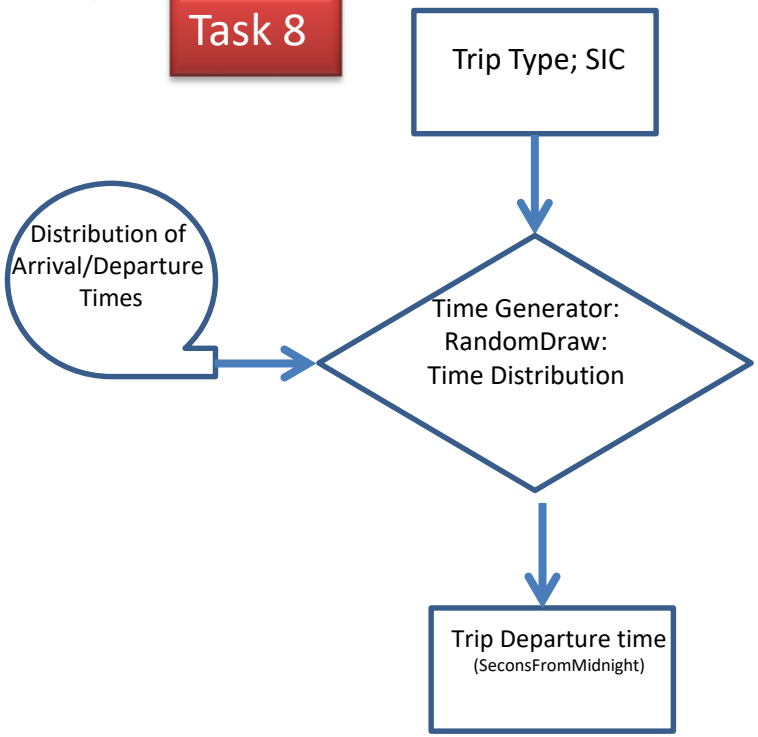
1. Select Other County Using: Attractiveness-Weighted Random Draw

Attractiveness (i)= (Patrons (I)/AllPatrons)/{$D(i,j)^2 + D(j,k)^2$};
Where i is destination county; j is current county; k is home county

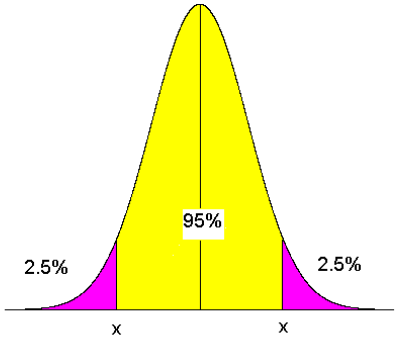
2. Select "Other" Business using: Patronage-Weighted Random Draw within selected county

(ID)	number of trips	Chain	Home Lat	Home Long	Home County	Trip Type	Distance	Trip# of day	dest (Lat)	dest (Long)	SIC Dest.	Destination	pointer	Start Time	End Time	Trip Type	Distance	Trip# of day	dest (Lat)
1	7	7	4	5	0	3	12132	1	13	14	100	6	22	15	16	7	76714	2	40.22129
2	5	5	4	5	0	3	12132	1	13	14	101	6	22	15	16	7	77184	2	39.72739
3	4	4	4	5	0	3	12132	1	13	14	102	6	22	15	16	7	77347	2	40.97935
4	4	3	4	5	0	1	18872	1	18	19	17	0	23	20	21	2	18872	2	0
5	7	7	4	5	0	1	18872	1	18	19	17	0	23	20	21	6	76936	2	40.59235

Task 8



Assigning Trip Departure Times



- For: H->W; H->School; W->Other
- Work backwards from Desired Arrival Time using
  - Distance and normally distributed Speed distribution, and
  - Non-symmetric early late probabilities
- Else, Use Stop Duration with non-symmetric early late probabilities based on SIC Cod

124 | 35911 | 40457 | 60305 | 65700 | 0 | 0 | 0

NJ_PersonTrip file

Home County	All Trips Trips #	TripMiles Miles	AverageTM Miles
ATL	936,585	27,723,931	29.6
BER	3,075,434	40,006,145	13.0
BUC	250,006	9,725,080	38.9
BUR	1,525,713	37,274,682	24.4
CAM	1,746,906	27,523,679	15.8
CAP	333,690	11,026,874	33.0
CUM	532,897	18,766,986	35.2
ESS	2,663,517	29,307,439	11.0
GLO	980,302	23,790,798	24.3
HUD	2,153,677	18,580,585	8.6
HUN	437,598	13,044,440	29.8
MER	1,248,183	22,410,297	18.0
MID	2,753,142	47,579,551	17.3
MON	2,144,477	50,862,651	23.7
MOR	1,677,161	33,746,360	20.1
NOR	12,534	900,434	71.8
NYC	215,915	4,131,764	19.1
OCE	1,964,014	63,174,466	32.2
PAS	1,704,184	22,641,201	13.3
PHL	46,468	1,367,405	29.4
ROC	81,740	2,163,311	26.5
SAL	225,725	8,239,593	36.5
SOM	1,099,927	21,799,647	19.8
SOU	34,493	2,468,016	71.6
SUS	508,674	16,572,792	32.6
UNI	1,824,093	21,860,031	12.0
WAR	371,169	13,012,489	35.1
WES	16,304	477,950	29.3
Total	**32,862,668**	**590,178,597**	**19.3**

- **9,054,849** records
  - One for each person in **NJ_Resident** file
- Specifying **32,862,668** Daily Person Trips
  - Each characterized by a precise
    - **{oLat, oLon, oTime, dLat, dLon, Est_dTime}**

New Jersey Summary Data

Item	Value
Area (mi^2)	8,061
# of Pixels Generating at Least One O_Trip	21,643
Area of Pixels (mi^2)	5,411
% of Open Space	32.9%
# of Pixels Generating 95% of O_Trips	9,519
# of Pixels Generating 50% of O_Trips	1,310
# of Intra-Pixel Trips	447,102
# of O_Walk Trips	1,943,803
# of All O_Trips	32,862,668
Avg. All O_TripLength (miles)	19.6
# of O_aTaxi Trips	30,471,763
Avg. O_aTaxiTripLength (miles)	20.7
Median O_aTaxiTripLength (miles)	12.5
95% O_aTaxiTripLength (miles)	38.0

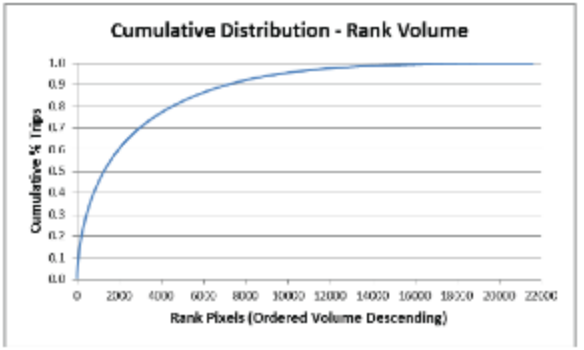


Figure 4.14: NJ State - Cumulative Distribution by Rank of Volume of Pixel.

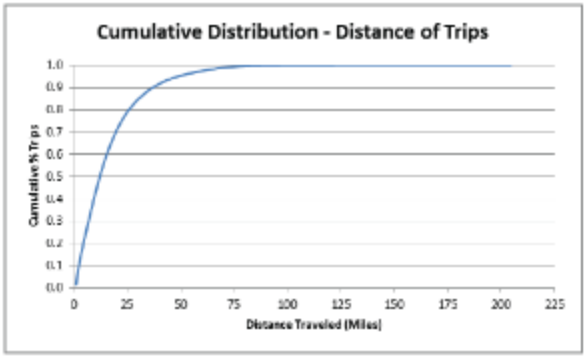


Figure 4.15: NJ State - Cumulative Distribution of Distance Traveled.

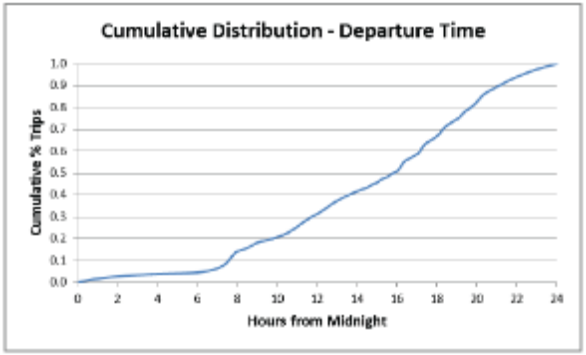


Figure 4.13: NJ State - Cumulative Distribution by Departure Time.

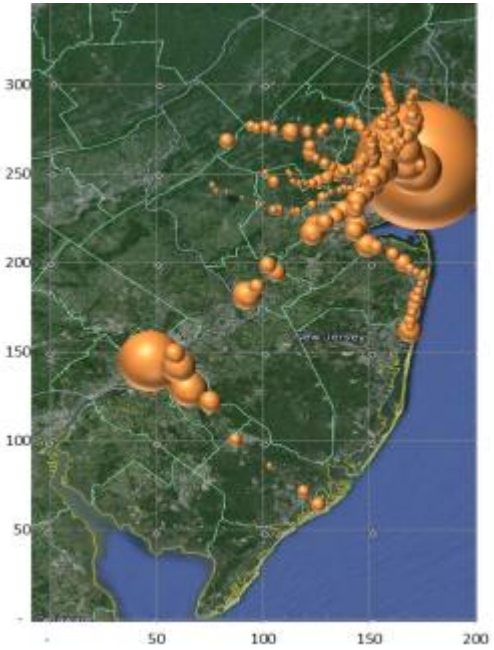
Analysis of aTaxi Demand in Mercer County

CD=3p; DD=300sec; MaxCircuity=20%

- 469,020 aTaxi Departures throughout typical "October weekday"
  - 935 "50-passenger" aTaxi Departures
  - 8,127 "15-passenger" aTaxi Departures
  - 283,779 "6-passenger" aTaxi Departures
  - 176,179 "2-passenger" aTaxi Departures
- 527,724 aTaxi Arrivals throughout typical "October weekday"
  - 1,089 "50-passenger" aTaxi Arrivals
  - 8,472 "15-passenger" aTaxi Arrivals
  - 272,653 "6-passenger" aTaxi Arrivals
  - 245,510 "2-passenger" aTaxi Arrivals
- ~58,704 aTaxis will need to be repositioned outside of Mercer County overnight.
  - ~154 "50-passenger" aTaxis will need to be repositioned **out** of Mercer County overnight
  - ~345 "15-passenger" aTaxis will need to be repositioned **out** of Mercer County overnight
  - ~11,126 "6-passenger" aTaxis will need to be repositioned **into** Mercer County overnight.
  - ~69,331 "2-passenger" aTaxis will need to be repositioned **out** of Mercer County overnight.

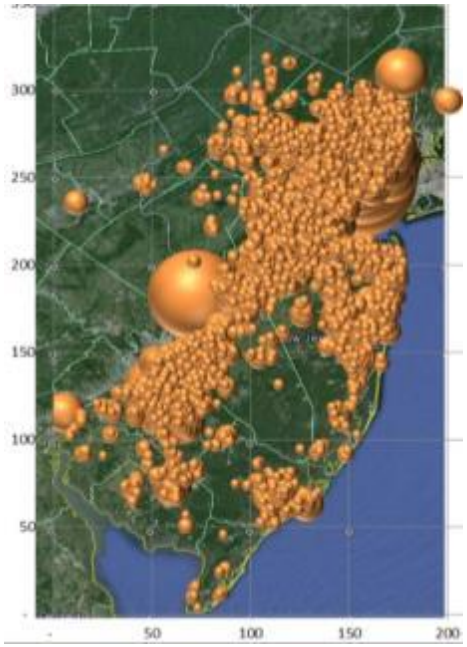
Spatial Aggregation

- By walking to a station/aTaxiStand
  - A what point does a walk distance makes the aTaxi trip unattractive relative to one's personal car?
  - ¼ mile (5 minute) max
- By using the rail system for some trips
  - Trips with at least one trip-end within a short walk to a train station.
  - Trips to/from NYC or PHL

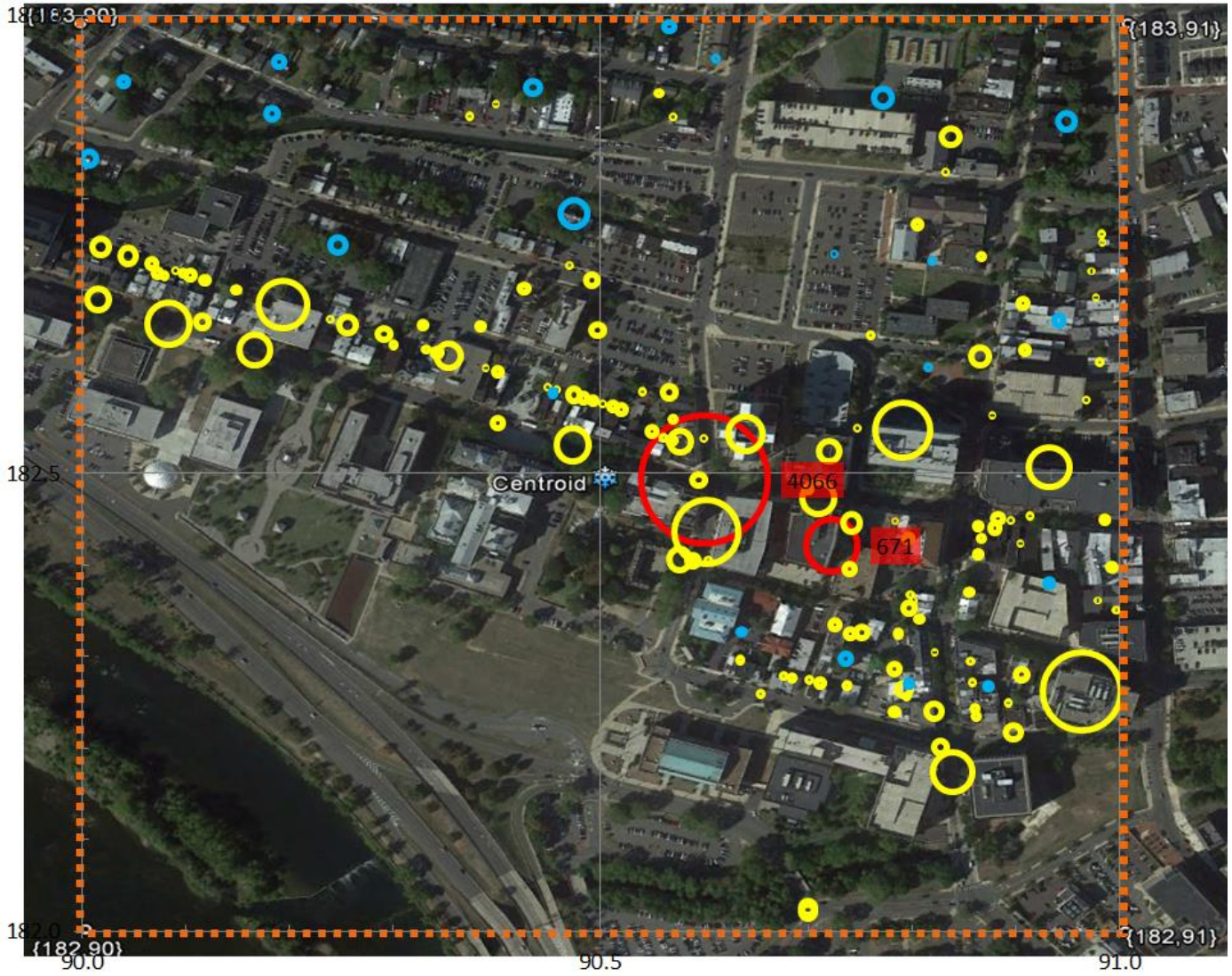


Spatial Aggregation

- By walking to a station/aTaxiStand
  - A what point does a walk distance makes the aTaxi trip unattractive relative to one's personal car?
  - ¼ mile (5 minute) max
- By using the rail system for some trips
  - Trips with at least one trip end within a short walk to a train station.
  - Trips to/from NYC or PHL
- **By sharing rides with others that are basically going in my direction**
  - **No trip has more than 20% circuity added to its trip time.**



Mercer County Pixel {182,90} Trenton



Item	Value
Activity Locations	135
Employment	8,654
Population	707
School Enrollment	4,737

Work

Home (Block Centroid)

School

Pixel Centroid

Mercer County Pixel {181,93} Chambersburg

Item	Value
Activity Locations	113
Employment	2,295
Population	5,622
School Enrollment	594

Work

Home (Block Centroid)

School

Pixel Centroid

Mercer County Pixel {181,93} Chambersburg

Item	Value
Activity Locations	113
Employment	2,295
Population	5,622
School Enrollment	594

Work

Home (Block Centroid)

School

Pixel Centroid

PAVE PRINCETON AUTONOMOUS VEHICLE ENGINEERING

Mercer County Pixel {199,102} Princeton

Item	Value
Activity Locations	16
Employment	2,490
Population	2,430
School Enrollment	1,951

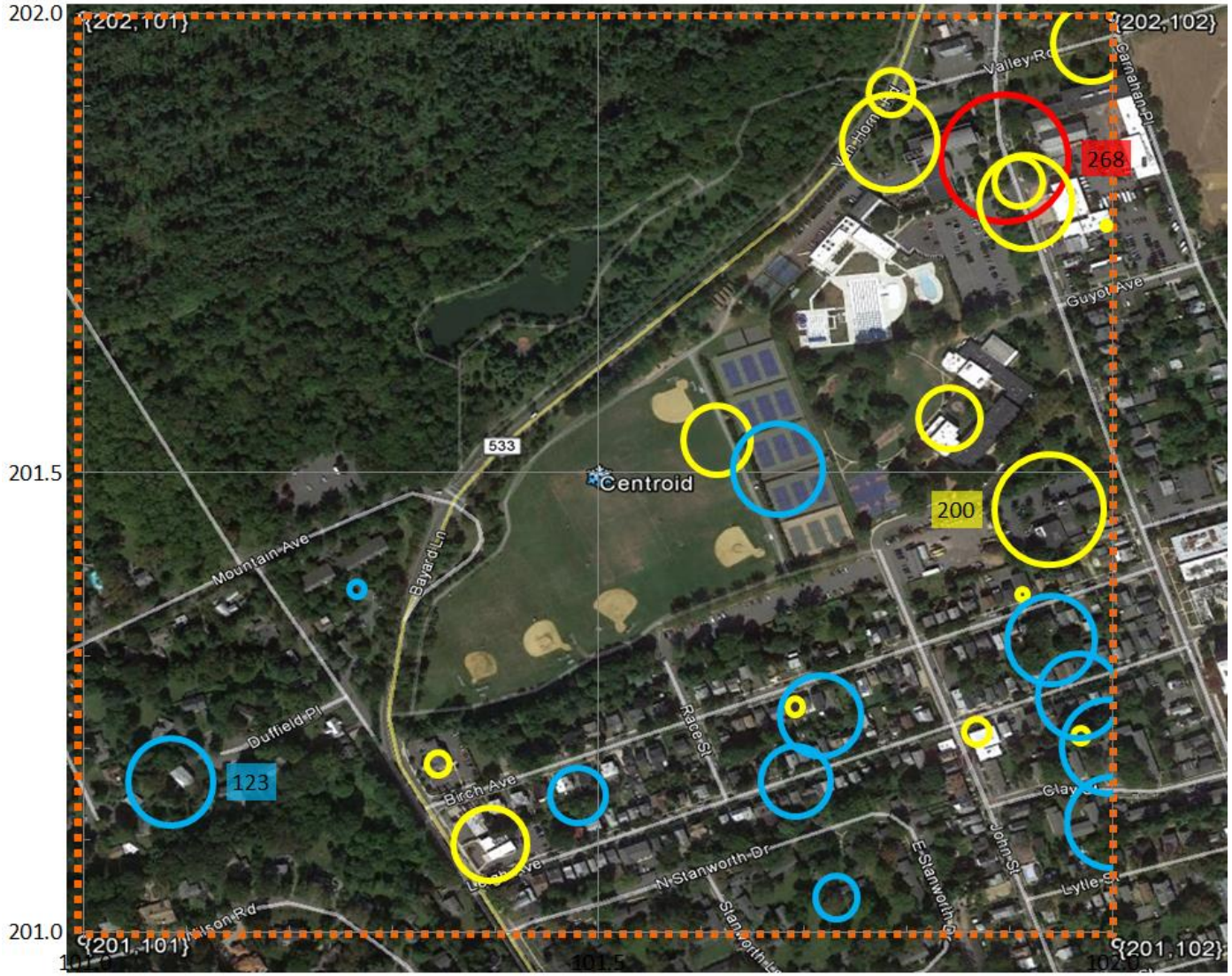
Work

Home (Block Centroid)

School

Pixel Centroid

Mercer County Pixel {201,101} Princeton



Item	Value
Activity Locations	27
Employment	925
Population	1,056
School Enrollment	268

Work

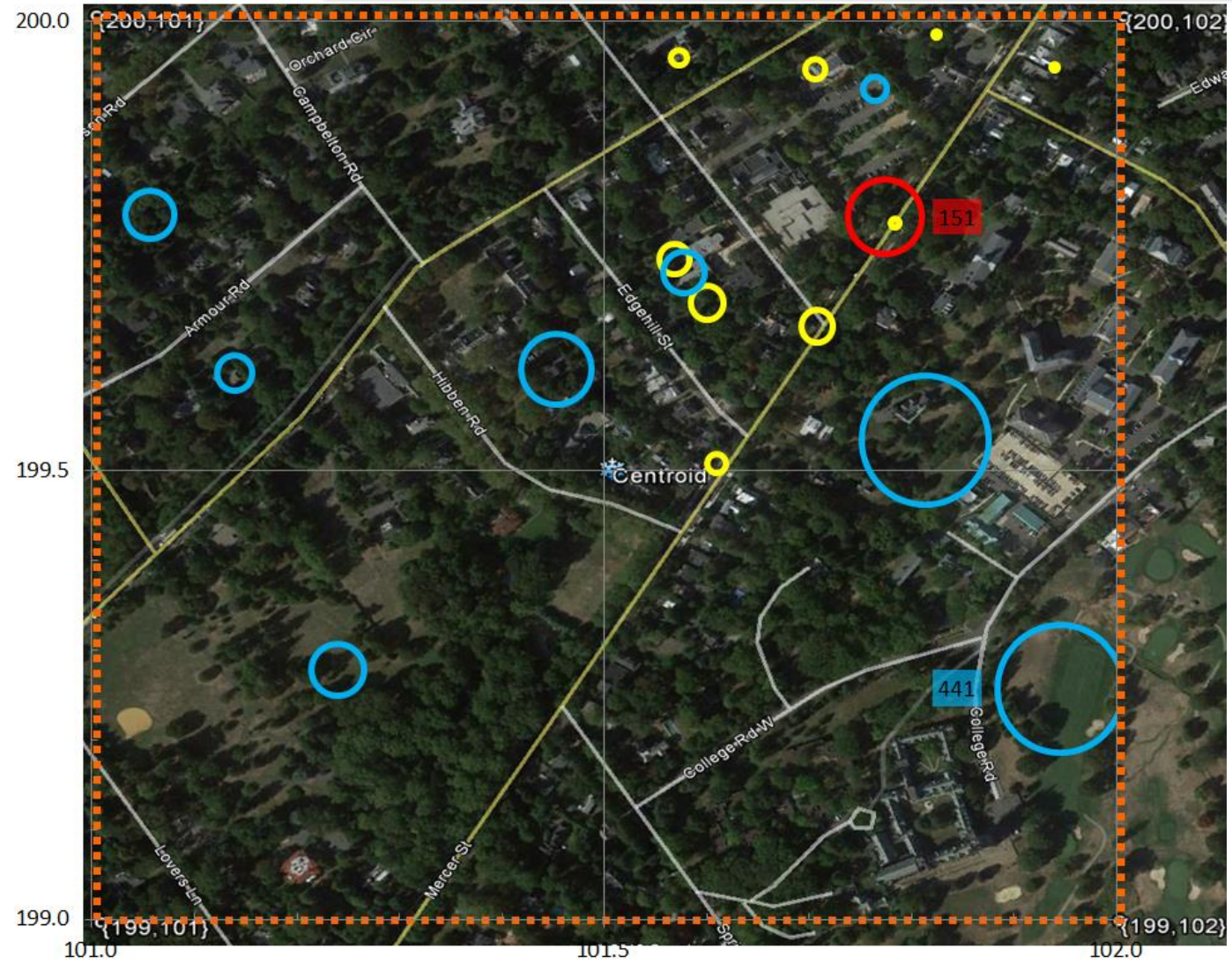
Home (Block Centroid)

School

Pixel Centroid

PAVE PRINCETON AUTONOMOUS VEHICLE ENGINEERING

Mercer County Pixel {199,101} Princeton



Item	Value
Activity Locations	18
Employment	116
Population	1,268
School Enrollment	151

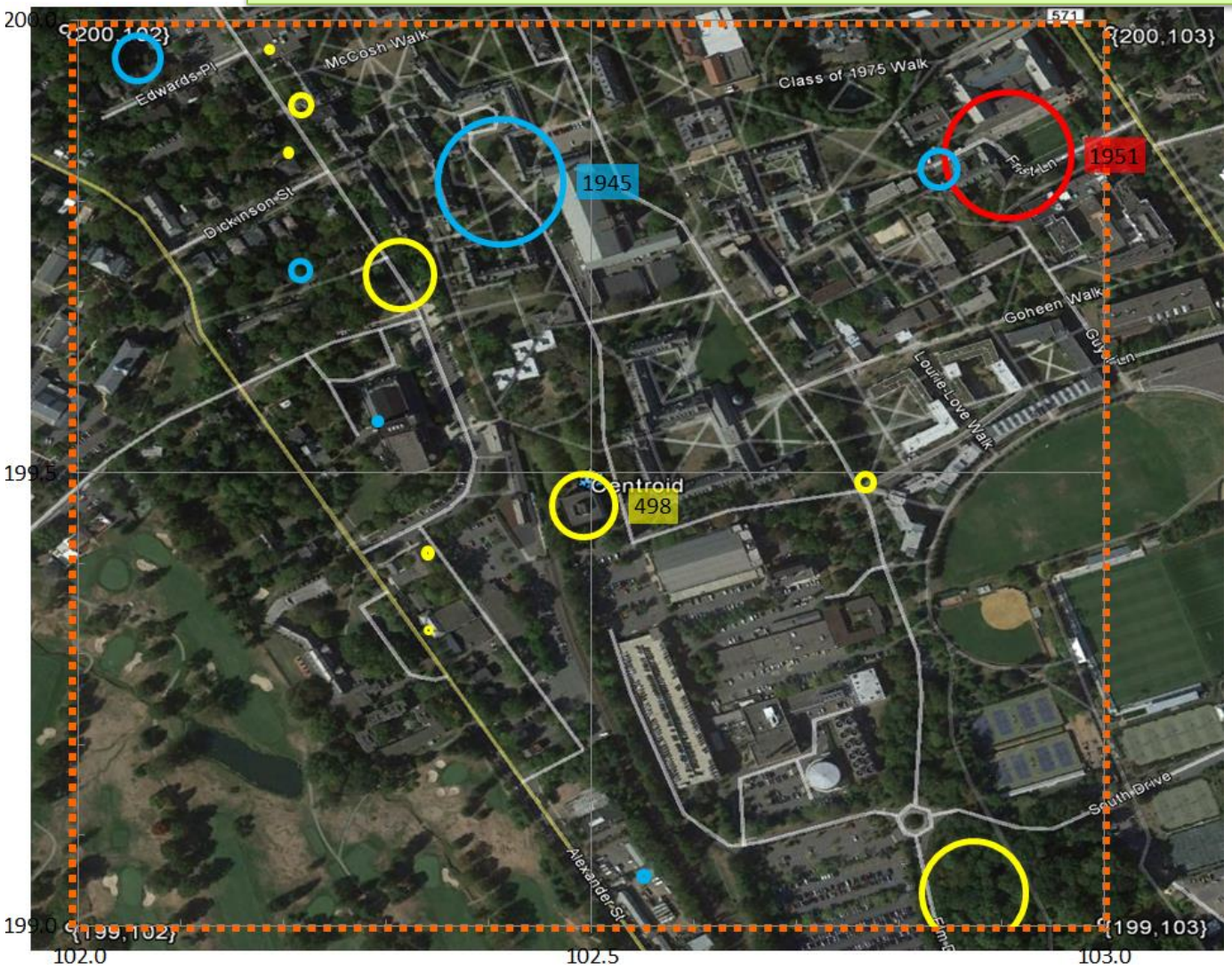
Work

Home (Block Centroid)

School

Pixel Centroid

Mercer County Pixel {199,102} Princeton



Item	Value
Activity Locations	16
Employment	2,490
Population	2,430
School Enrollment	1,951

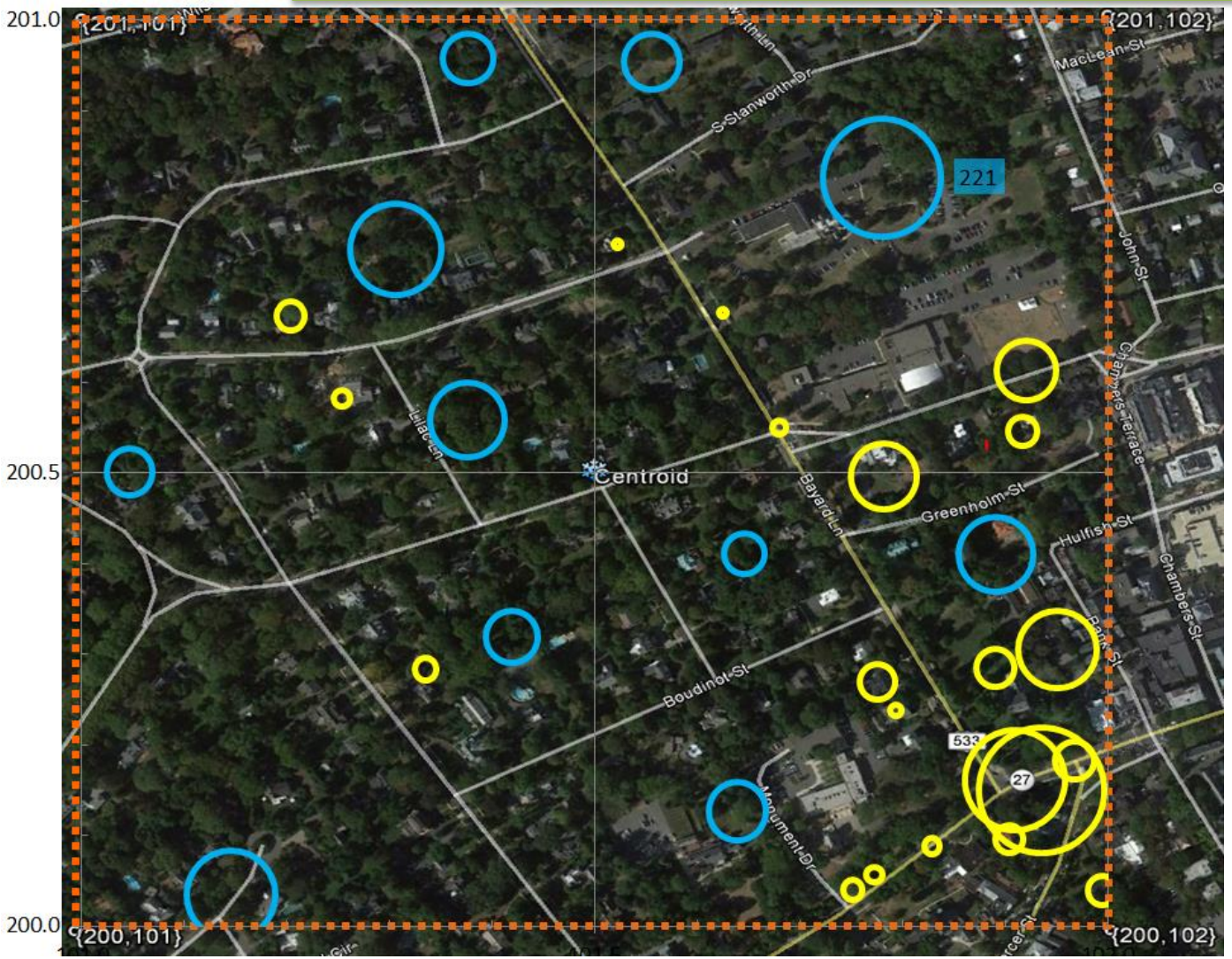
Work

Home (Block Centroid)

School

Pixel Centroid

Mercer County Pixel {200,101} Princeton



Item	Value
Activity Locations	32
Employment	789
Population	906
School Enrollment	0

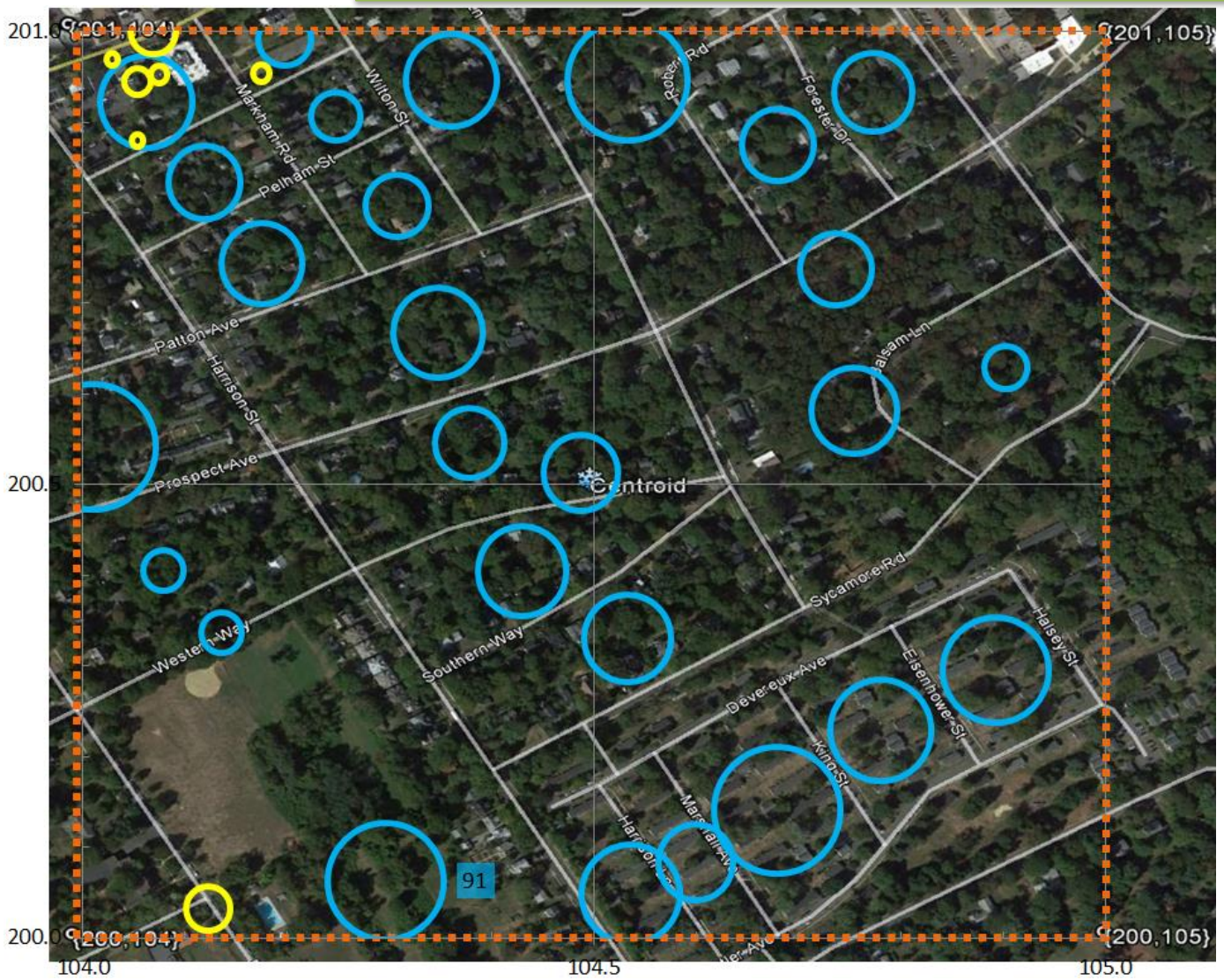
Work

Home (Block Centroid)

School

Pixel Centroid

Mercer County Pixel {200,104} Princeton



Item	Value
Activity Locations	34
Employment	38
Population	1,332
School Enrollment	0

Work

Home (Block Centroid)

School

Pixel Centroid

Bergen County Pixel {266,162} Rutherford

Item	Value
Activity Locations	131
Employment	3,809
Population	2,352
School Enrollment	896

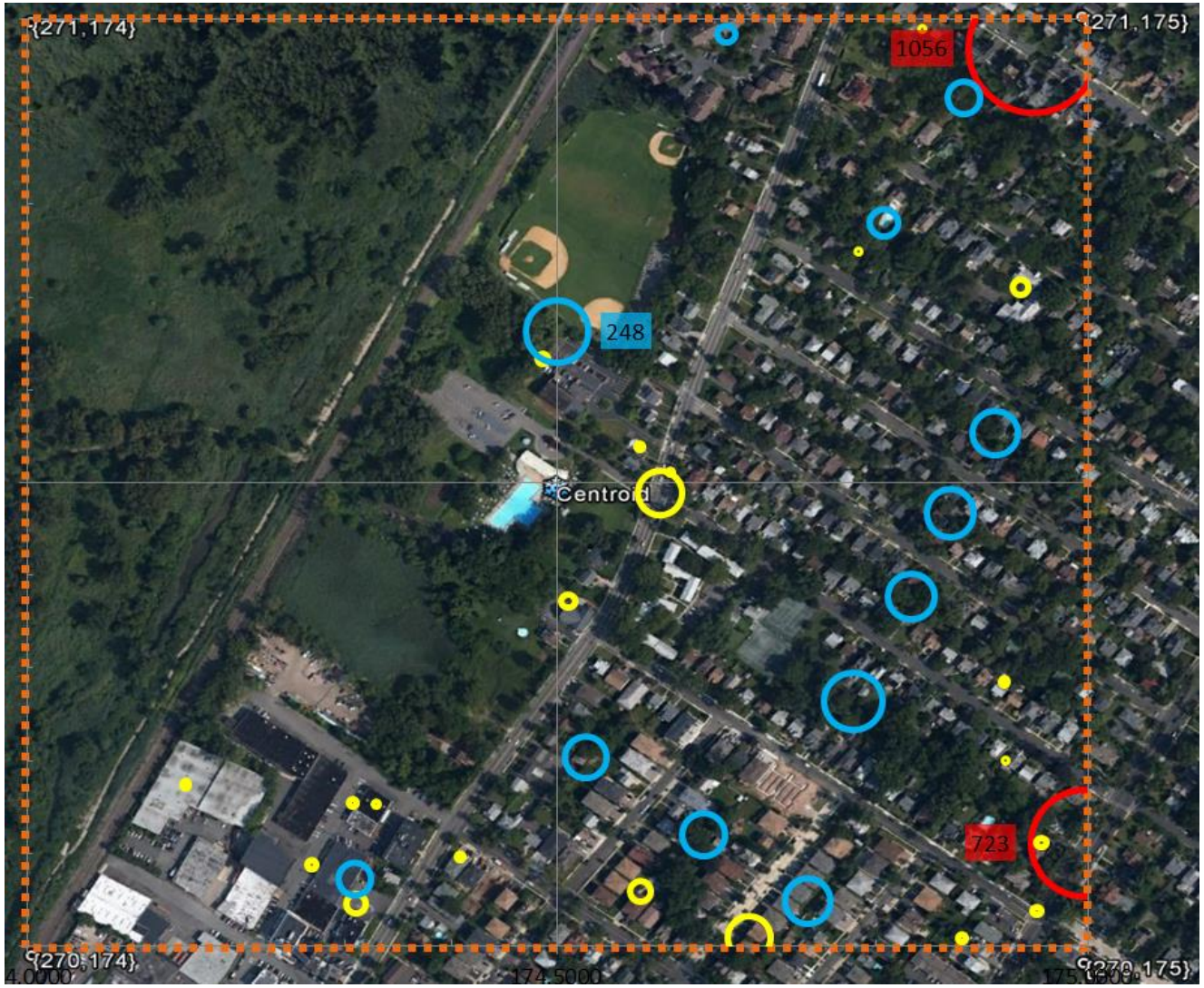
Work

Home (Block Centroid)

School

Pixel Centroid

Bergen County Pixel {270,174} Leonia



Item	Value
Activity Locations	35
Employment	364
Population	1,428
School Enrollment	1,779

Work

Home (Block Centroid)

School

Pixel Centroid

What about the whole country?

A National Disaggregate Transportation Demand Model for the Analysis of Autonomous Taxi Systems

Alexander Penn Hill Wyrough, Jr.

Advisor: Professor Alain L. Kornhauser *71

Trip Files are Available If You want to Play

A National Disaggregate Transportation Demand Model for the Analysis of Autonomous Taxi Systems

Alexander Penn Hill Wyrough, Jr.

Advisor: Professor Alain L. Kornhauser *71

The North American Grid

18 million pixel
0.5mi. x 0.5 mi.
Centered @
37° N Latitude, -97.50° W Longitude

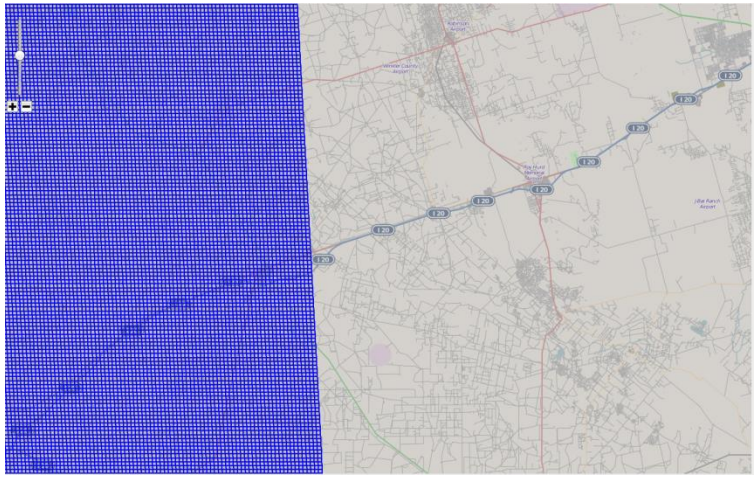


Table 2.1: SQL Table Structure

ID	X	Y	C_Long	C_Lat	BL_Long	BL_Lat	BR_Long	BR_Lat	TL_Long	TL_Lat	TR_Long	TR_Lat
20172271942	2694	848	-70,81	43,13	-70,82	43,13	-70,81	43,13	-70,82	43,14	-70,81	43,14
20172271943	2693	849	-70,82	43,14	-70,83	43,14	-70,82	43,14	-70,82	43,14	-70,81	43,14
20172472799	2698	845	-70,78	43,11	-70,79	43,11	-70,78	43,11	-70,78	43,12	-70,78	43,12
20172472800	2697	846	-70,79	43,12	-70,79	43,12	-70,78	43,12	-70,79	43,12	-70,78	43,12
20172472801	2696	847	-70,80	43,13	-70,80	43,12	-70,79	43,12	-70,80	43,13	-70,79	43,13
20172472802	2695	848	-70,80	43,13	-70,81	43,13	-70,80	43,13	-70,81	43,14	-70,80	43,14

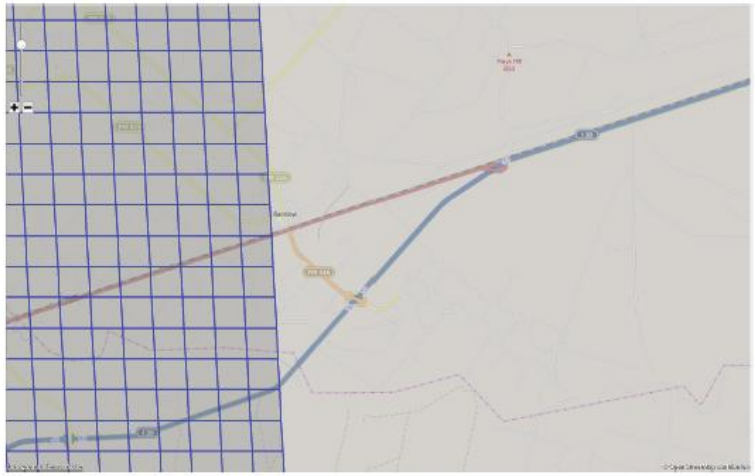


Figure 2.2: The grid displayed on our OSM interface in Texas zoomed in

Public Schools in the US

Nation-Wide Businesses

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

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

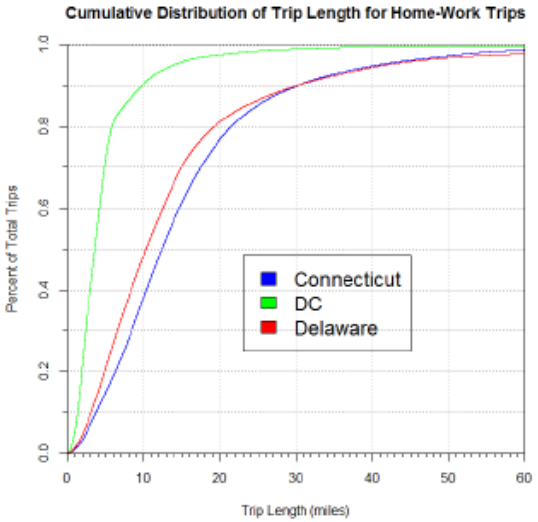
US_PersonTrip file will have..

- **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}**
- Will Perform Nationwide aTaxi AVO analysis
- Results

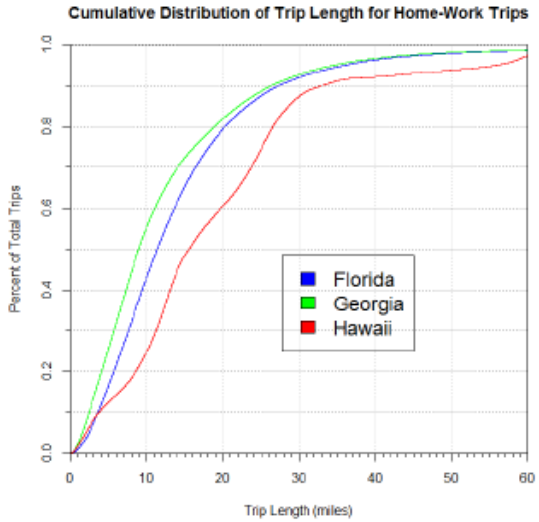
Residence State	County Code	Tract Code	Block Code	HH ID	HH TYPE	Latitude	Longitude	Age	Sex	Traveler Type	Income Amount	School Name	SchoolLat	SchoolLon
47	037	15620	1001	420163	0	36.0734	-86.6281	48	0	5	$49,267.50	NA	NA	NA
47	037	15620	1001	420163	0	36.0734	-86.6281	13	1	1	$0.00	DUPONT TYLER MIDDLE SCHOOL	36.1995	-86.6118
47	037	15620	1001	420163	0	36.0734	-86.6281	14	0	1	$0.00	ANTIOCH HIGH SCHOOL	36.0474	-86.5990
47	037	15620	1001	420163	0	36.0734	-86.6281	10	0	1	$0.00	LAKEVIEW ELEMENTARY DESIGN CENTER	36.0790	-86.6307
47	037	15620	1001	420164	0	36.0734	-86.6281	46	1	5	$143,175.51	NA	NA	NA
47	037	15620	1001	420164	0	36.0734	-86.6281	13	0	1	$0.00	WRIGHT MIDDLE SCHOOL	36.1003	-86.7341
47	037	15620	1001	420164	0	36.0734	-86.6281	12	0	1	$0.00	DONELSON MIDDLE SCHOOL	36.1664	-86.6564
47	037	15620	1001	420164	0	36.0734	-86.6281	13	0	1	$0.00	JOHN F. KENNEDY MIDDLE SCHOOL	36.0541	-86.5991
47	037	15620	1001	420165	0	36.0734	-86.6281	40	1	5	$129,436.10	NA	NA	NA
47	037	15620	1001	420165	0	36.0734	-86.6281	12	1	1	$0.00	CROFT MIDDLE DESIGN CENTER	36.0879	-86.7340
47	037	15620	1001	420165	0	36.0734	-86.6281	12	1	1	$0.00	JOHN F. KENNEDY MIDDLE SCHOOL	36.0541	-86.5991
47	037	15620	1001	420165	0	36.0734	-86.6281	12	1	1	$0.00	ANTIOCH MIDDLE SCHOOL	36.0552	-86.6717

Figure 2.7: Task 3 Sample Output for Tennessee Residents

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				

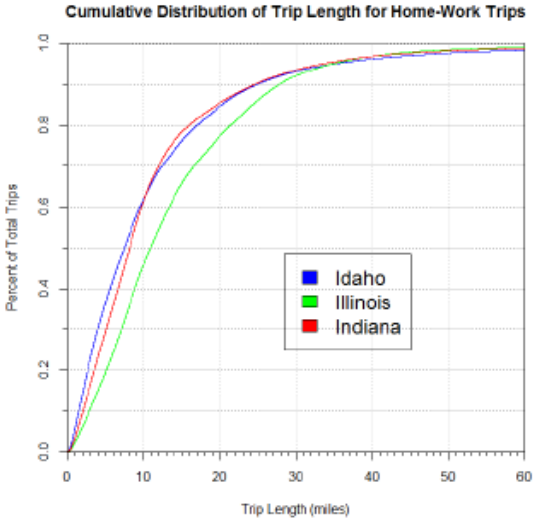


(a) Connecicut, D.C., Delaware

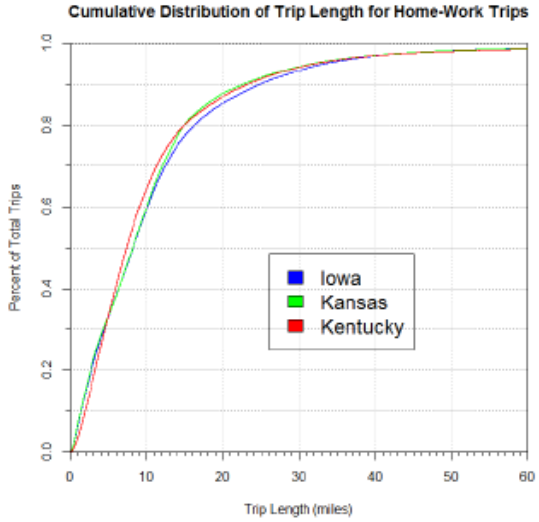


(b) Florida, Georgia, Hawaii

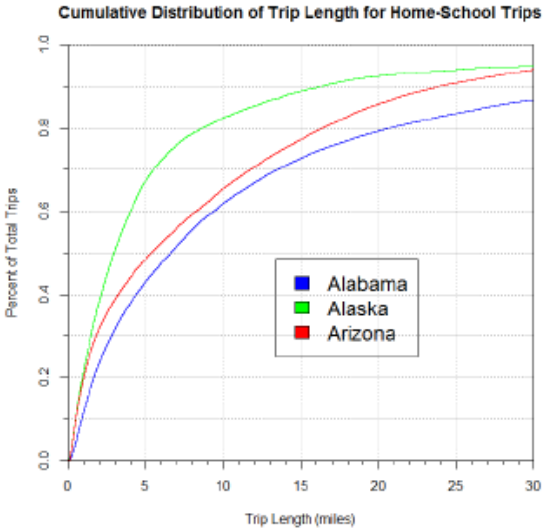
Figure 4.7: Cumulative Distribution of Trip Length For Commutes by State (ID - KY)



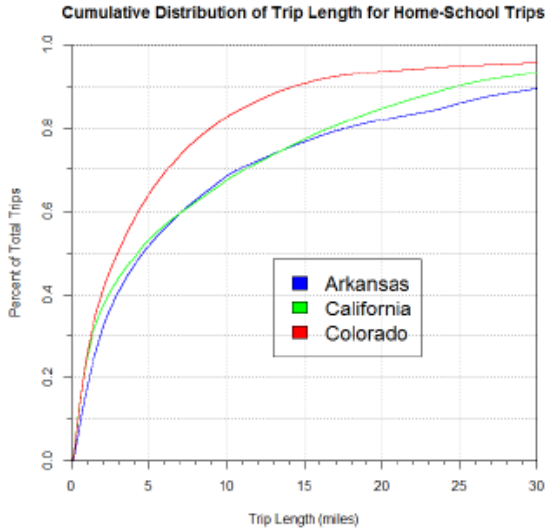
(a) Idaho, Illinois, Indiana



(b) Iowa, Kansas, Kentucky

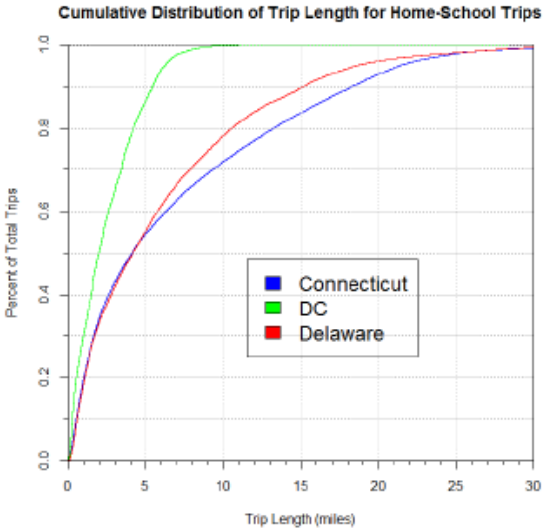


(a) Alabama, Alaska, Arizona

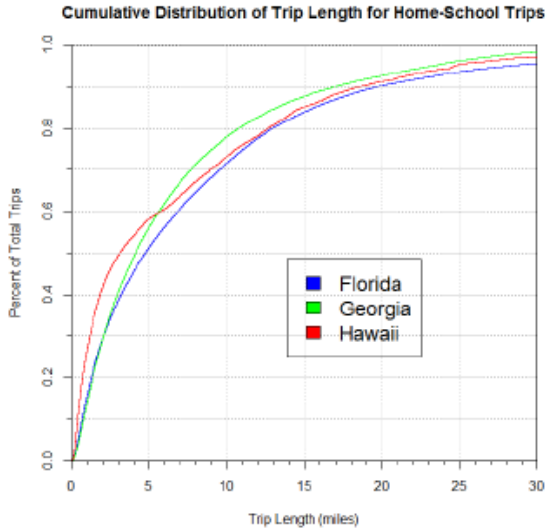


(b) Arkansas, California, Colorado

Figure 4.19: Cumulative Distribution of Trip Length For School Trips by State (CT - HI)



(a) Connecicut, D.C., Delaware



(b) Florida, Georgia, Hawaii

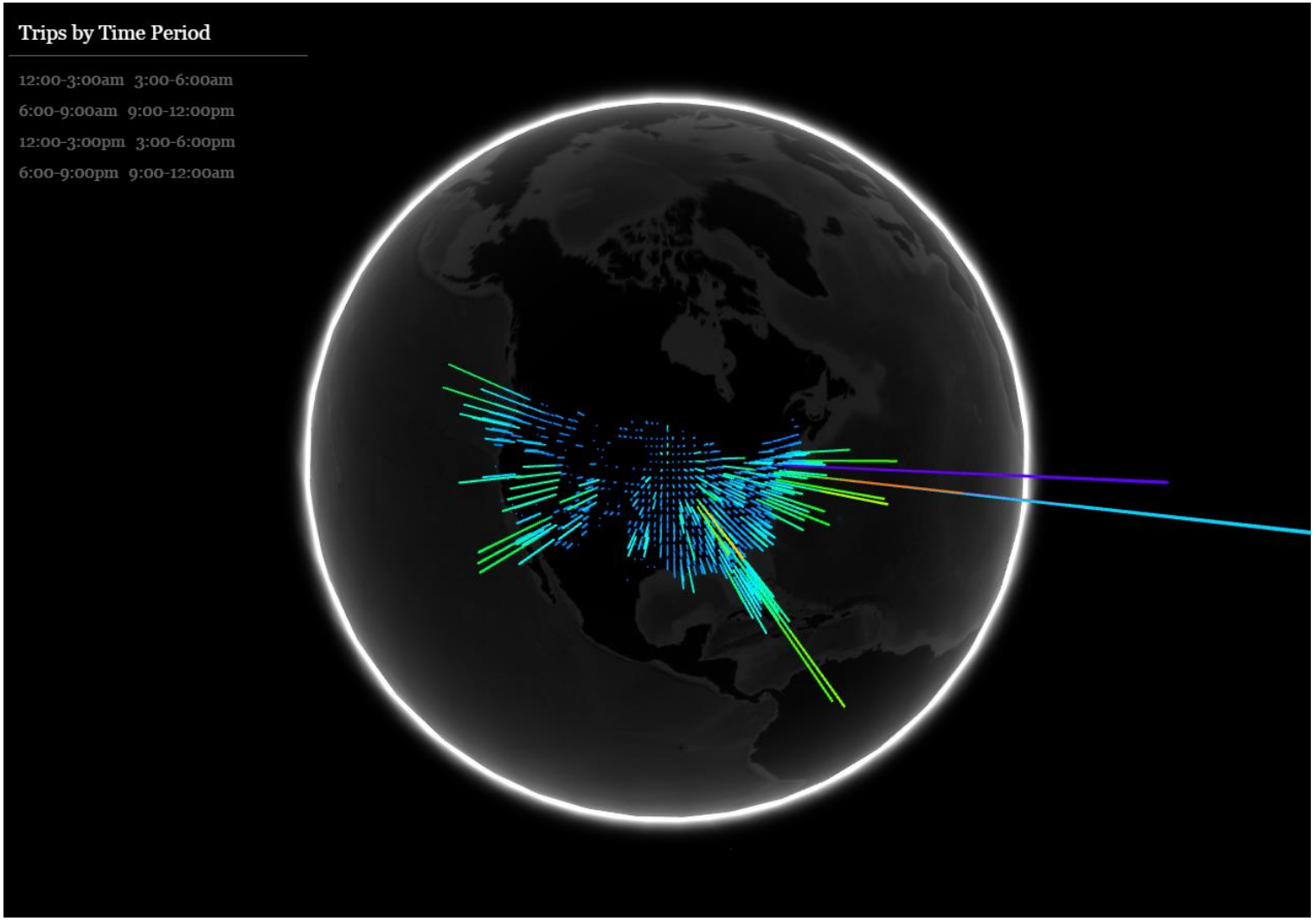
Manhattan (New York County)

- Simulated population of 1,585,873 residents
- 8,085,055 trips *originate* within Manhattan
- 52,759,156 person-trip miles for Manhattan oTrips
- 3,010,666 unique travelers (1,424,793 non-resident travelers – Commuters)
- Mean Trip Length = 6.53 miles; Median Trip Length = 3.31 miles
- Interesting differences between commuter and resident population traveling through Manhattan

Manhattan (New York County)

Manhattan (New York County)

Visualizing Synthesized Individual Person Trips on a Typical Day Throughout the Lower 48



http://162.209.99.128/globe/ (Use Chrome; wait for it to load)

Outline

- Background on Smart Driving Cars (Where we are today)
- What is Today's Demand for Mobility (Synthesizing Individual Person trips for new Jersey and the Nation)
- **How Might Those Trips be Served by aTaxis**

Uncongested Mobility for All

New Jersey's Area-wide aTaxi System

ORF 467

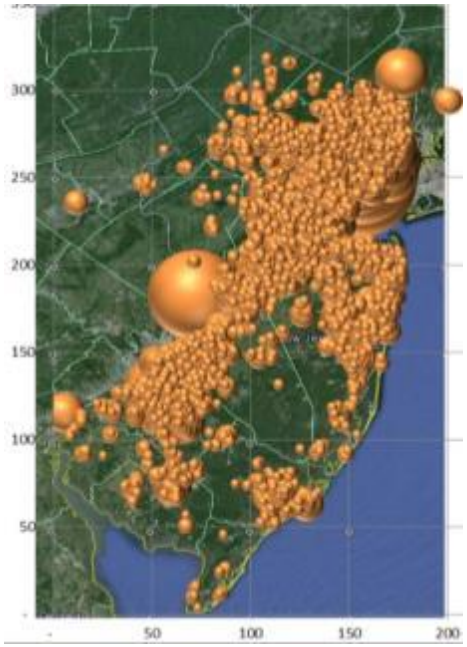
Professor Alain L.Kornhauser

Iris Chang '13
Christina Clark '13
JingKang Gao '13
Damjan Korac '13
Brett Leibowitz '13
Philip Oasis '13
Zixi Xu '13
Jaison Zachariah '13
Natasha Harpalani '14
Eileen Lee '14
Alice Lin '14
Aria Miles '14
Hannah Rajeshwar '14
Lucia Wang '14
Charquia Wright '14
Kristin Bergeson '15
Franklyn Darnis '15
Matthew Shackleford '15
Sonia Skoularikis '15
Roger Sperry '15
Andrew Swoboda '15

Operations Research and Financial Engineering
Princeton University
Fall 2012 - 2013

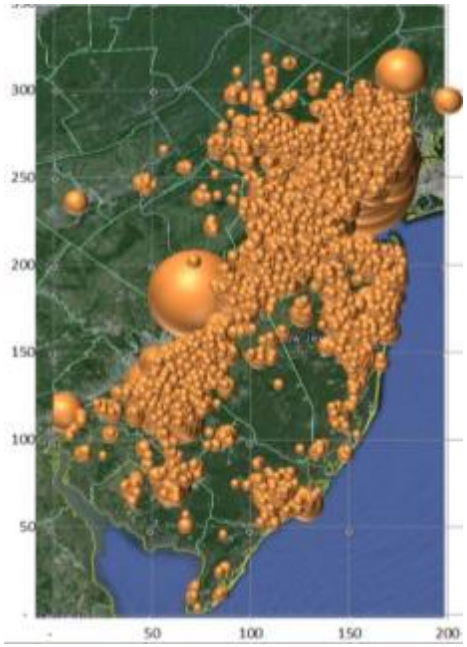
aTaxis and RideSharing

- **"AVO < 1" RideSharing**
  - Eliminate the "Empty Back-haul"; AVO Plus
- **"Organized" RideSharing**
  - Diverted to aTaxis
- **"Tag-along" RideSharing**
  - Only Primary trip maker modeled, "Tag-alongs" are assumed same after as before.
- **"Casual" RideSharing**
  - This is the opportunity of aTaxis
  - How much spatial and temporal aggregation is required to create significant casual ride-sharing opportunities.



Spatial Aggregation

- **By walking to a station/aTaxiStand**
  - **At what point does a walk distance makes the aTaxi trip unattractive relative to one's personal car?**
  - **¼ mile (5 minute) max**
- **Like using an Elevator!**



Elevator

Pixelation of New Jersey

NJ State Grid

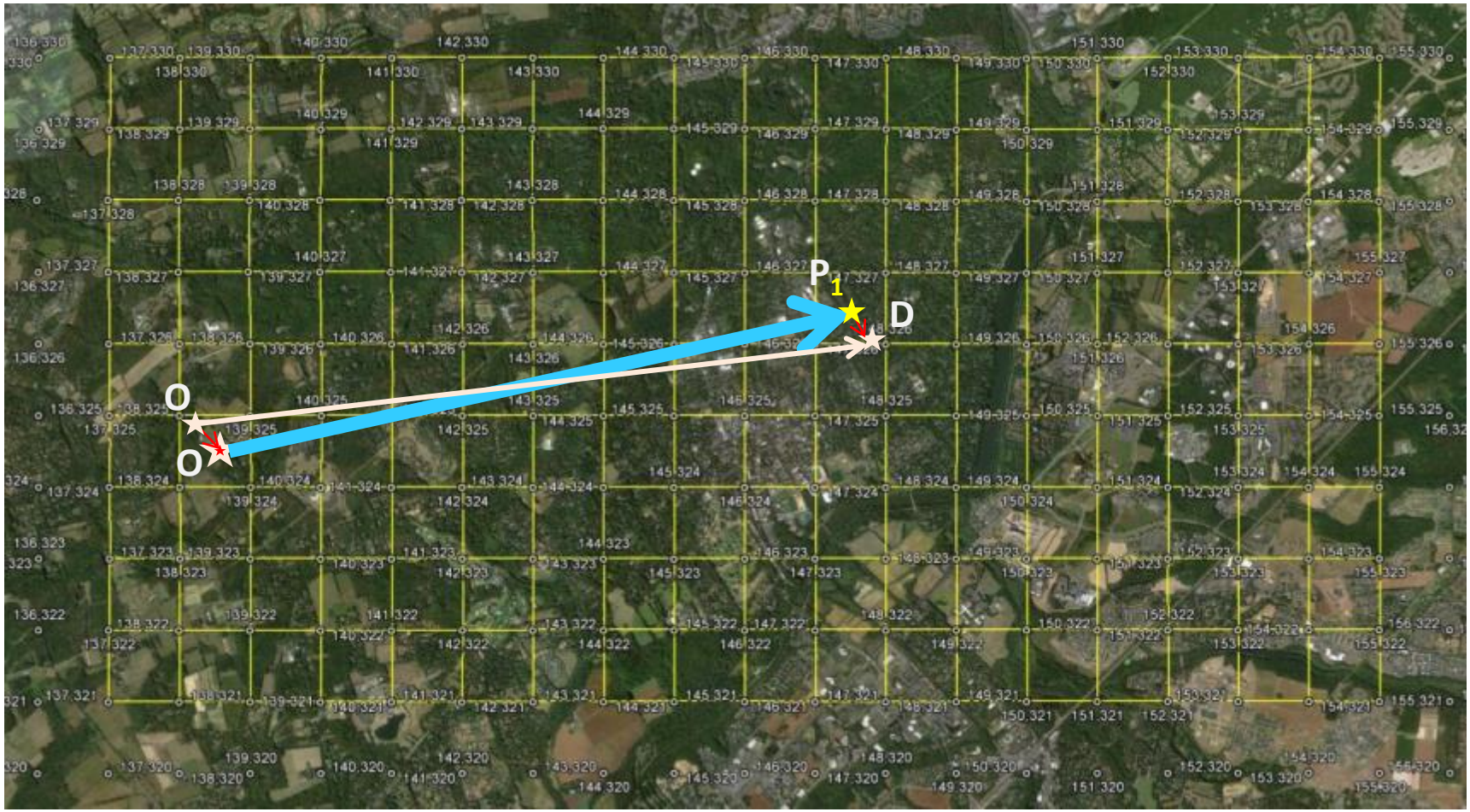
Zoomed-In Grid of Mercer

Pixelating the State with half-mile Pixels

xPixel = *floor{108.907 * (longitude + 75.6)}*
yPixel = *floor{138.2 * (latitude – 38.9))*

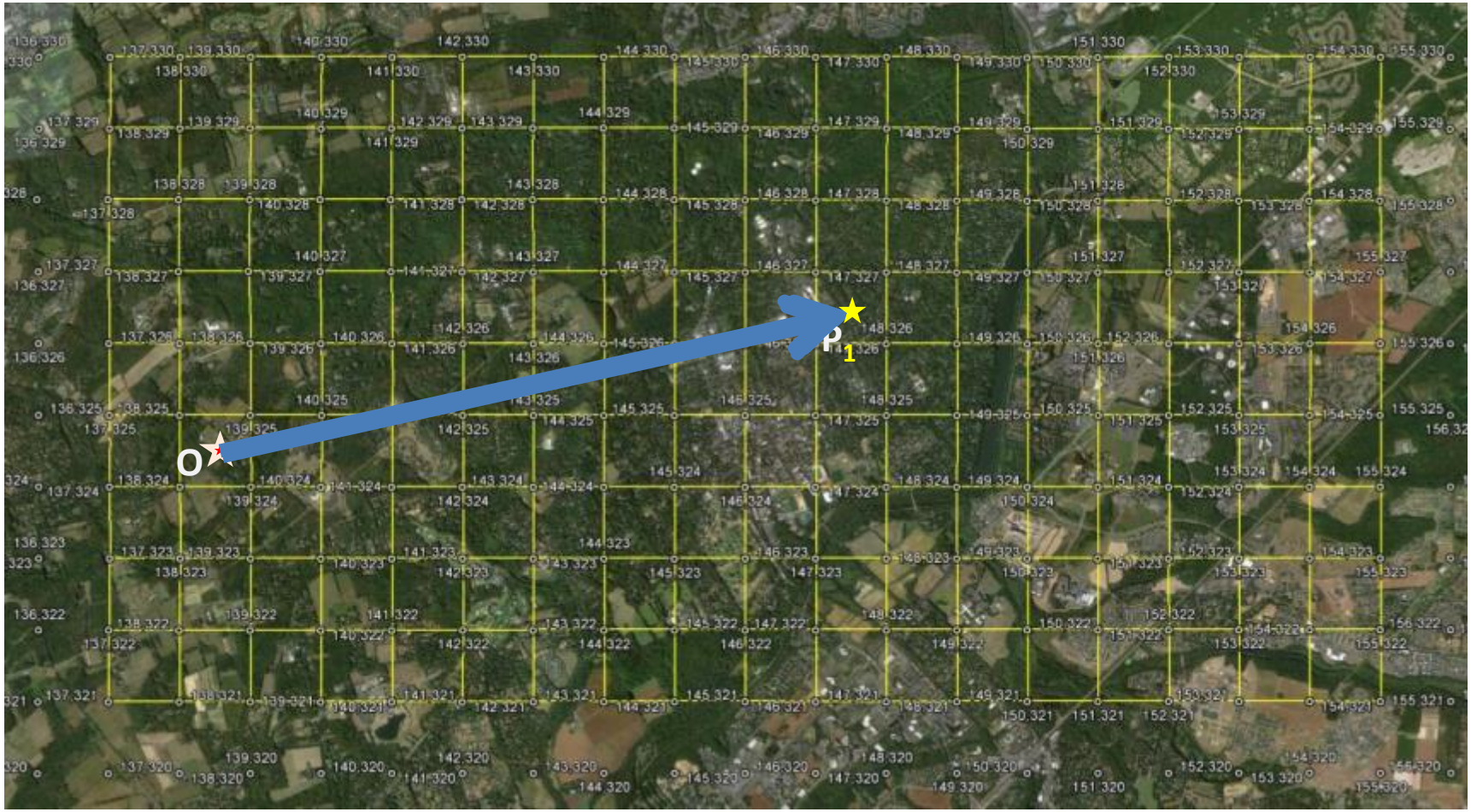
An aTaxiTrip

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



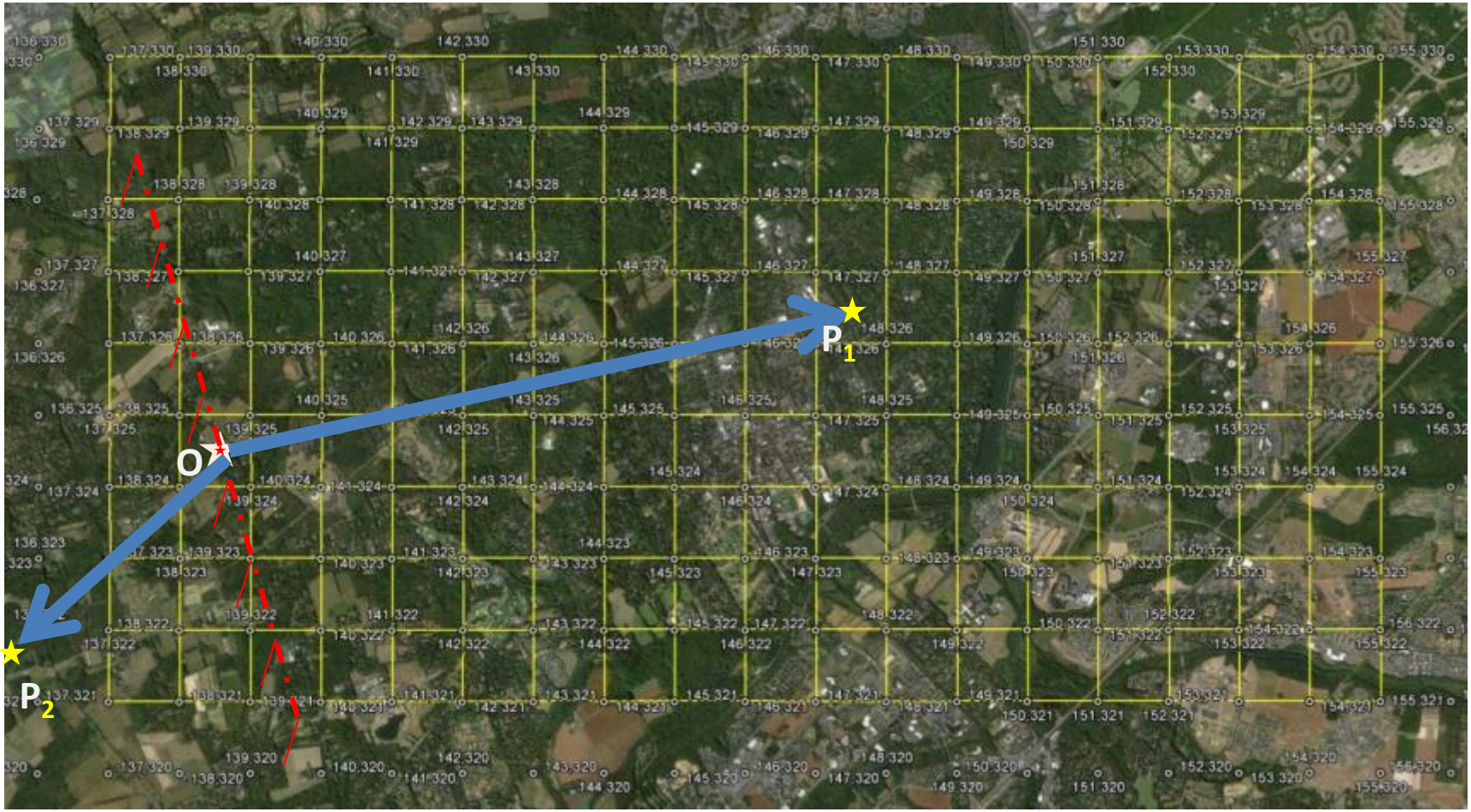
Common Destination (CD)
CD=1p: Pixel -> Pixel (p->p) Ride-sharing

TripMiles = 3*L*

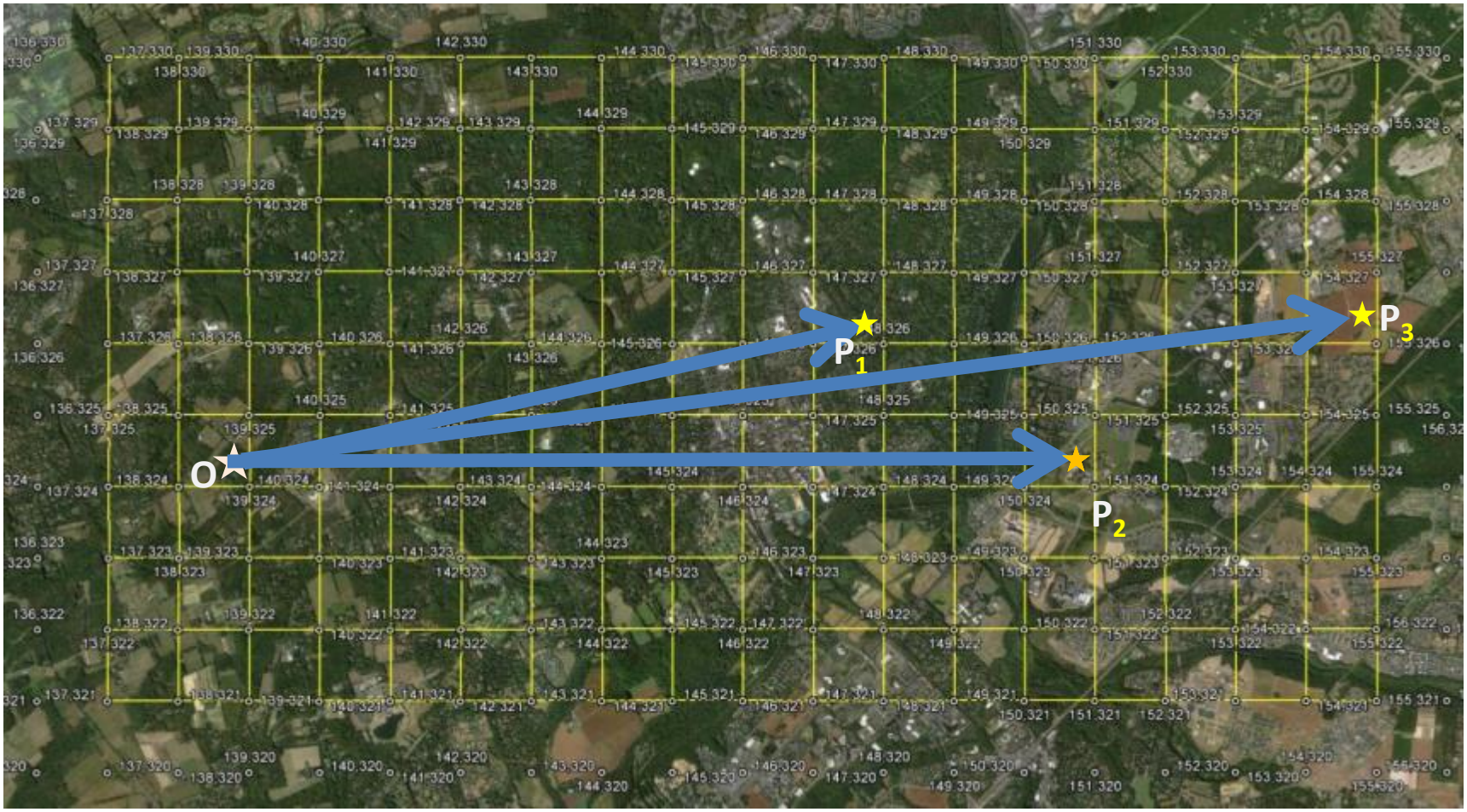


PersonMiles = 3L
aTaxiMiles = L
AVO = PersonMiles/aTaxiMiles = 3

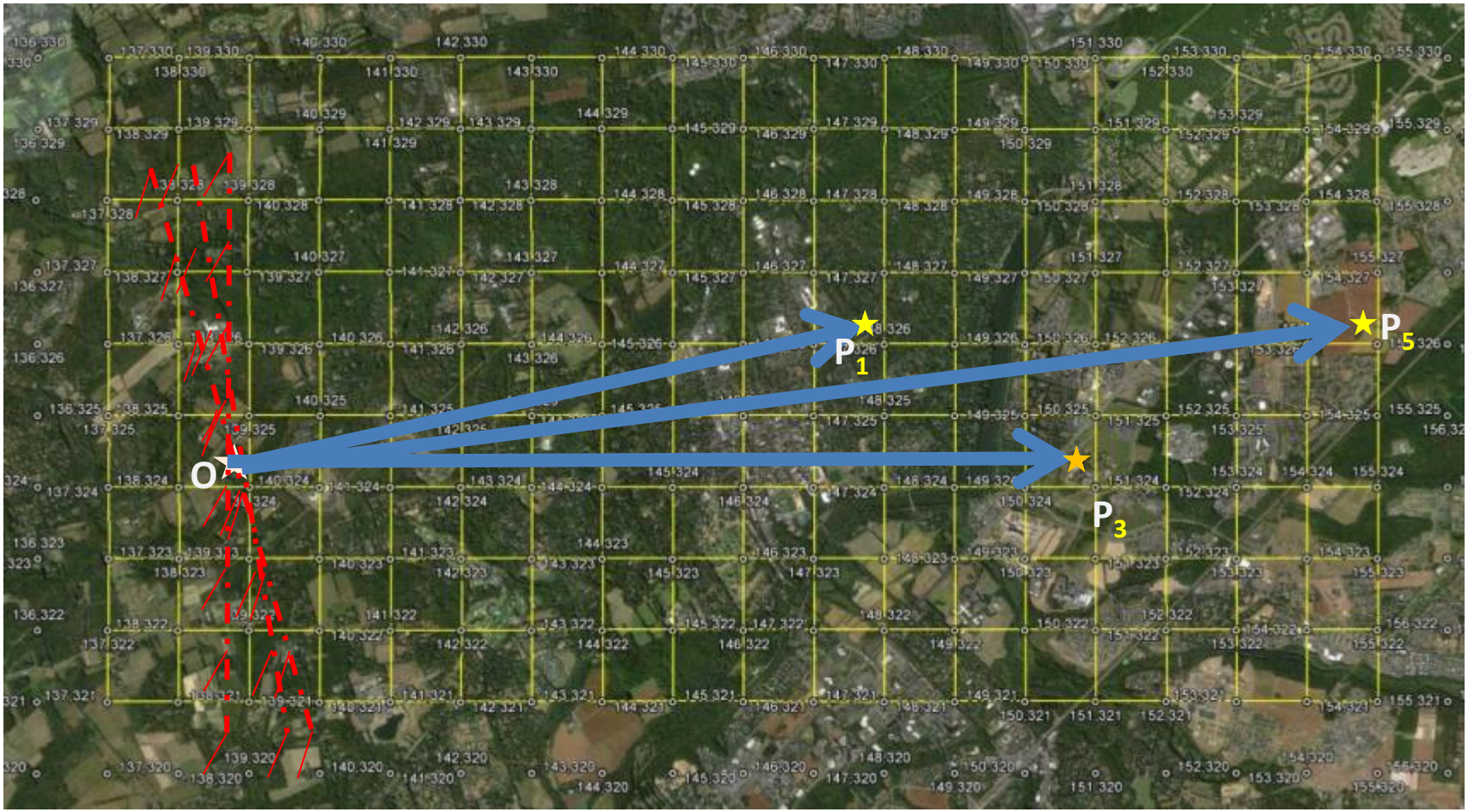
CD= 3p: Pixel ->3Pixels Ride-sharing



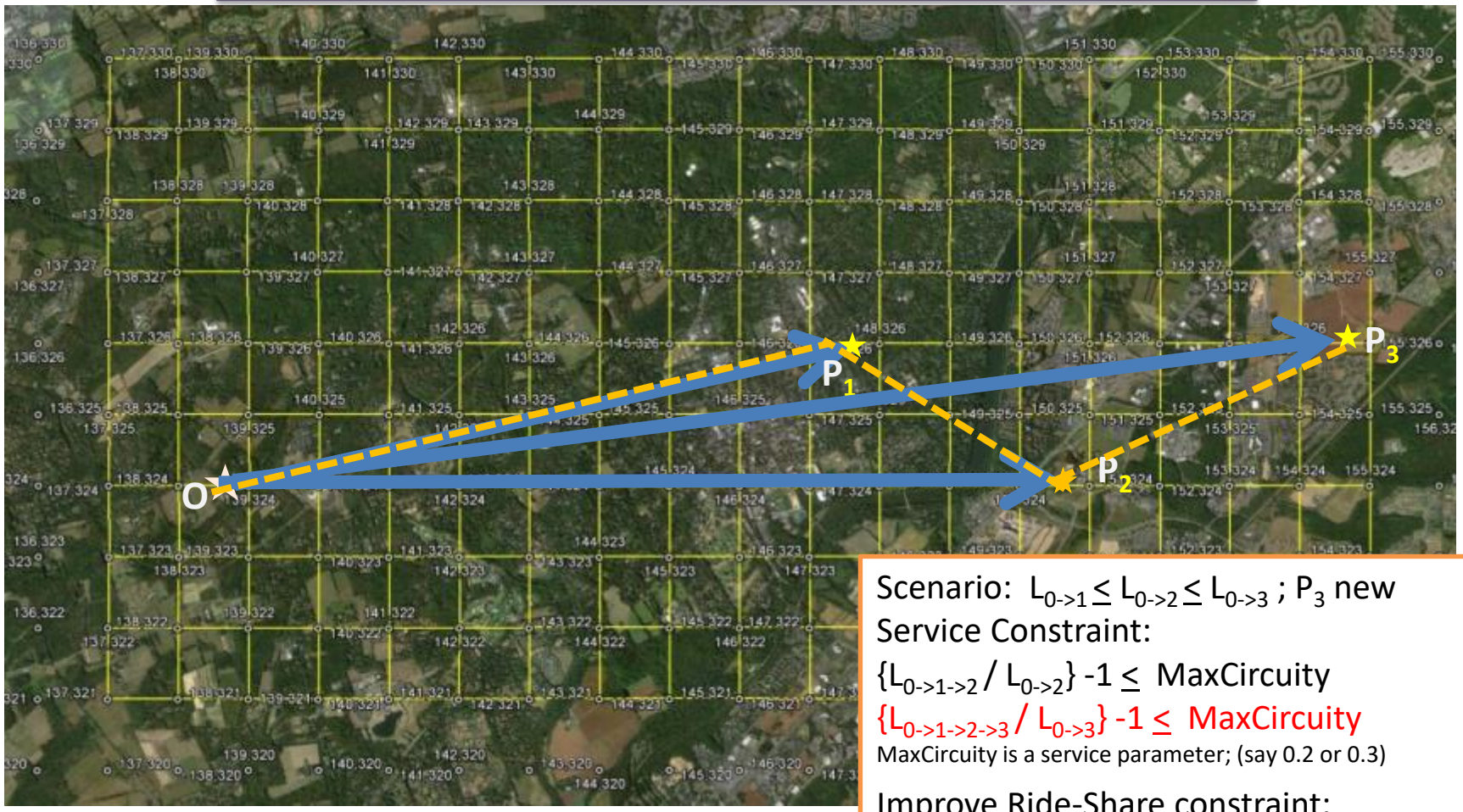
CD= 3p: Pixel ->3Pixels Ride-sharing



CD= 3p: Pixel ->3Pixels Ride-sharing



CD= 3p: Pixel ->3Pixels Ride-sharing; P_3 New



Scenario: $L_{0->1} \leq L_{0->2} \leq L_{0->3}$; P_3 new

Service Constraint:

$\{L_{0->1->2} / L_{0->2}\} - 1 \leq$ MaxCircuity

$\{L_{0->1->2->3} / L_{0->3}\} - 1 \leq$ MaxCircuity

MaxCircuity is a service parameter; (say 0.2 or 0.3)

Improve Ride-Share constraint:

$(AVO_{Rideshare\ 1,2} > AVO_{Alone})$

$\{L_{0->1} + L_{0->2}\} > L_{0->1->2}$

$(AVO_{Rideshare\ 1,2,3} > AVO_{Rideshare\ 1,2} + AVO_{3\ Alone})$;

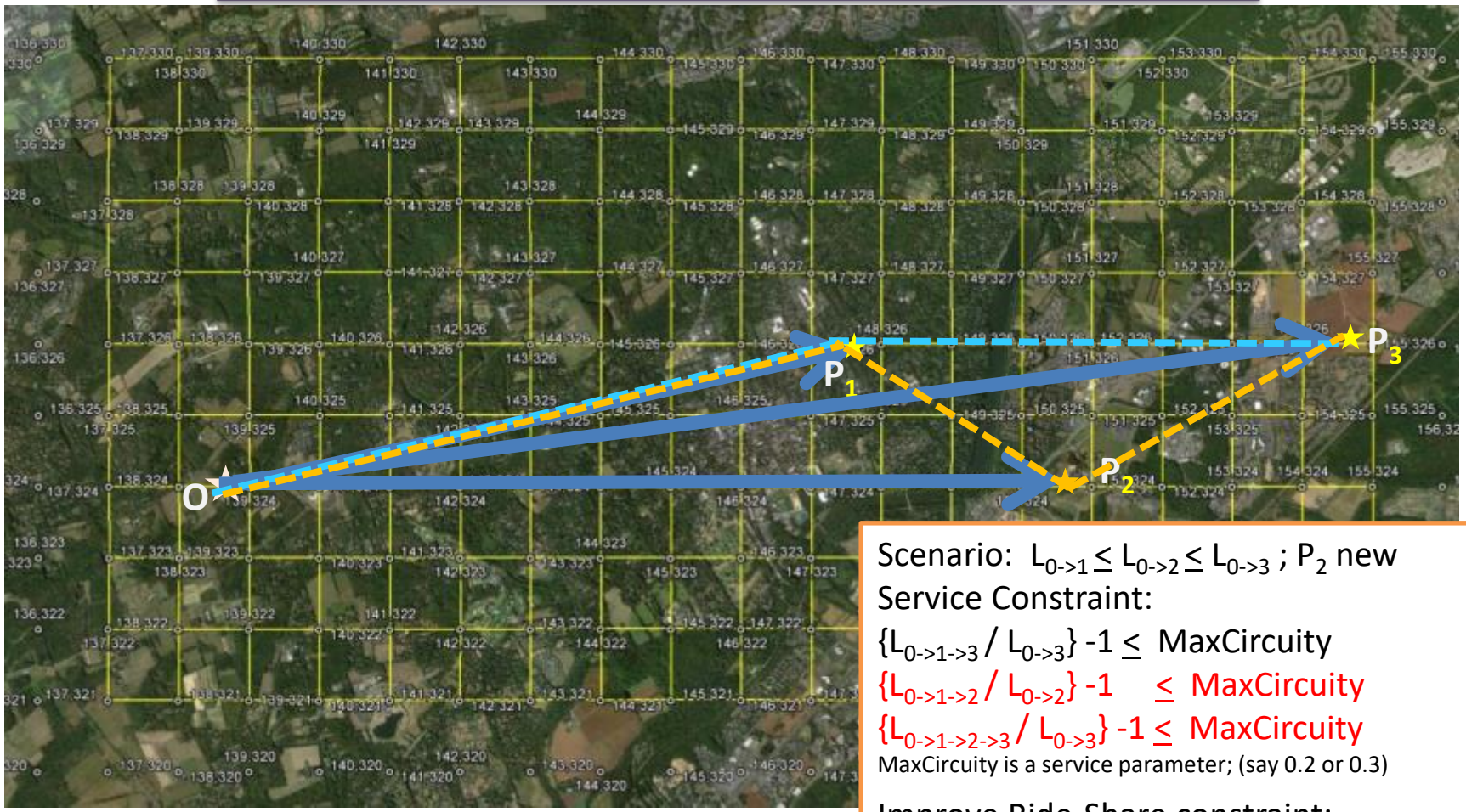
$\{N_{0->1} * L_{0->1} + N_{0->2} * L_{0->2} + N_{0->3} * L_{0->3}\} / \{L_{0->1->2->3}\}$

$> \{N_{0->1} * L_{0->1} + N_{0->2} * L_{0->2} + N_{0->3} * L_{0->3}\} / \{L_{0->1->2} + L_{0->3}\}$

Numerators are identical; Therefore:

$\{L_{0->1->2} + L_{0->3}\} > L_{0->1->2->3}$

CD= 3p: Pixel ->3Pixels Ride-sharing; P_2 New



Scenario: $L_{0->1} \leq L_{0->2} \leq L_{0->3}$; P_2 new

Service Constraint:

$\{L_{0->1->3} / L_{0->3}\} - 1 \leq$ MaxCircuity

$\{L_{0->1->2} / L_{0->2}\} - 1 \leq$ MaxCircuity

$\{L_{0->1->2->3} / L_{0->3}\} - 1 \leq$ MaxCircuity

MaxCircuity is a service parameter; (say 0.2 or 0.3)

Improve Ride-Share constraint:

$(AVO_{Rideshare\ 1,3} > AVO_{Alone})$

$\{L_{0->1} + L_{0->3}\} > L_{0->1->3}$

$(AVO_{Rideshare\ 1,2,3} > AVO_{Rideshare\ 1,3} + AVO_{2\ Alone})$;

$\{N_{0->1} * L_{0->1} + N_{0->2} * L_{0->2} + N_{0->3} * L_{0->3}\} / \{L_{0->1->2->3}\}$

$> \{N_{0->1} * L_{0->1} + N_{0->2} * L_{0->2} + N_{0->3} * L_{0->3}\} / \{L_{0->1->3} + L_{0->2}\}$

Numerators are identical; Therefore:

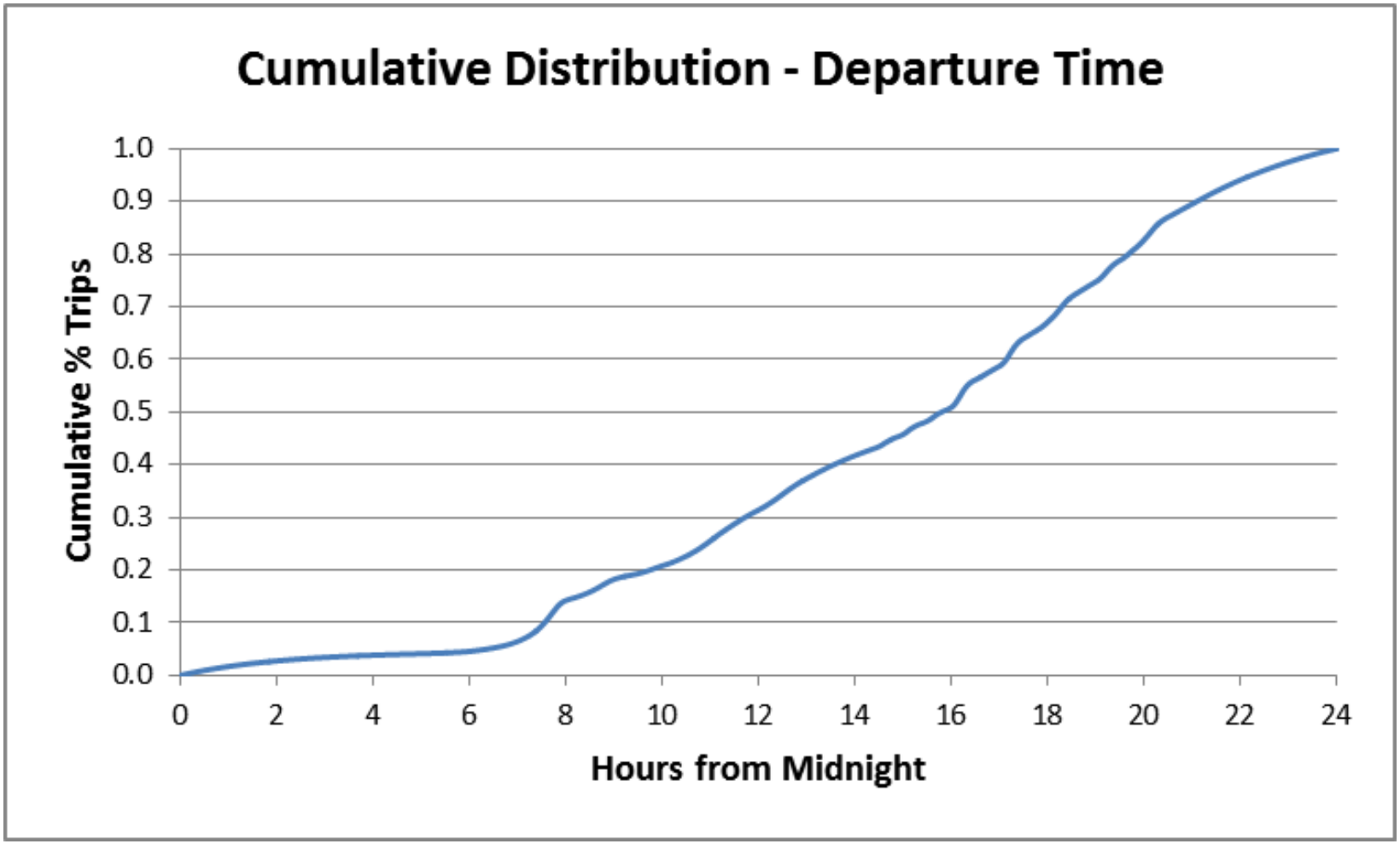
$\{L_{0->1->3} + L_{0->2}\} > L_{0->1->2->3}$

NJ Transit Train Station "Consumer-shed"

An aTaxiTrip

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

NJ_PersonTrip file



Traffic Flow Display System: Typical Weekday autonomousTaxi Trips throughout NJ

Trips generated by Princeton University Trip Synthesizer

County Pixel Direction: Only Origin Origin County: Type: Taxi AVO:1 Timeframe: 00:00 am - 12:00 pm Load

Princeton University 2014

http://depler.no/route/#/

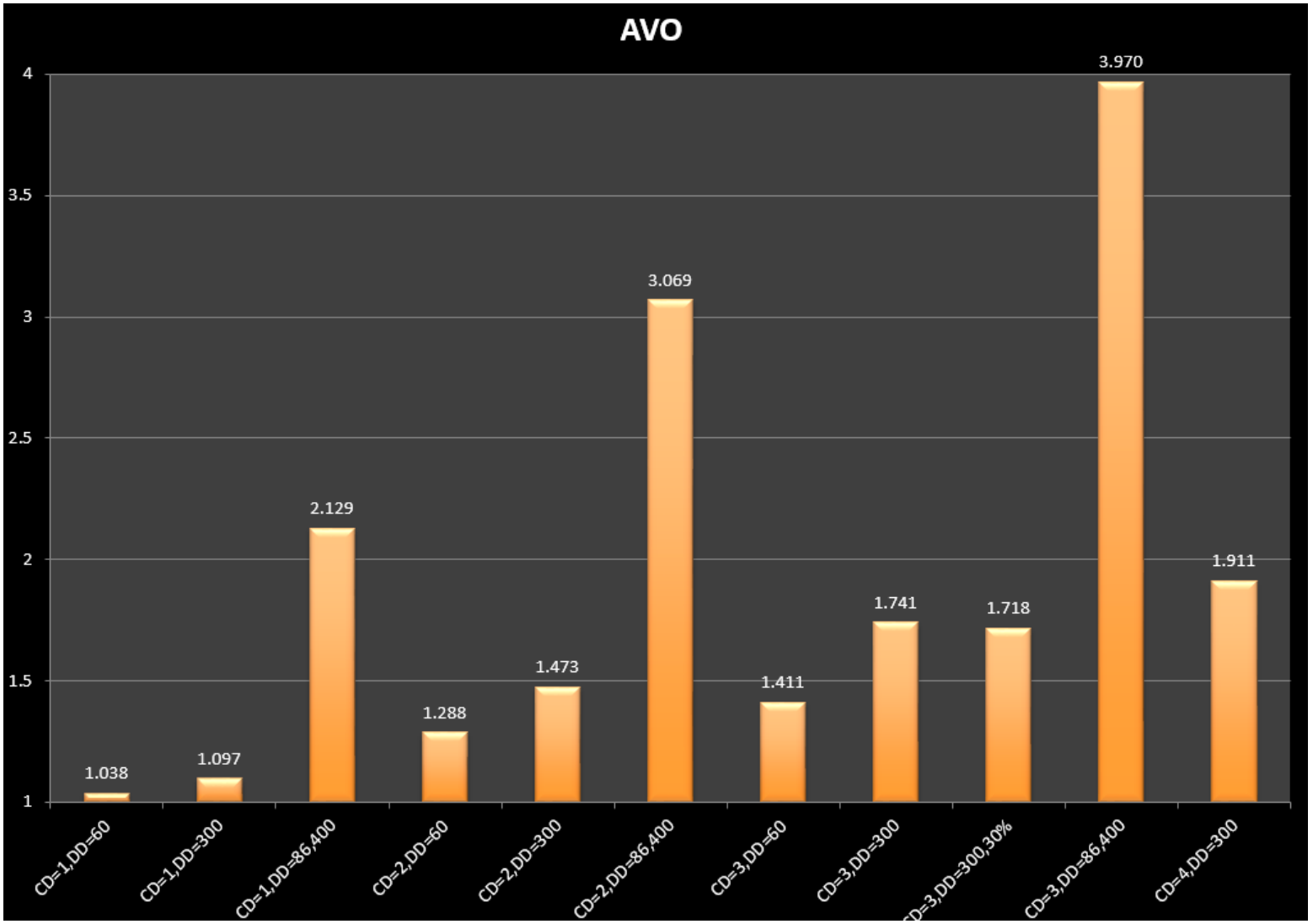
Elevator Analogy of an aTaxi Stand Temporal Aggregation

Departure Delay: DD = 300 Seconds

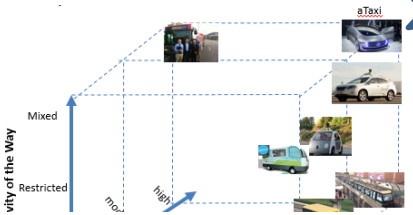
Elevator Analogy of an aTaxi Stand 60 seconds later

Typical Daily NJ-wide AVO

CD: Common Destinations; DD: Departure Delay (in Seconds)



Princeton University

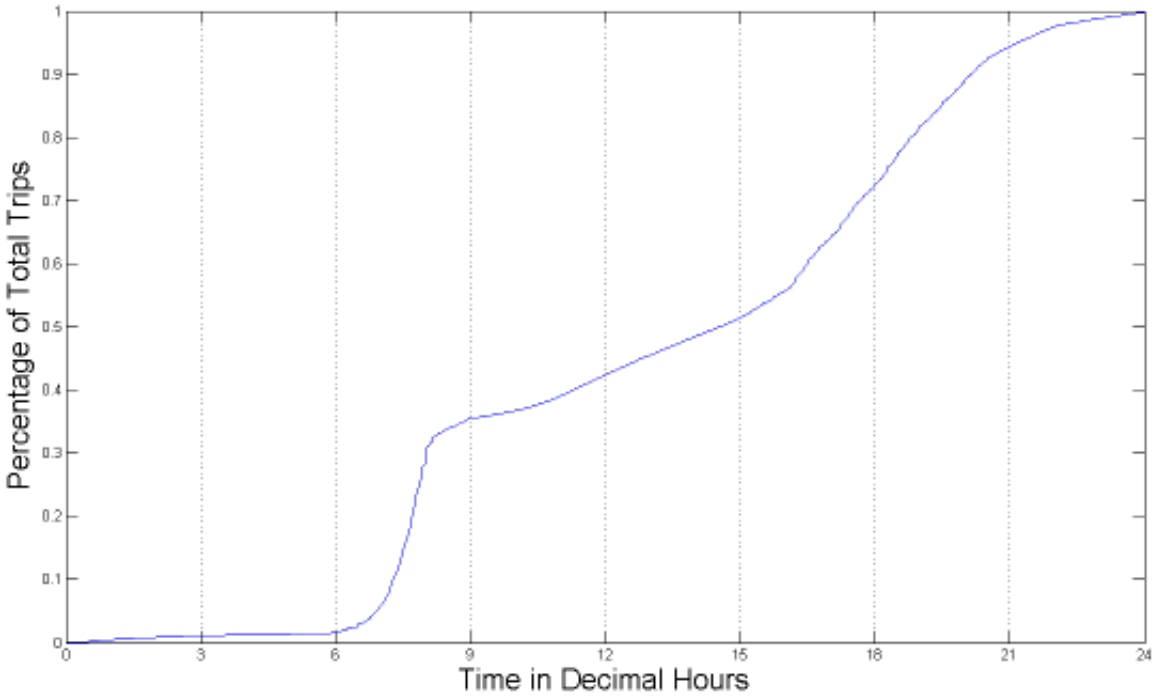


"Last Mile" Impact on NJ Transit Rail

Train Statistics	
Total Train Trips	1,513,339
Train Passenger Miles	24.37 million mi.
Average Train Trip Length	16.12 mi.

Table 1: Train Network

(Today: 281,576, +537% !)



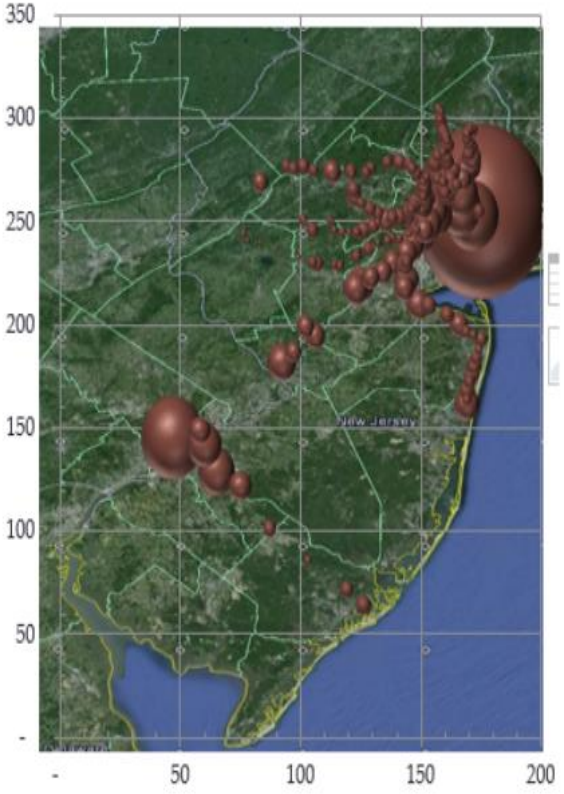
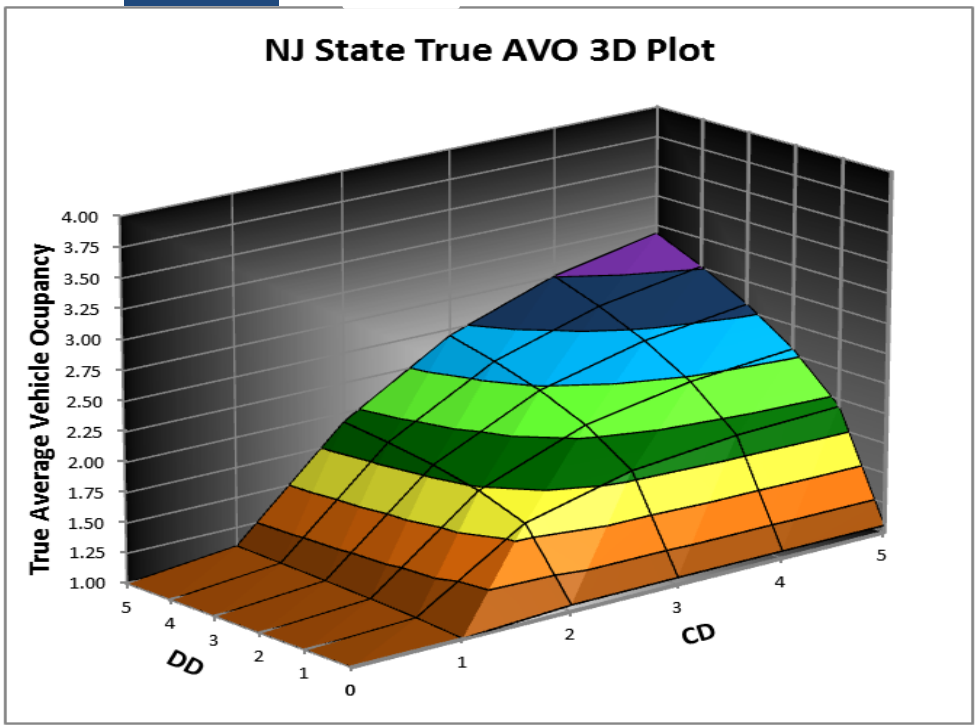


Figure 7: Geographic Spread of Passenger Volume of Train Trips

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
DD = 1		1.04	1.59	1.81	1.90	1.94
DD = 2		1.06	1.73	2.07	2.23	2.30
DD = 3		1.07	1.82	2.23	2.45	2.56
DD = 4		1.08	1.88	2.35	2.62	2.76
DD = 5		1.10	1.92	2.45	2.76	2.93



Traffic Flow Display System: Typical Weekday autonomousTaxi Trips throughout NJ

Trips generated by Princeton University Trip Synthesizer

County Pixel Direction: Only Origin Origin County: Type: Taxi AVO:1 Timeframe: 00:00 am - 12:00 pm Load

Princeton University 2014

http://depler.no/route/#/

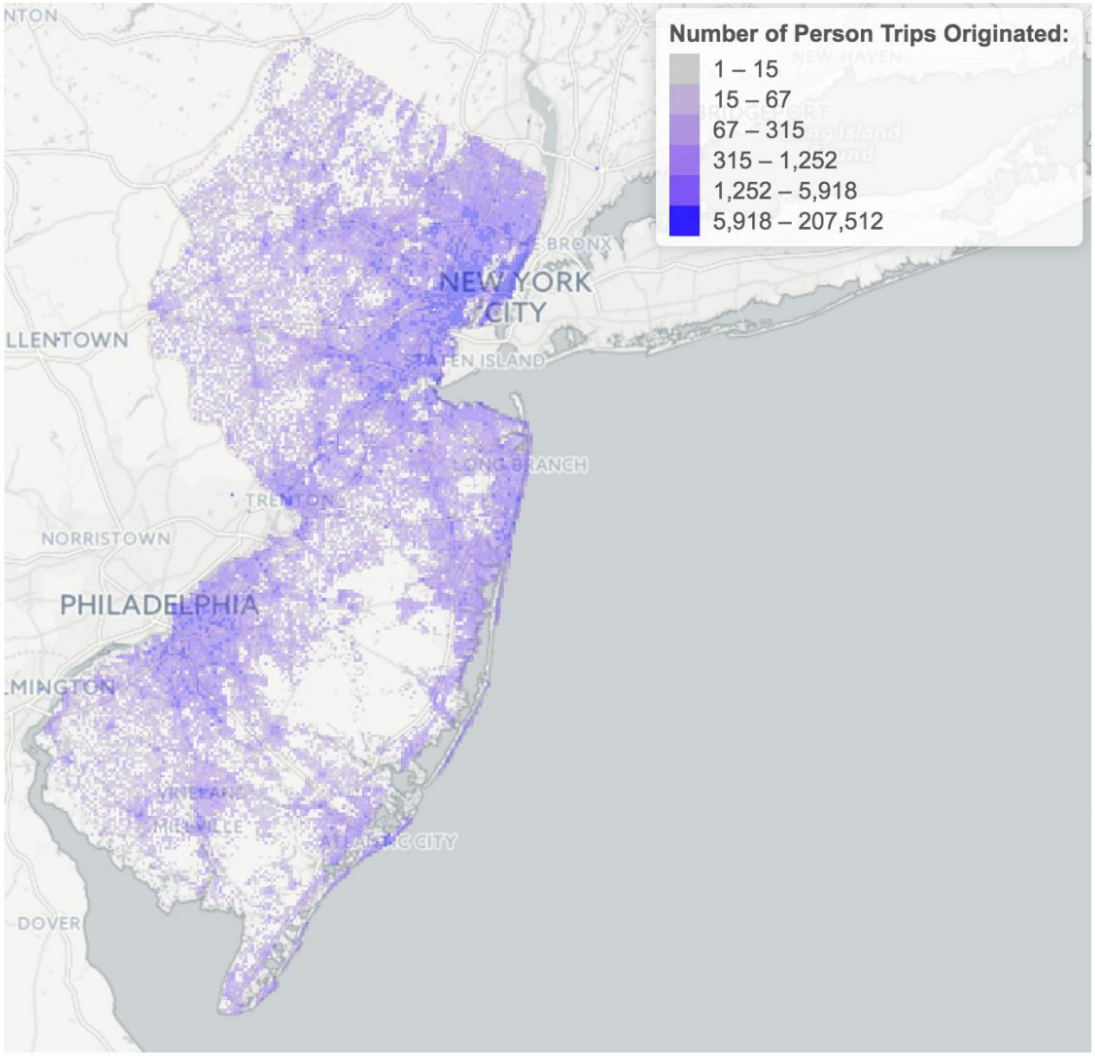


Figure 3.3: Spatial distribution of person trips originated in each pixel. The breaks represent the 10th, 25th, 50th, 75th, and 95th percentiles of the data. 95% of the pixels have fewer than 5,918 Person Trips originated.

New York City Taxicab Transportation Demand Modeling for the Analysis of Ridesharing and Autonomous Taxi Systems

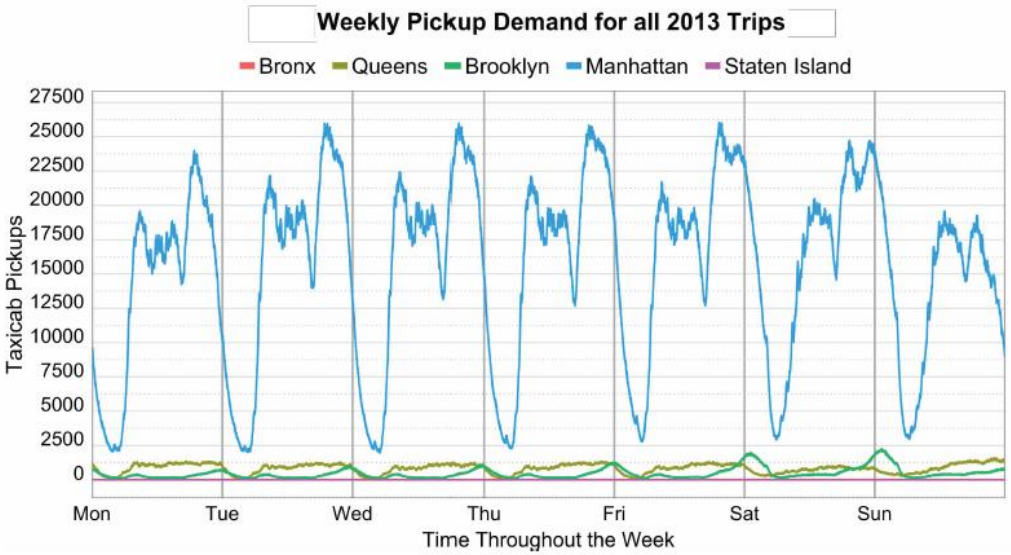
Andrew James Touloukian Swoboda

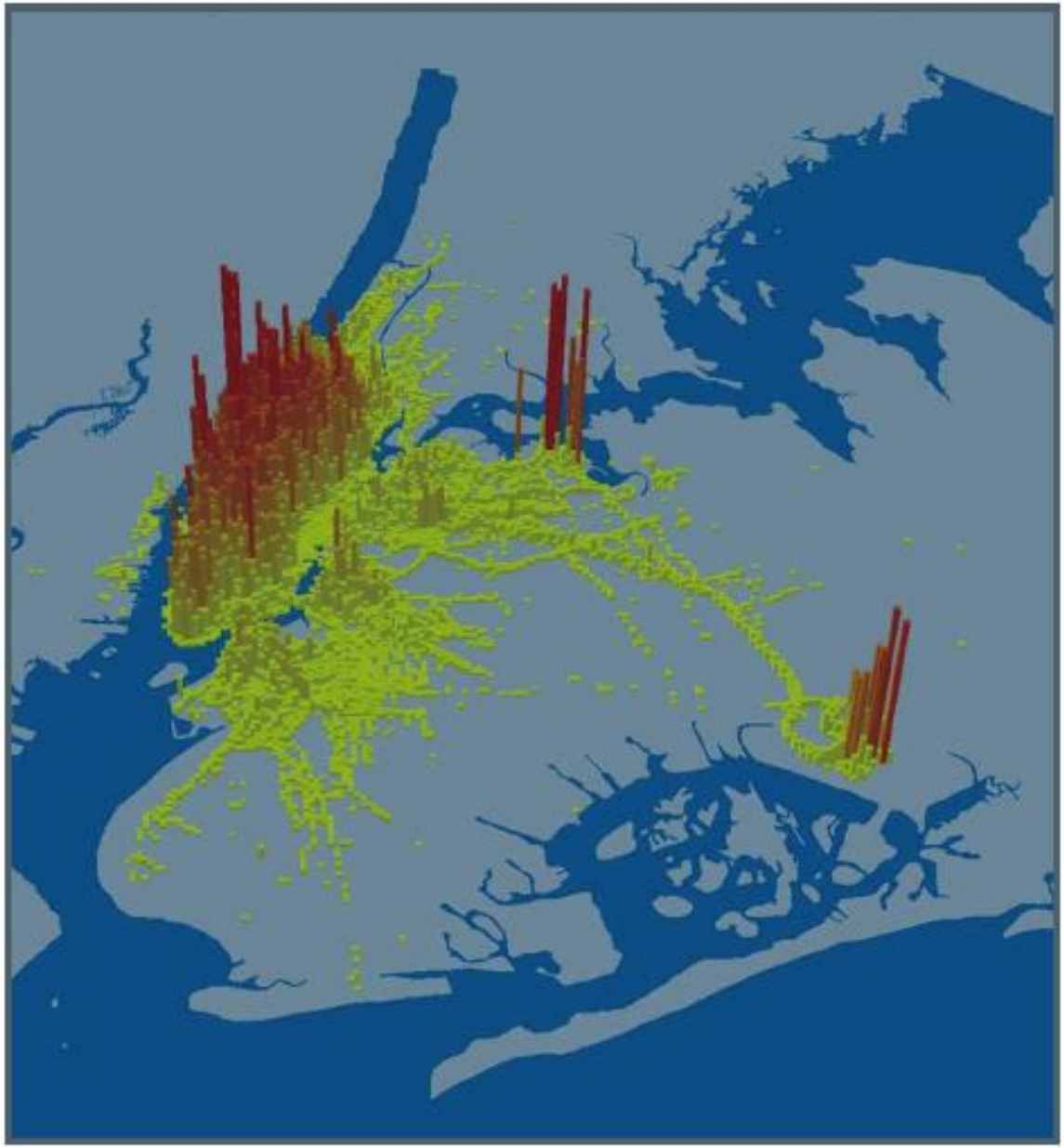
Advisor: Professor Alain L. Kornhauser '71

2013 NY TLC Stats

- 168,779,842 TLC Trips during 2013 calendar year
  - 66% 35 or under; 35% 21<->35
- 42,821 drivers and 13,741 unique taxicabs.
- 1,155,367 unique taxicab pickups @ Penn Station

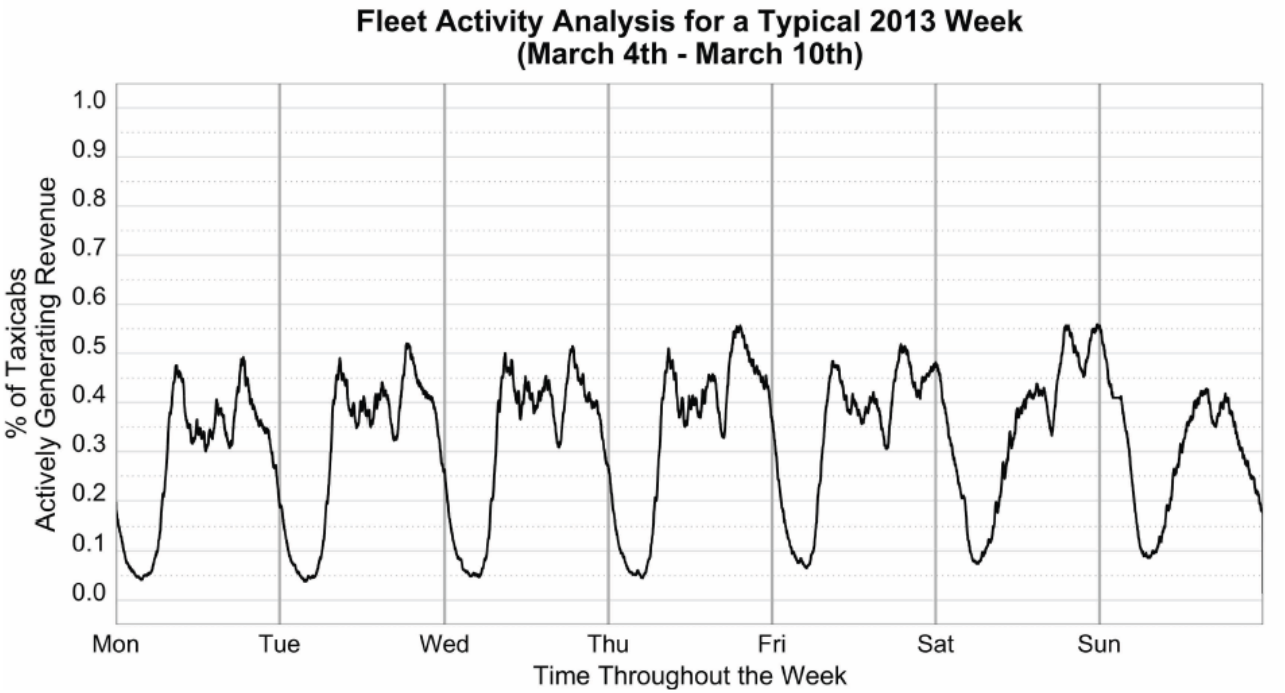
Figure 3.1.1: Per-Minute Trip Demand during 2013 by Weekday





(b) 2013 NYC TLC Pickup Demand

Figure 3.5.2: Per-Minute View: Proportion of Fleet Generating Revenue



Concentration of departure “areas

Figure 5.3.1: Cumulative Distribution Function of Taxicab Pickups

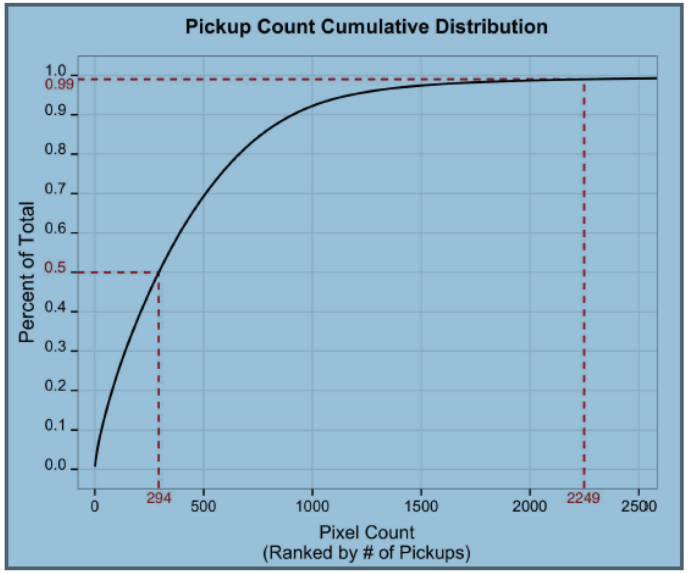
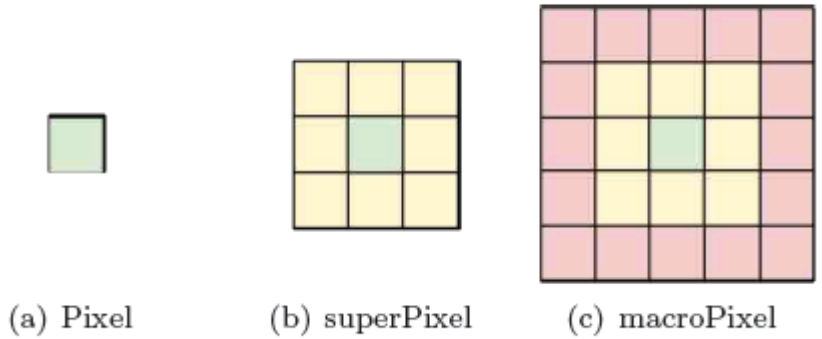


Table 5.2: Pixels with the Most Drop-offs

Pixel ID	Drop-off Count	Latitude	Longitude	Contextual Information
51414	1,123,473	40.7509003	-73.9904022	Penn Station (7th Ave & 34th St)
51120	980,991	40.7494011	-73.9923019	Penn Station (7th Ave entrance)
51713	584,258	40.7523003	-73.9789963	Grand Central Station
49355	543,071	40.7406998	-74.0056992	Grand Central Station
52586	536,007	40.7566986	-73.9904022	NY Port Authority Bus Terminal

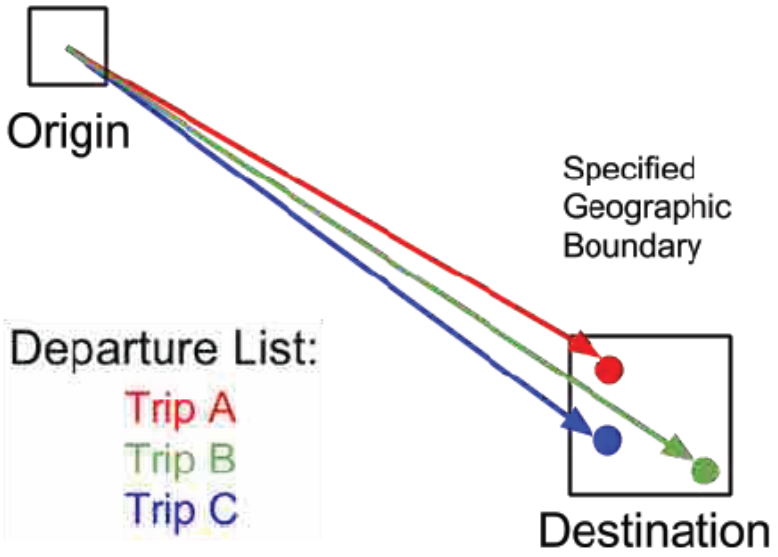
Figure 5.2.2: Visualization of Pixel Sizes

Pixel = 0.01 Sq. Mile



(a) Pixel (b) superPixel (c) macroPixel

Figure 6.2.1: Logic of $(CD = 1)$ Ridesharing Policy

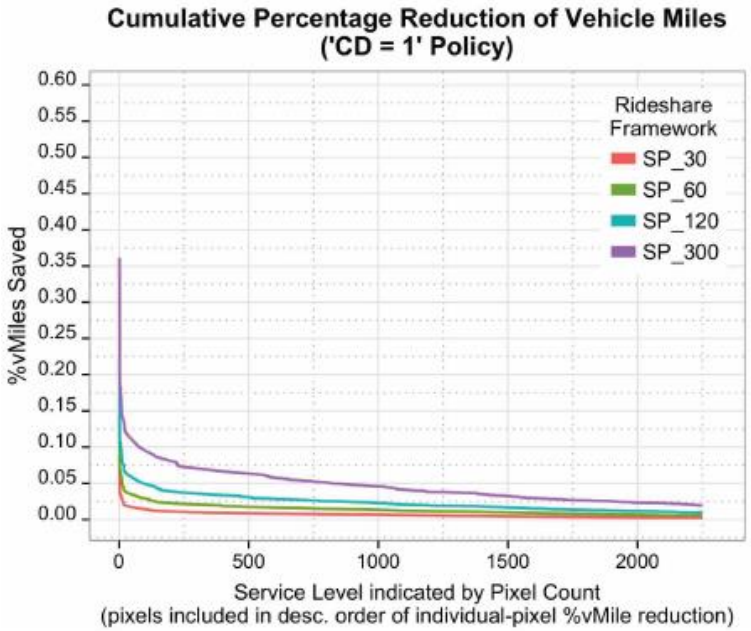


Common Destination

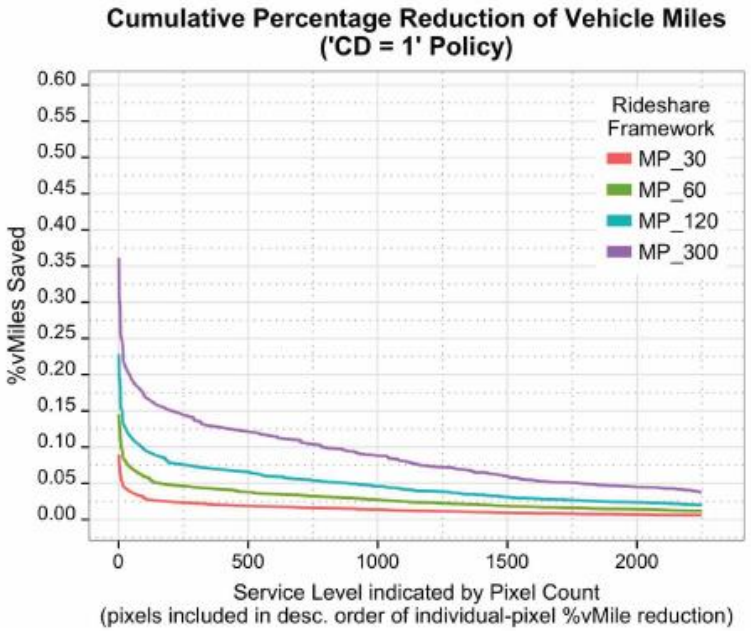
Table 6.1: ($CD = 1$) Ridesharing Policy at Two Service Levels — Transit Hubs vs. All of NYC

	Major Transportation Hubs			All NYC Pixels		
Rideshare Framework	ADO	% vMiles	% TaxiRed	ADO	% vMiles	% TaxiRed
SP_30	1.77	0.62	3.09	1.73	0.27	1.32
SP_60	1.80	1.25	5.85	1.74	0.56	2.72
SP_120	1.85	2.09	9.37	1.75	0.97	4.68
SP_300	1.96	3.95	16.6	1.79	1.93	9.31
MP_30	1.81	1.41	6.69	1.74	0.60	3.02
MP_60	1.88	2.68	11.8	1.76	1.20	5.97
MP_120	1.98	4.25	17.8	1.79	2.00	9.87
MP_300	2.22	7.34	28.5	1.88	3.75	18.1

Figure 6.2.2: Taxicab Vehicle Mile Reduction



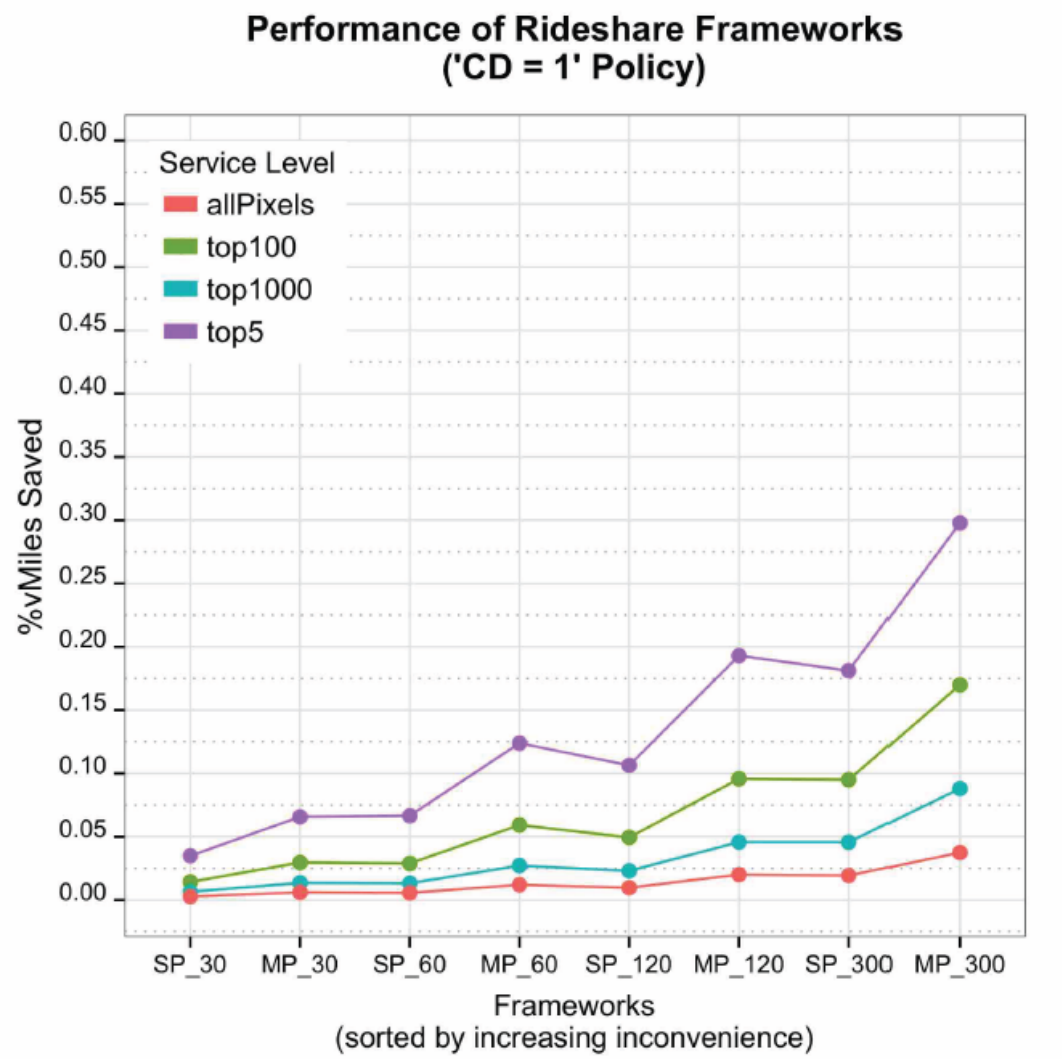
(a) SuperPixel Boundary



(b) MacroPixel Boundary

Figure 6.2.1: Logic of $(CD = 1)$ Ridesharing Policy

Figure 6.2.3: Effectiveness of $(CD = 1)$ Policy Under Different Frameworks



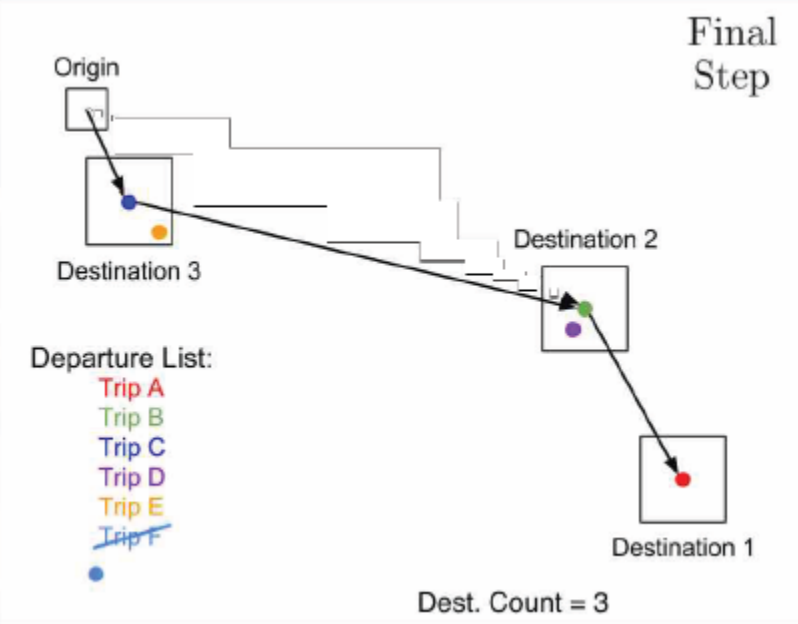
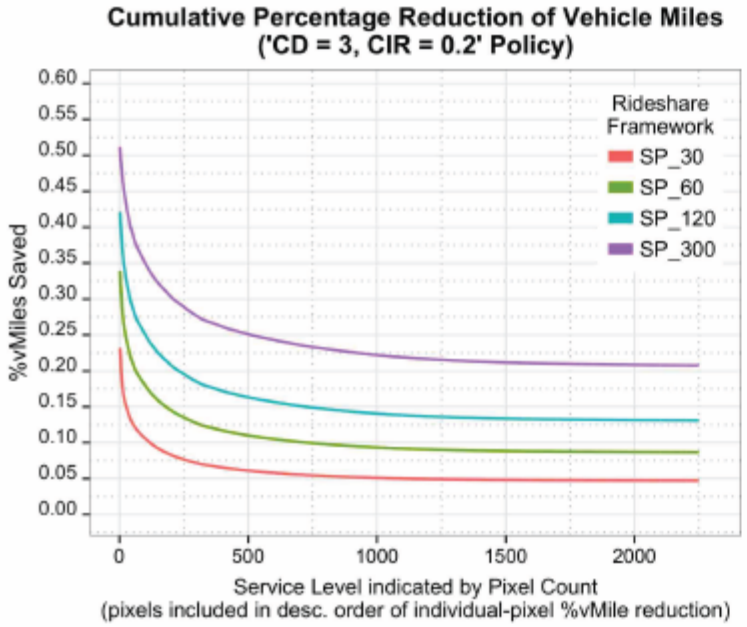


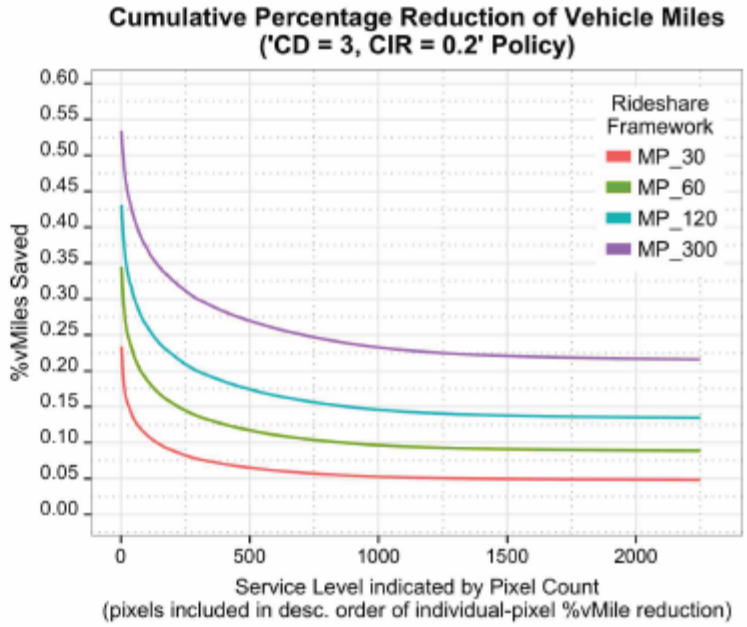
Table 6.2: $(CD = 3, CIR = 0.2)$ Ridesharing Policy at Two Service Levels

	Major Transportation Hubs			All NYC Pixels		
Rideshare Framework	ADO	% vMiles	% TaxiRed	ADO	% vMiles	% TaxiRed
SP_30	1.98	12.74	15.70	1.77	4.74	6.72
SP_60	2.23	21.11	26.27	1.82	8.67	12.83
SP_120	2.53	28.71	36.15	1.90	13.09	19.94
SP_300	3.16	38.78	49.61	2.10	20.76	32.47
MP_30	1.99	12.92	16.21	1.77	4.86	6.95
MP_60	2.24	21.44	27.02	1.83	8.90	13.22
MP_120	2.56	29.33	37.24	1.91	13.48	20.54
MP_300	3.24	40.12	51.39	2.11	21.60	33.53

Figure 6.3.2: Taxicab Vehicle Mile Reduction



(a) SuperPixel Boundary



(b) MacroPixel Boundary

Figure 6.3.3: Effectiveness of $(CD = 3, CIR = 0.2)$ Policy Under Different Frameworks

Performance of Rideshare Frameworks
('CD = 3, CIR = 0.2' Policy)

Take-away…

- Except for from a few locations, the spatial and temporal distribution of 2013 taxi trips is **VERY DIFFUSE**!
- In order to achieve a 25% reduction in occupied taxi miles, service would have to substantially degrade making users wait up to 5 minutes before departure and traveling as much as 20% father/longer to drop off ride sharers in as many as 2 intermediate locations.
- Opening up ride-sharing to all other trips would certainly increase ridesharing without increasing VMT; HOWEVER, these trips would be take away from walking or reduce existing ride-sharing on conventional buses an subways.

Outline

- Background on Smart Driving Cars (Where we are today)
- What is Today's Demand for Mobility (Synthesizing Individual Person trips for new Jersey and the Nation)
- How Might Those Trips be Served by aTaxis
- **How Large of a Fleet Will One Need to Serve These Trips**
  (How would one approach the empty aTaxi management problem)

Empty aTaxi Repositioning Problem

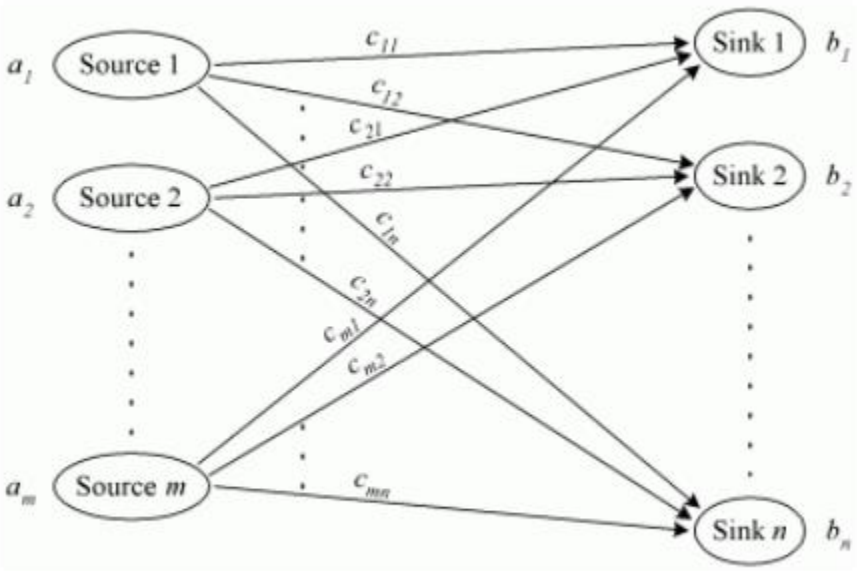


Figure 1.1: Example bipartite graph for the classic transshipment problem.

If demand is CONSTANT in time

Persons moving from a2b by time of day

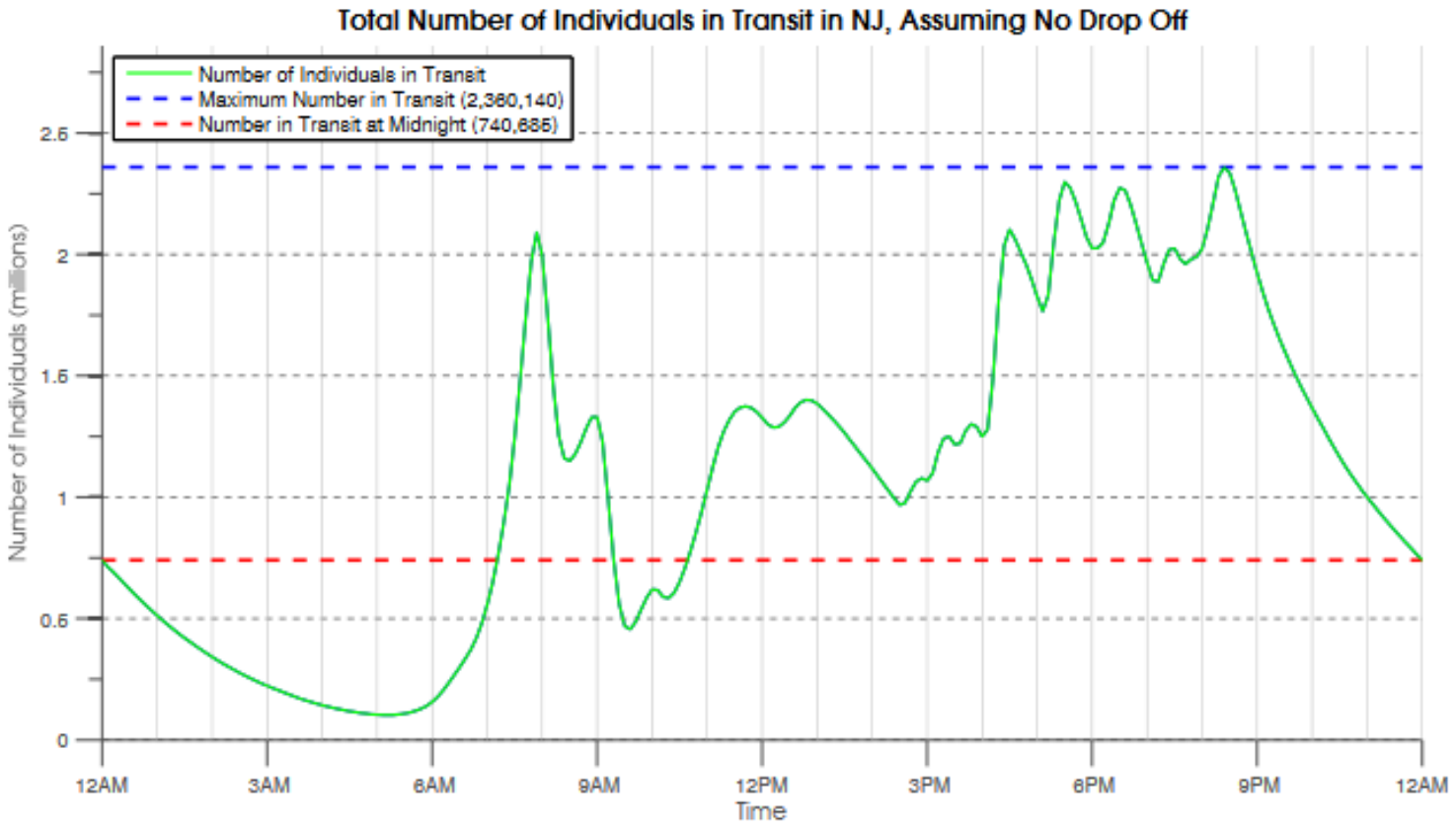


Figure 4.1: Number of individuals in transit in NJ if one were to assume no drop offs.

aTaxis$_{(DD=300,\ CD=3)}$ moving from a2b by time of day

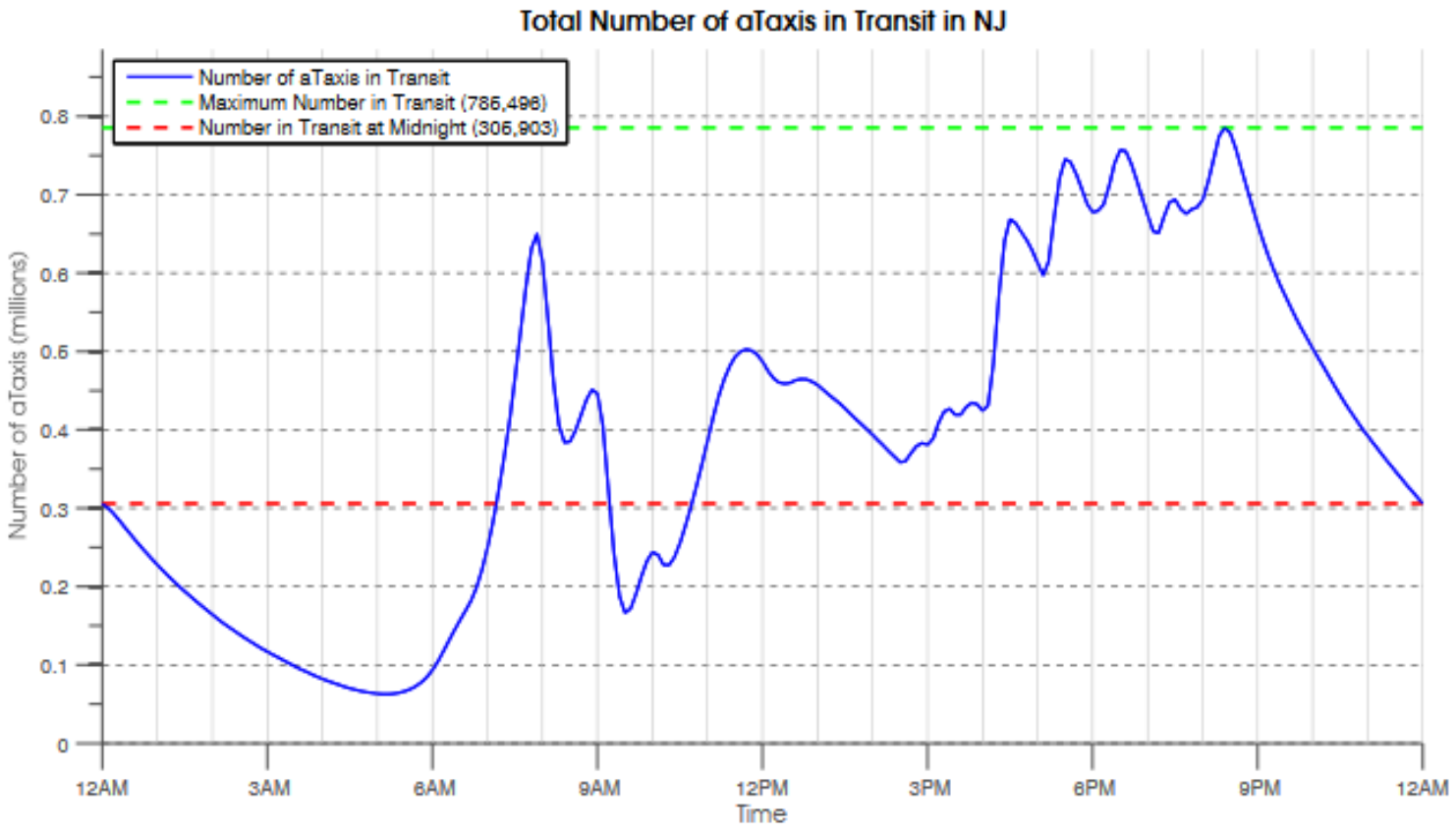


Figure 4.3: Number of aTaxis in Transit in NJ.

Instantaneous AVO by time of day

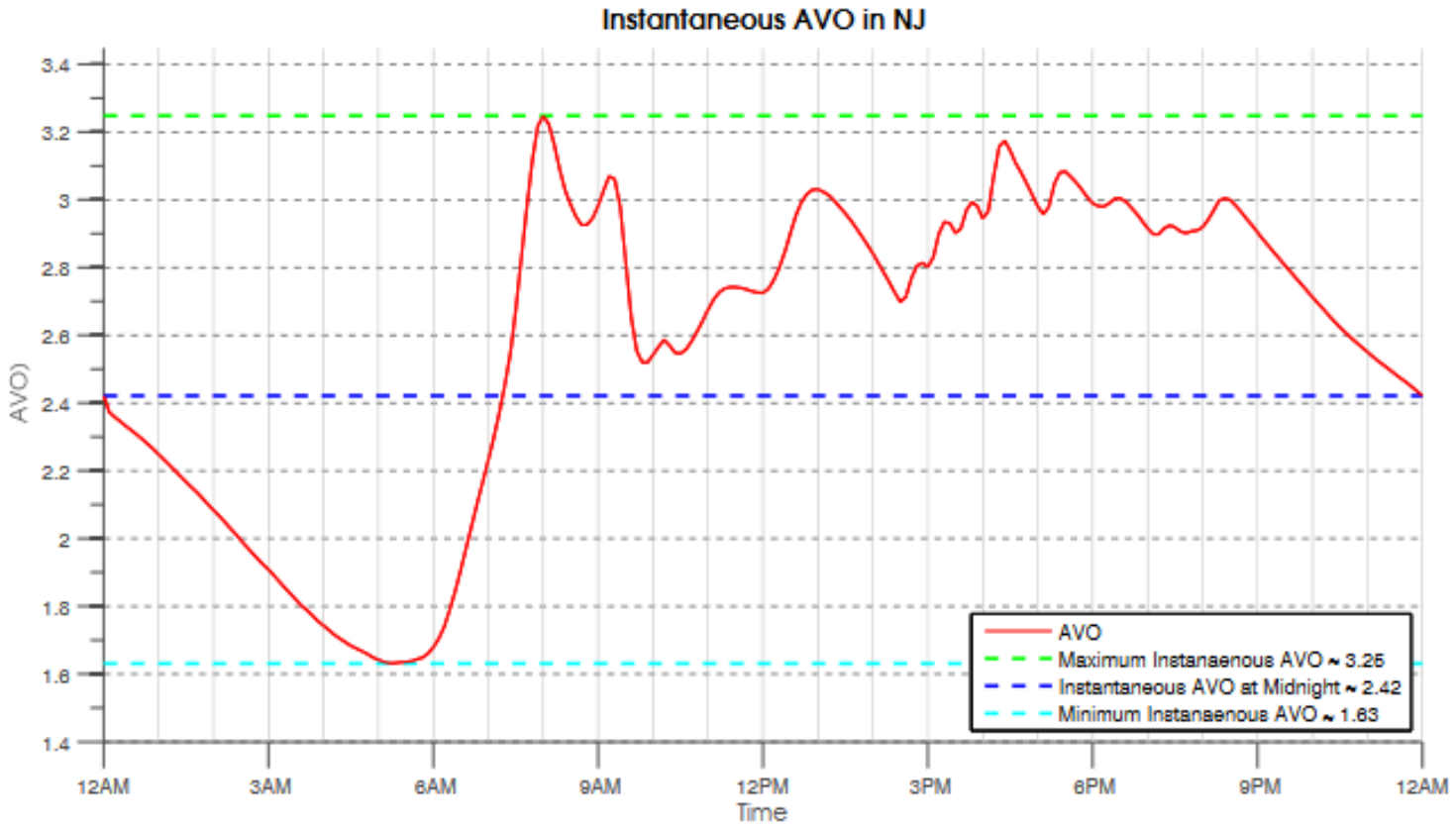
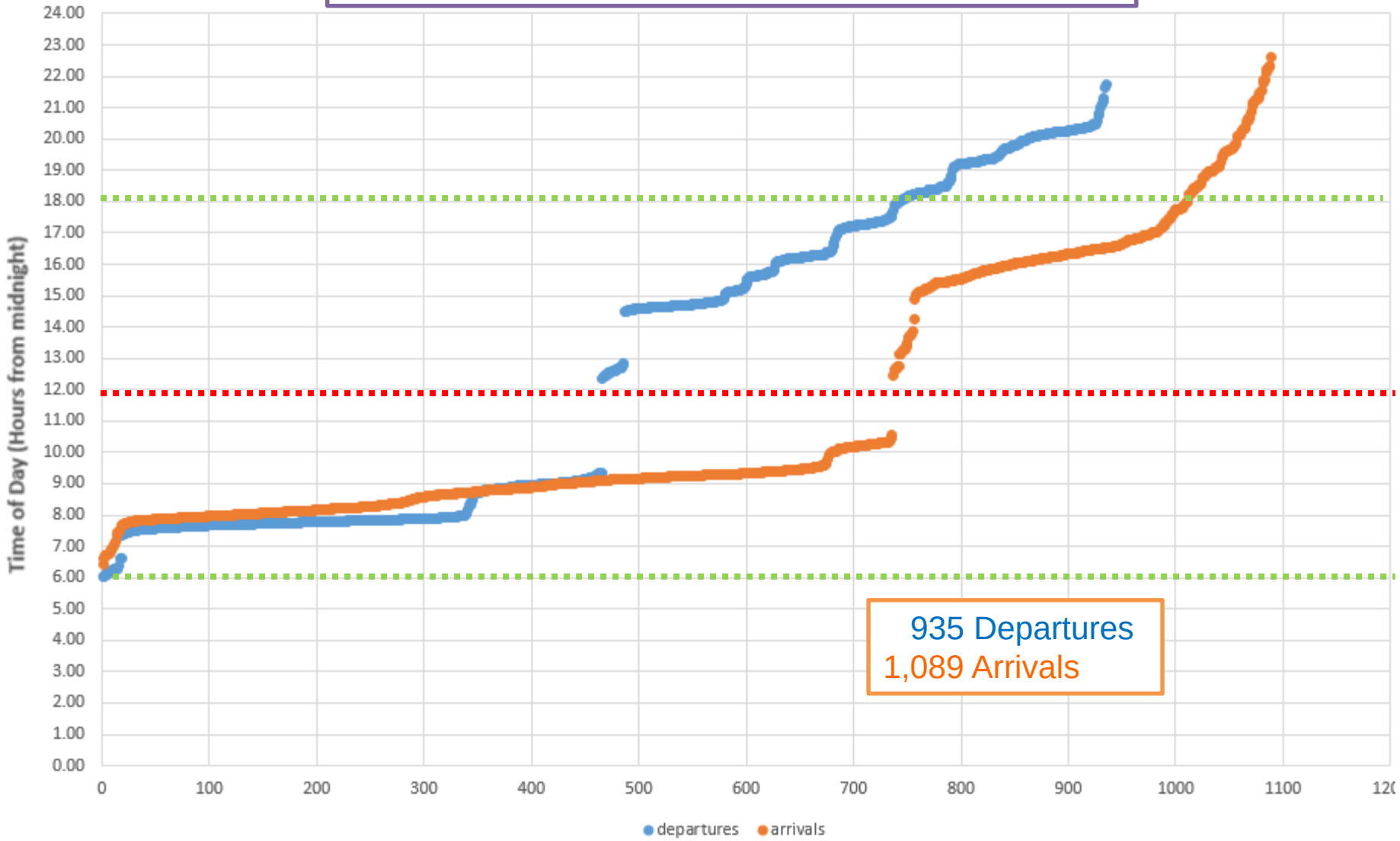
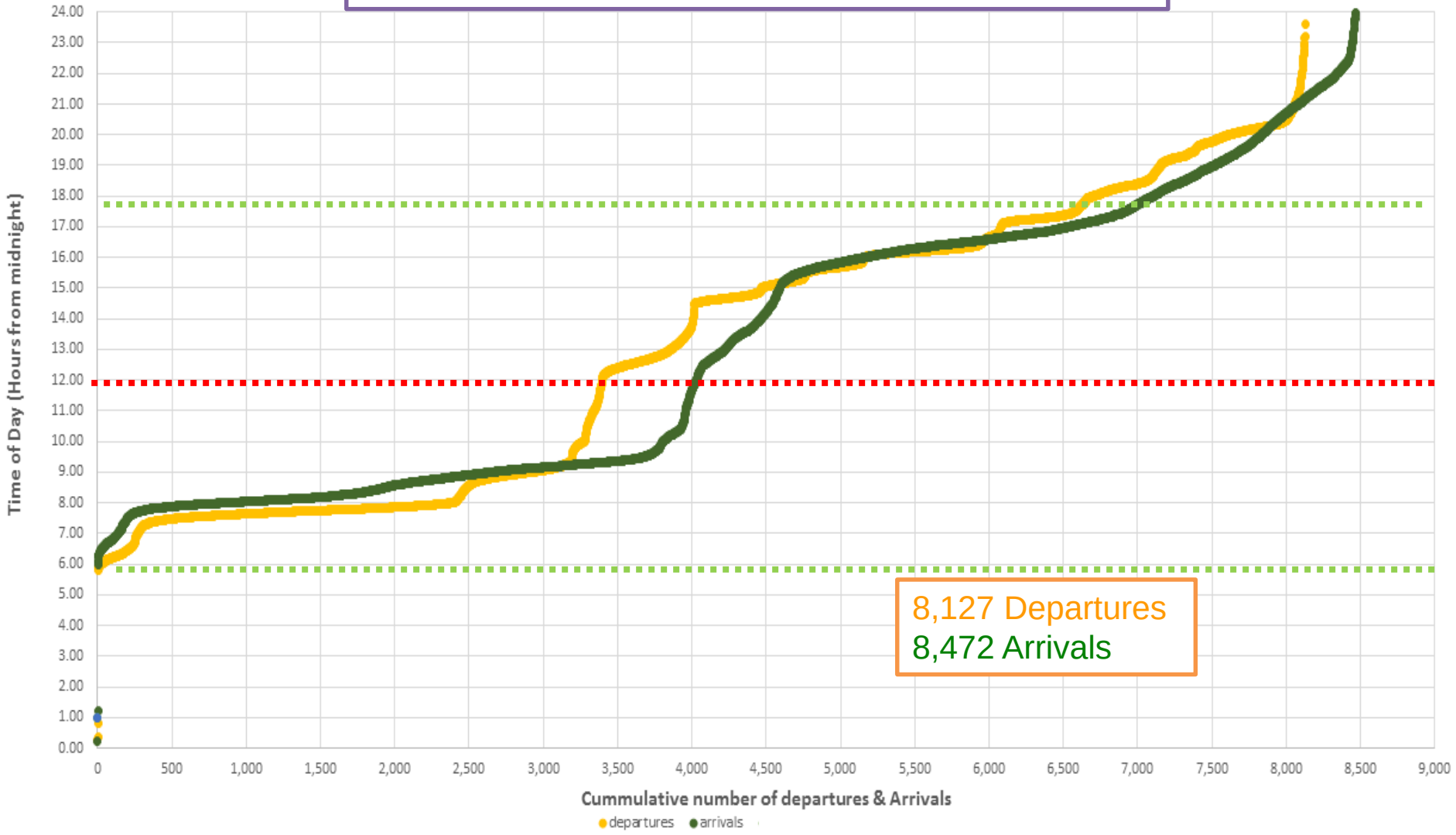


Figure 4.4: Instantaneous AVO if one were to assume no drop offs.

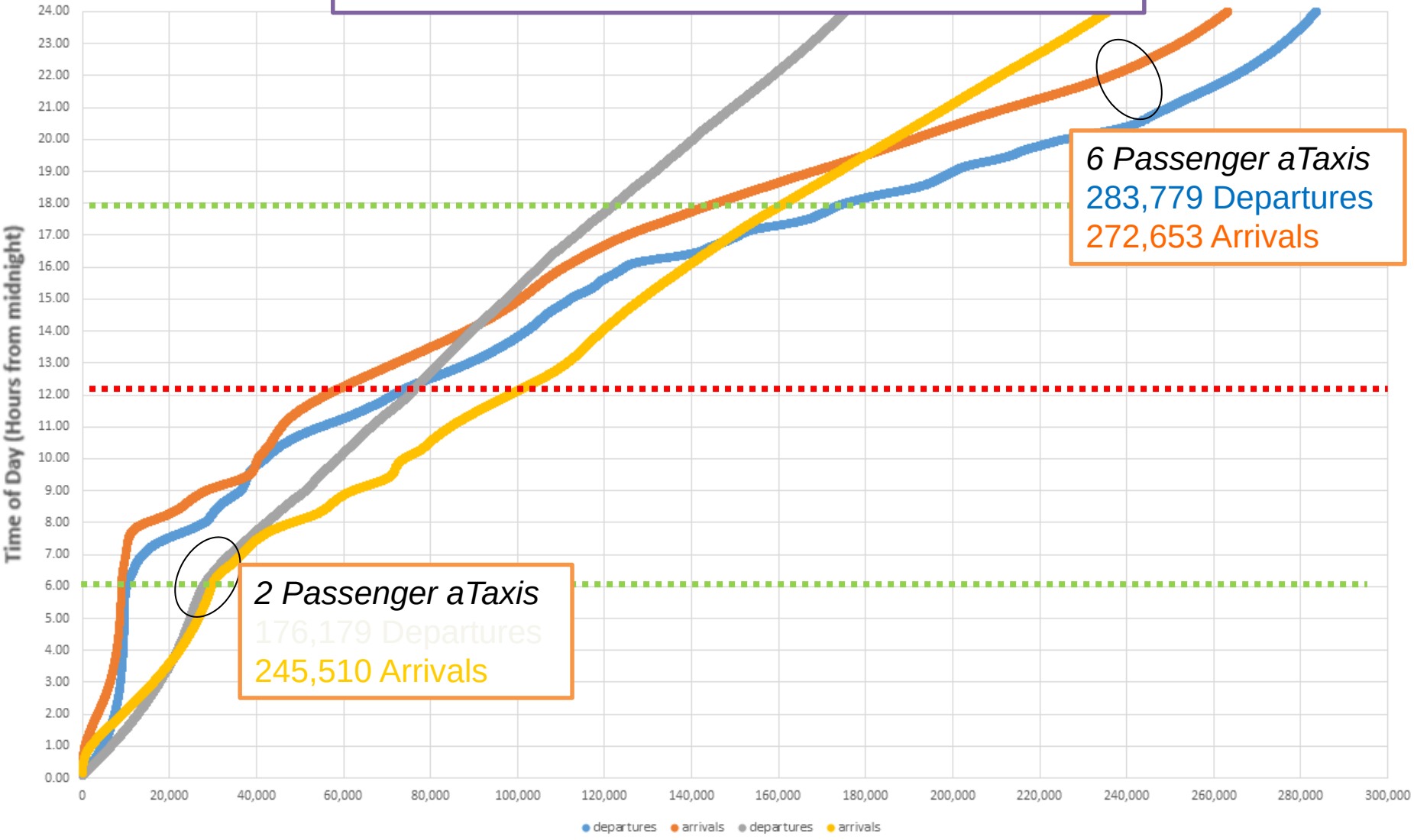
Mercer County Cumulative Departures & Arrivals
50 passenger aTaxis
CD=3p; DD=300Sec.; MaxCircuity= 20%



Mercer County Cumulative Departures & Arrivals
15 passenger aTaxis
CD=3p; DD=300Sec.; MaxCircuity= 20%



Mercer County Cumulative Departures & Arrivals
2 passenger & 6 passenger aTaxis
CD=3p; DD=300Sec.; MaxCircuity= 20%



Mercer County Pixel {200,103} Princeton

Item	Value
Activity Locations	57
Employment	1,336
Population	1,062
School Enrollment	0

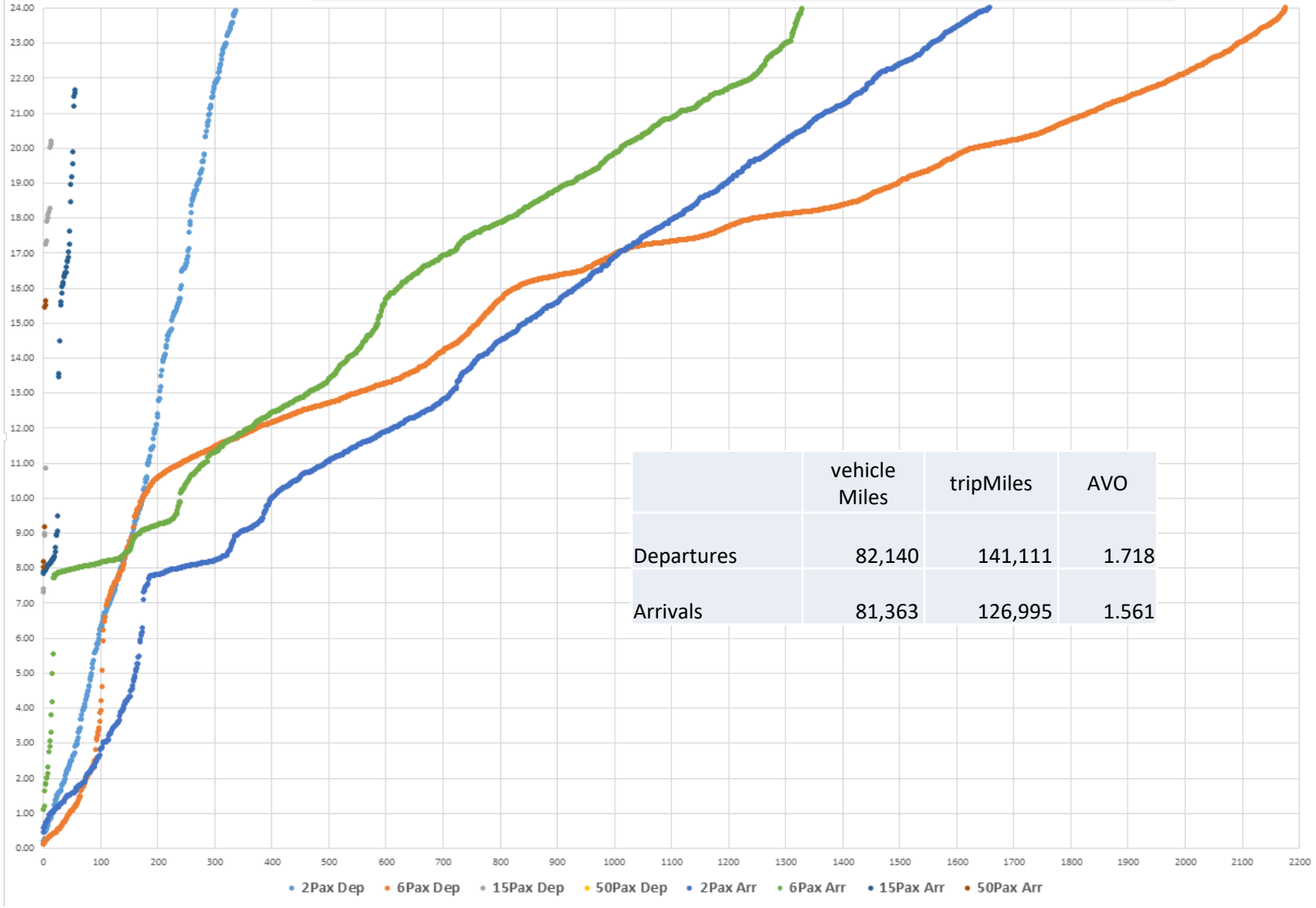
Work

Home (Block Centroid)

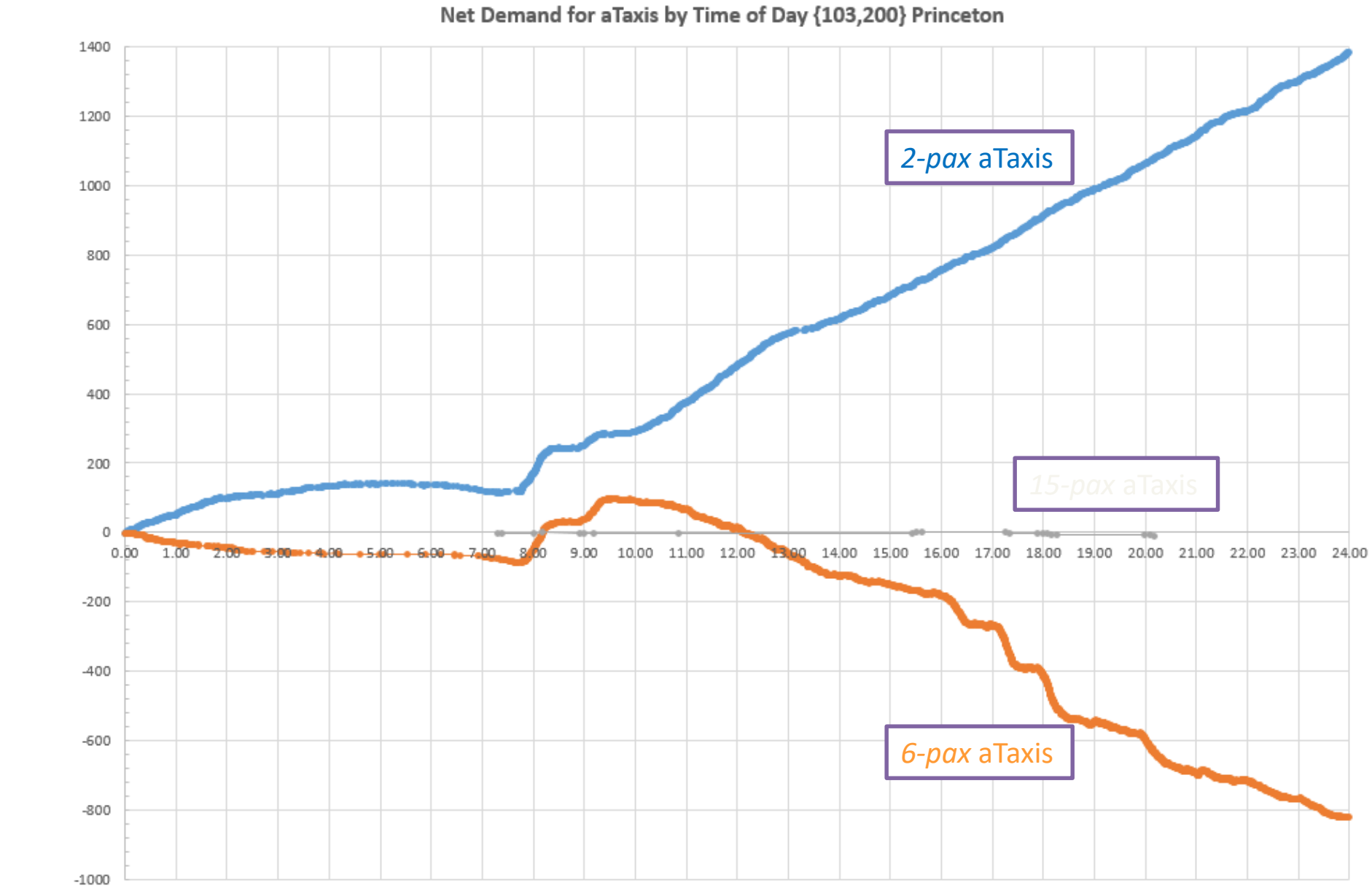
School

Pixel Centroid

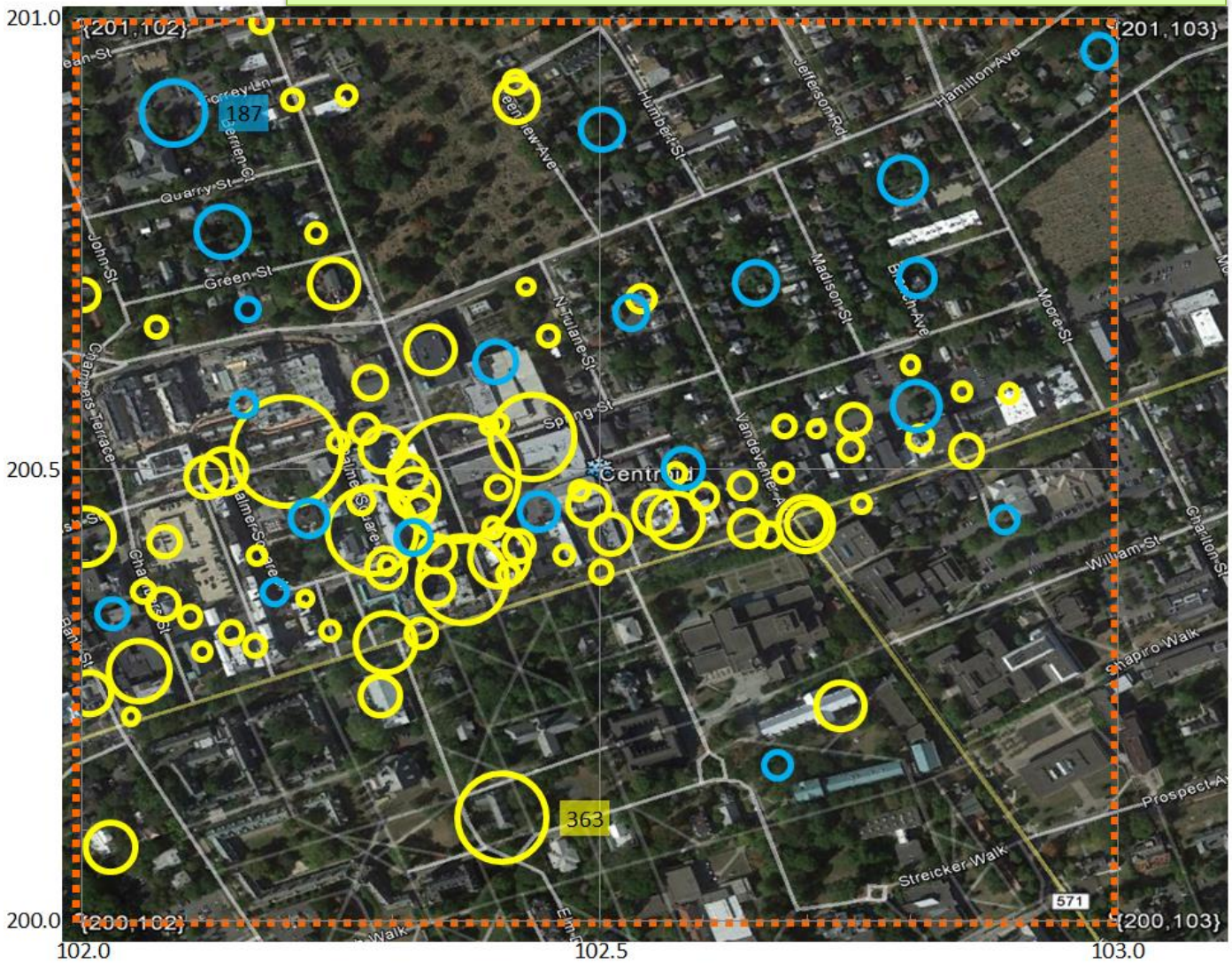
Mercer County Pixel {y=200,x=103} Princeton



	vehicle Miles	tripMiles	AVO
Departures	82,140	141,111	1.718
Arrivals	81,363	126,995	1.561


Net Demand for aTaxis by Time of Day {103,200} Princeton
1400
1200
1000
800
600
400
200
0
-200
-400
-600
-800
-1000
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
11.00
12.00
13.00
14.00
15.00
16.00
17.00
18.00
19.00
20.00
21.00
22.00
23.00
24.00
2-pax aTaxis
15-pax aTaxis
6-pax aTaxis

Mercer County Pixel {200,102} Princeton



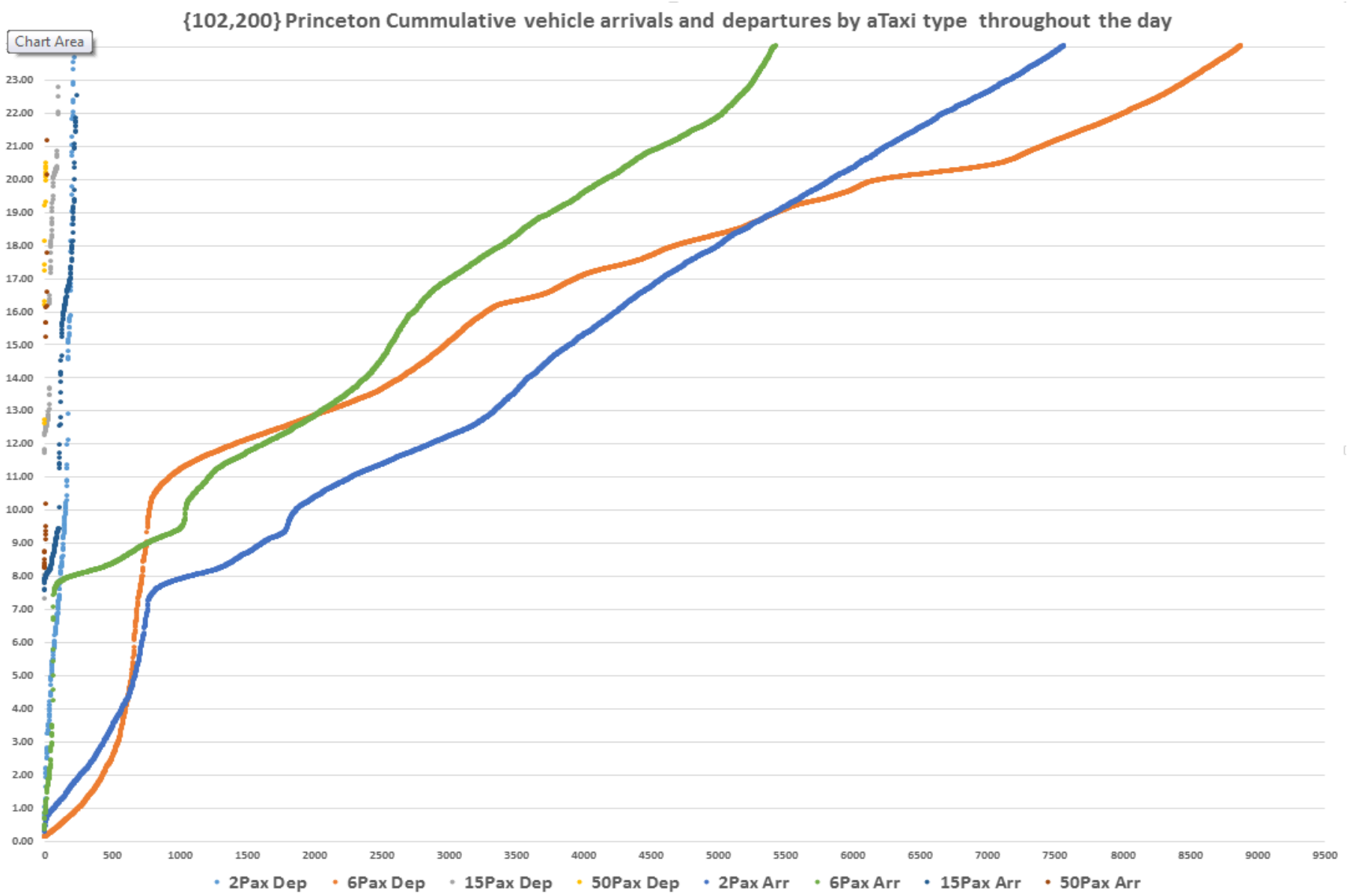
Item	Value
Activity Locations	165
Employment	6,617
Population	1,325
School Enrollment	0

Work

Home (Block Centroid)

School

Pixel Centroid


{102,200} Princeton Cummulative vehicle arrivals and departures by aTaxi type throughout the day
Chart Area
23.00
22.00
21.00
20.00
19.00
18.00
17.00
16.00
15.00
14.00
13.00
12.00
11.00
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000
6500
7000
7500
8000
8500
9000
9500
2Pax Dep
6Pax Dep
15Pax Dep
50Pax Dep
2Pax Arr
6Pax Arr
15Pax Arr
50Pax Arr

Discussion!

Thank You

alaink@princeton.edu

www.SmartDrivingCar.com