

# Characterization of the Geographic Patterns of Fuel Consumption and Emissions of Freight Vehicles in the Albany-New York City Corridor

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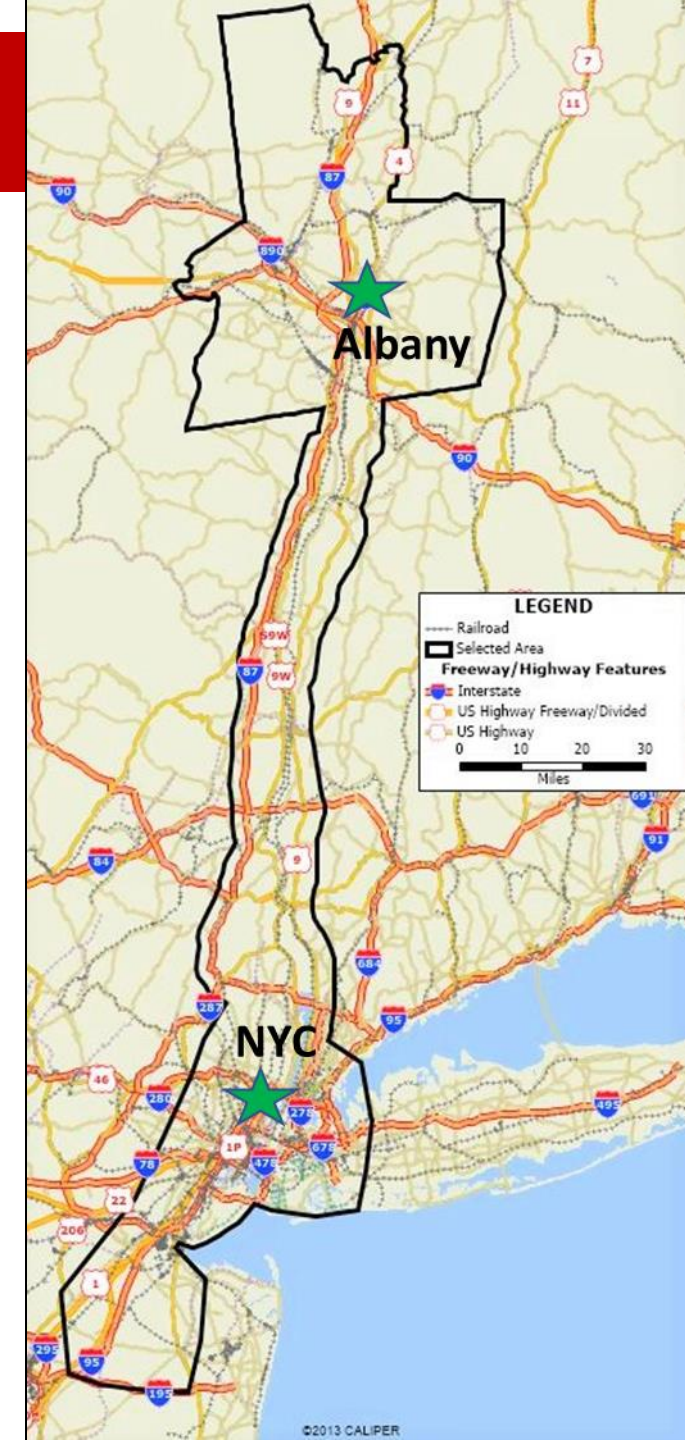
# Objectives

- Use archival GPS data to characterize current patterns of fuel consumption and emissions produced by freight vehicles in the Albany MSA, New York City MSA, and the corridor in-between
- Provide policymakers with a comprehensive geographical analysis of emissions and fuel consumption patterns that could help them identify initiatives to enhance freight transportation efficiency
- Identify opportunities to improve the energy efficiency of freight transportation and reduce the emission of greenhouse gases

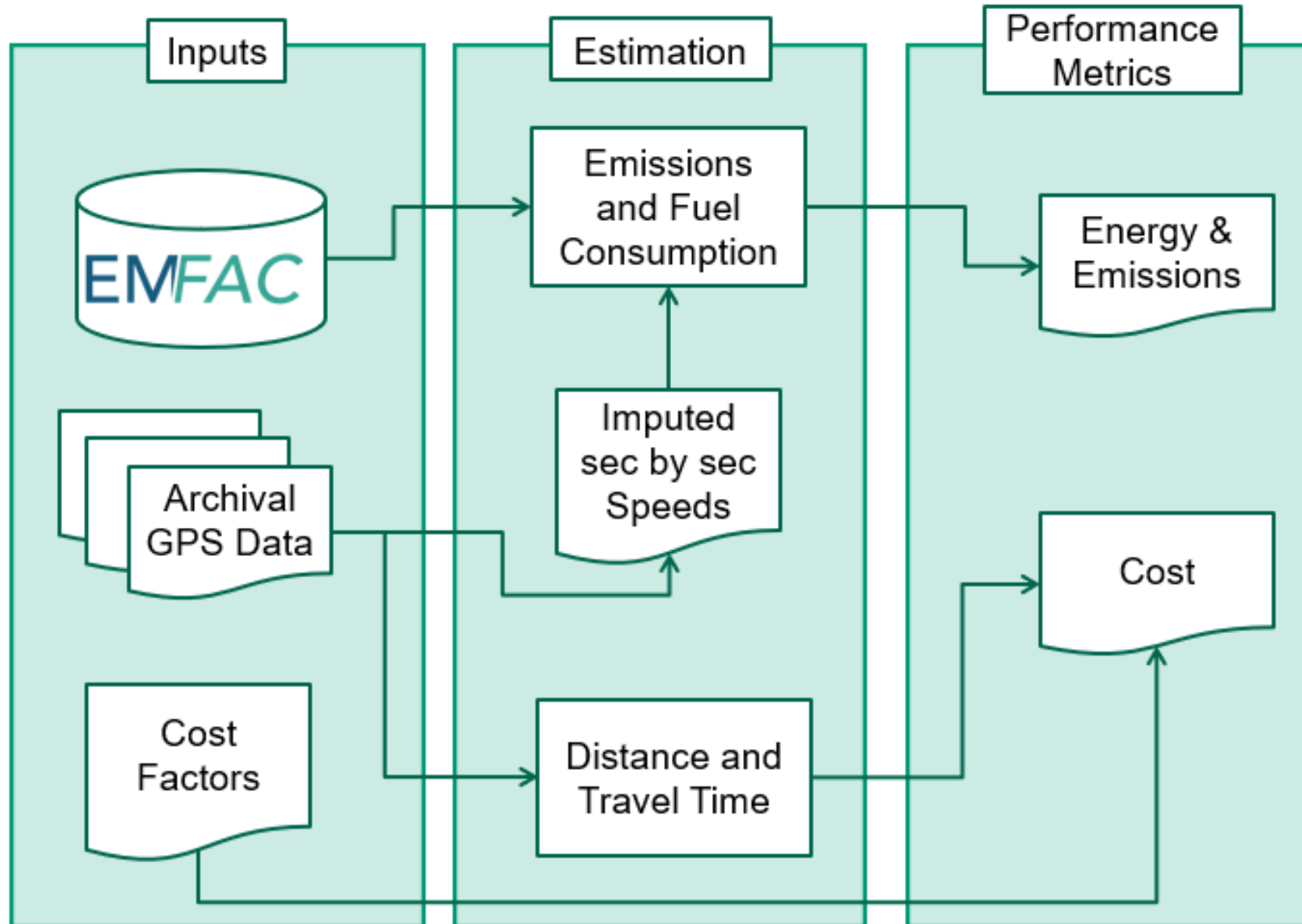


# Overview of GPS Data

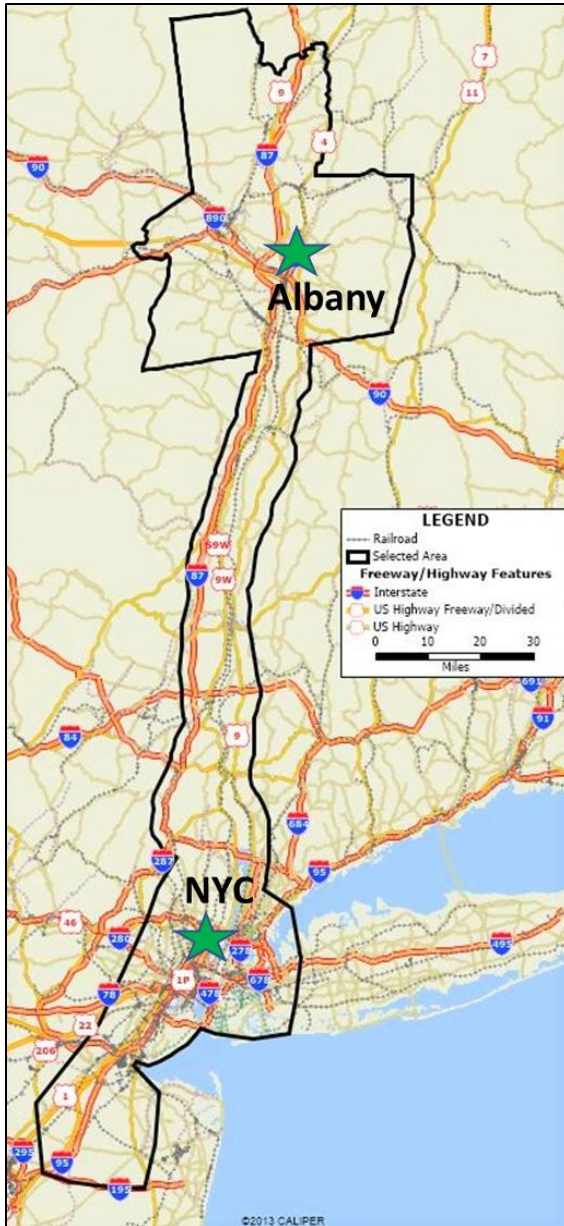
- GPS data from ATRI
  - 105 million points, 116,042 vehicles
  - Three different time periods:
    - July 16-27 (2018)
    - October 22-Nov 2 (2018)
    - June 3-14 (2019)
- Challenges:
  - Polling interval ranges 1-5 minutes (one second or lower is desired)
  - The team developed imputation techniques to obtain second-by-second speeds using the 1Hz GPS data collected by the team



# Data Processing



# Aggregate Metrics of Emissions and Fuel Consumption

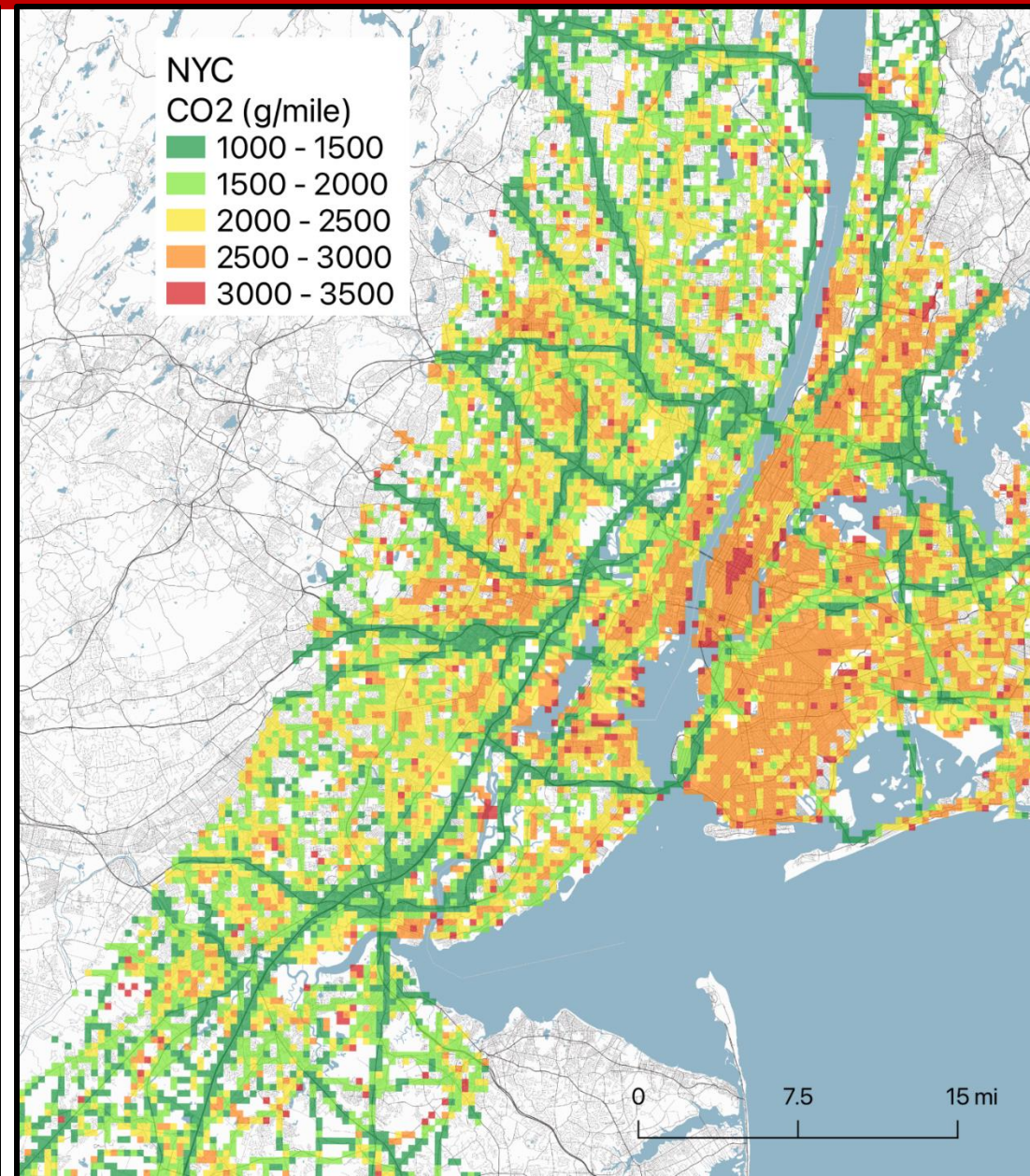
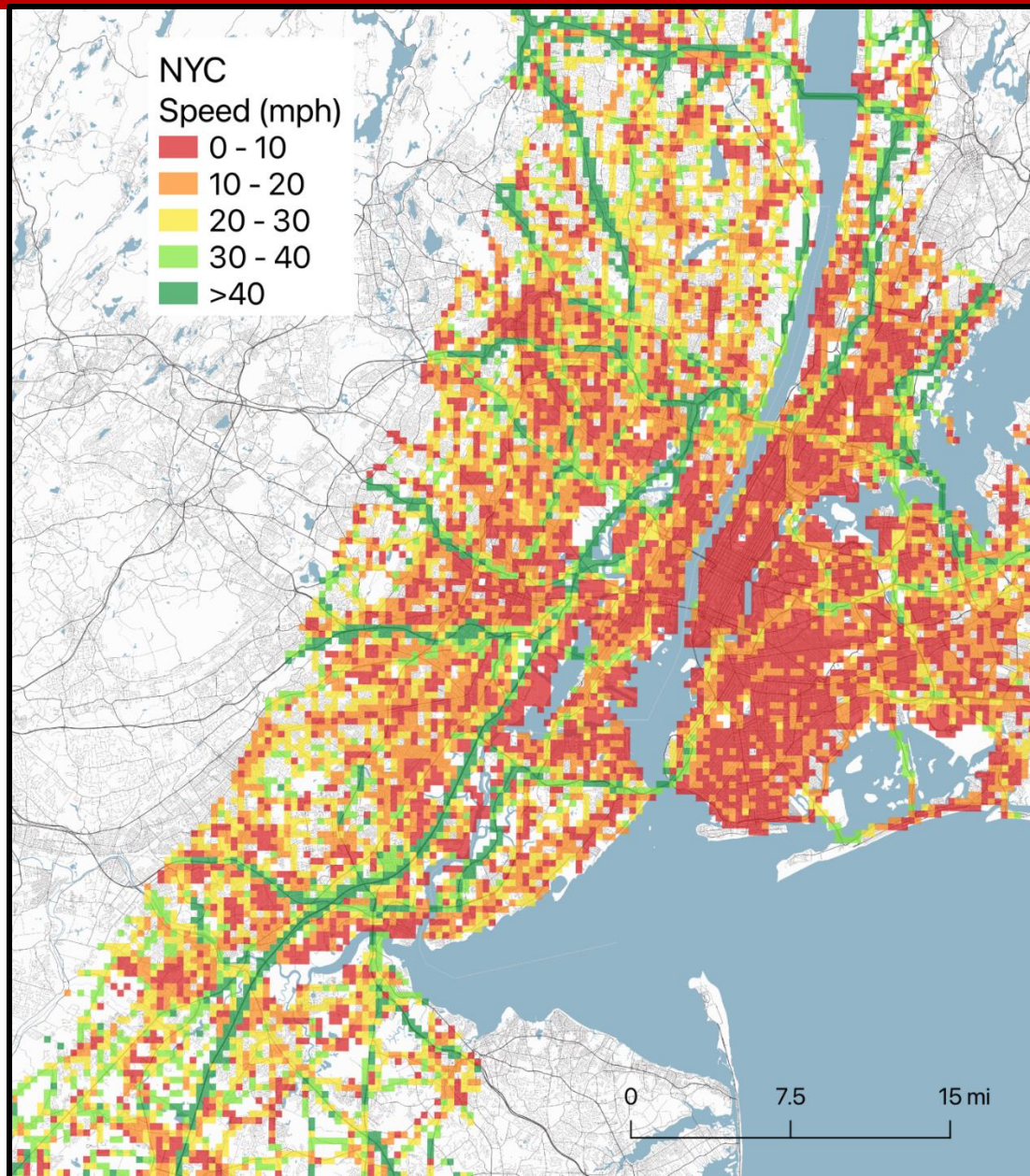


Geographical Areas		Albany	Corridor	NYC
Data Points		128,011,520	184,614,494	843,016,100
Average Speed (mph)		40.38	46.66	25.64
Fuel Consumption (gallons/100 miles)		11.15	11.03	12.50
Emissions (g/mile)	CO	0.14	0.13	0.25
	CO <sub>2</sub>	1238.68	1225.20	1389.30
	NO <sub>x</sub>	1.24	1.17	1.89
	PM <sub>10</sub>	0.0131	0.0136	0.0099
	PM <sub>2.5</sub>	0.0137	0.0142	0.0104
	ROG	0.0149	0.0146	0.0194
	TOG	0.0169	0.0166	0.0221

The corridor is the best in terms of fuel consumption and emissions, Albany comes in second, and NYC is the worst.

Results obtained using all datasets (Jul/2018, Oct/2018, Jun/2019)

# Example of Rasters (July/2018)

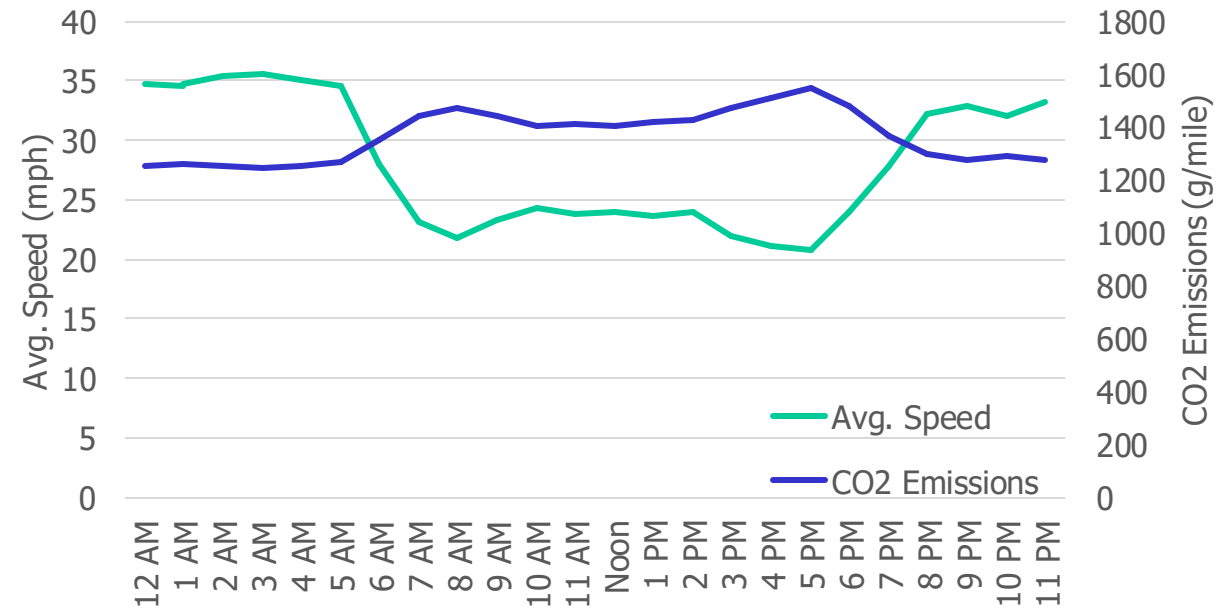
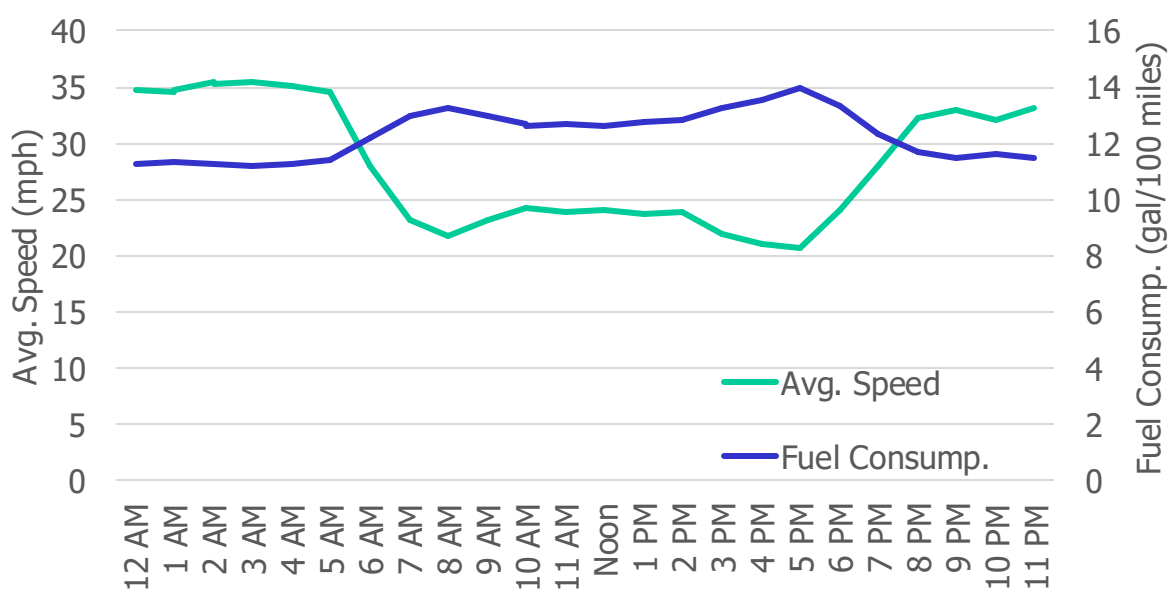


# Aggregate Metrics Including a Temporal Dimension

- Data points are aggregate based on the location and the time stamp
- Sample results for every hour of a typical business day in the NYC MSA
  - Computed from data on Tuesdays, Wednesdays and Thursdays from the July/2018 dataset

NYC MSA Typical Business Day

	12 AM	1 AM	2 AM	3 AM	4 AM	5 AM	6 AM	7 AM	8 AM	9 AM	10 AM	11 AM	Noon	1 PM	2 PM	3 PM	4 PM	5 PM	6 PM	7 PM	8 PM	9 PM	10 PM	11 PM
Avg Speed (mph)	34.74	34.73	35.42	35.51	35.15	34.51	27.97	23.20	21.82	23.23	24.24	23.87	24.00	23.70	23.96	21.96	21.11	20.71	24.04	27.92	32.25	32.97	32.06	33.14
Fuel Consump. (gal./100 miles)	11.30	11.32	11.27	11.22	11.25	11.42	12.18	12.95	13.27	12.96	12.66	12.67	12.63	12.76	12.85	13.26	13.57	13.95	13.33	12.31	11.69	11.49	11.61	11.47
CO2 emissions (g/mile)	1256	1258	1253	1247	1250	1269	1353	1439	1474	1440	1407	1408	1403	1417	1427	1473	1508	1550	1481	1368	1299	1276	1290	1274





# PANYNJ Preliminary Results

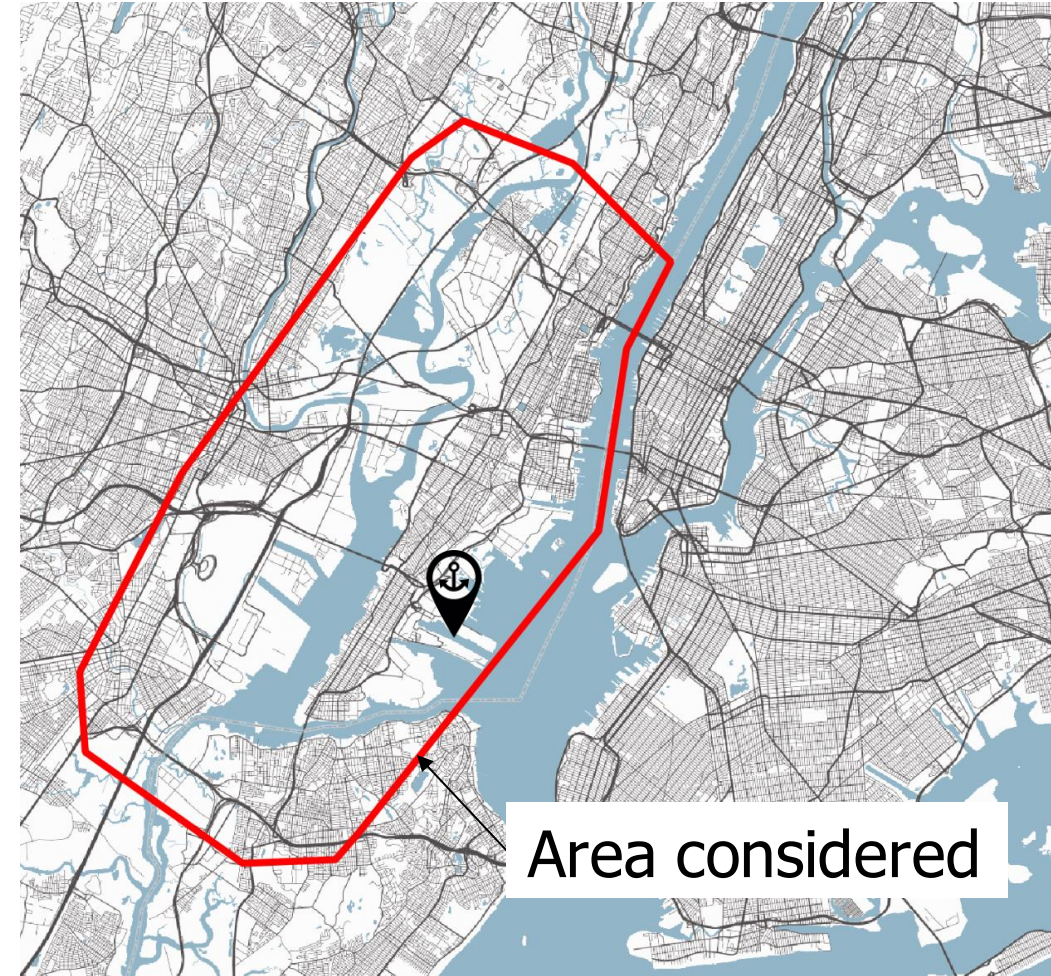


# Port Authority of New York and New Jersey (Preliminary Results)<sup>17</sup>

- Objective: investigate the impacts of extending/shifting port work hours to reduce emissions and fuel consumption
- Three periods were considered based on the working hours of the port

1) 3am-6am    2) 6am-6pm    3) 6pm-9pm

3h before ←    Current working hours    → 3h after



# Port of Newark: Emissions and Fuel Consumption Rates

3h before ←      Current working hours      → 3h after

Periods of the day	3am-6am	6am-6pm	6pm-9pm
Avg. Speed (mph)	25.95	18.57	22.71
Fuel Consumption (gal. / 100 miles)	11.95	13.58	13.06
CO (g / mile)	0.21	0.32	0.28
CO <sub>2</sub> (g / mile)	1327.33	1508.42	1450.80
NOX (g / mile)	1.65	2.40	2.17
PM <sub>2.5</sub> (g / mile)	0.0106	0.0078	0.0084
PM <sub>10</sub> (g / mile)	0.0110	0.0082	0.0088
ROG (g / mile)	0.0174	0.0228	0.0207
TOG (g / mile)	0.0198	0.0260	0.0236

A change of hours increases speed by 22% to 39%

A change of hours reduce CO<sub>2</sub> emissions by 13% to 33%

A change of hours reduce NOX emissions by 9% to 31%

Results obtained using the Jul/2018 dataset

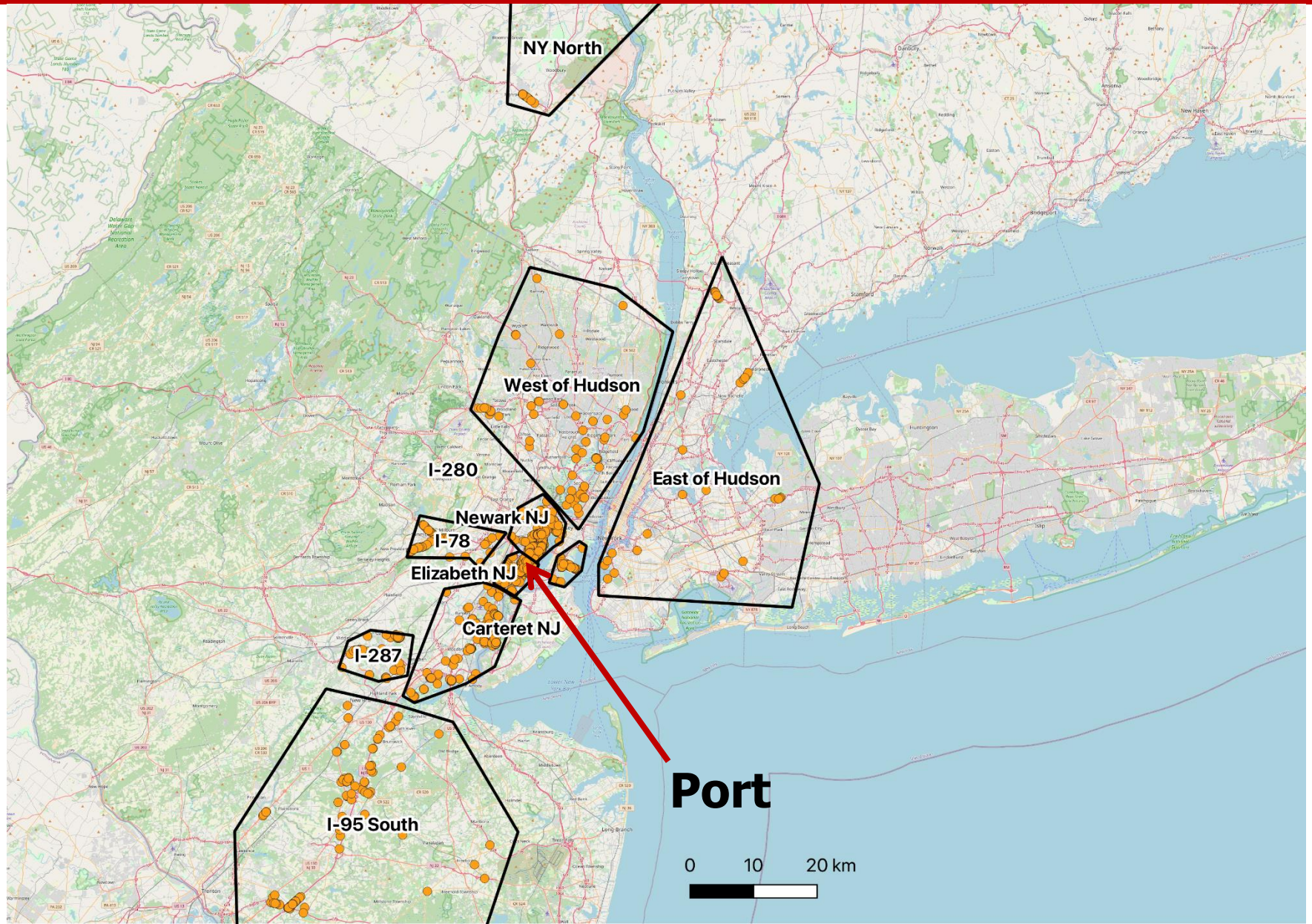


# Analysis by Origin of The Trips

- Investigated the effects of the arrival time at the port depending on the origin of the trip
- Aggregated the trips going to the port according to the time of arrival (one-hour intervals)
- Computed metrics:
  - Avg. Speed (mph)
  - CO<sub>2</sub> emission rate (g/mile)
  - Cost per mile travelled (US\$/mile)



# Origin Locations Considered



# Statistics

Location	Elizabeth NJ	Newark NJ	Bayonne	Carteret NJ	I-280	West of Hudson	I-287	East of Hudson	I-78	I-95 South	NY North
Number of Trips	2020	1490	69	477	15	71	72	40	209	232	20
Avg. Distance (mi)	3.04	6.28	18.73	14.28	21.49	21.75	26.87	40.02	14.96	42.37	66.25
Avg. Speed (mph)	5.86	9.43	12.20	14.60	18.49	20.58	21.96	25.76	26.56	36.03	37.01
Fuel (gal./100 miles)	19.85	16.78	15.41	14.46	13.08	12.76	13.14	12.41	12.37	11.55	11.16
CO (g/mile)	0.76	0.54	0.44	0.38	0.28	0.27	0.28	0.25	0.23	0.17	0.15
CO <sub>2</sub> (g/mile)	2205.11	1864.80	1711.97	1606.98	1453.74	1417.43	1459.92	1378.95	1374.20	1283.36	1239.81
NOx (g/mile)	4.99	3.72	3.22	2.79	2.22	2.07	2.18	1.92	1.83	1.42	1.30
PM <sub>10</sub> (g/mile)	0.0054	0.0068	0.0057	0.0071	0.0076	0.0080	0.0091	0.0083	0.0104	0.0128	0.0115
PM <sub>2.5</sub> (g/mile)	0.0057	0.0071	0.0060	0.0075	0.0079	0.0083	0.0095	0.0086	0.0108	0.0134	0.0120
ROG (g/mile)	0.04	0.0356	0.0325	0.0296	0.0255	0.0225	0.0255	0.0211	0.0212	0.0161	0.0146
TOG (g/mile)	0.0525	0.0396	0.0325	0.0296	0.0255	0.0225	0.0255	0.0211	0.0212	0.0184	0.0166
Cost (US\$/mile)	8.35	5.41	4.32	3.71	3.06	2.81	2.67	2.37	2.32	1.87	1.83

Longer trips produce more emissions in total, but shorter trips produce more emissions on a per mile basis



Decreasing cost, emissions, and fuel consumption per mile, increasing distance



# Analysis by Origin and Time of Arrival at the Port: Speed (mph)

Port Working Hours

Arrival Time at the Port	Elizabeth NJ	Newark NJ	Bayonne	Carteret NJ	I-280	West of Hudson	I-287	East of Hudson	I-78	I-95 South	NY North	Average
Midnight		13.03		34.26					19.18	56.25		24.05
1AM		10.69						44.73	45.05			29.45
2AM	7.36	14.24		26.14			27.14	37.83	45.72	66.75		29.14
3AM		9.92		34.23		42.49			25.89	62.36		24.34
4AM		7.31		29.35					32.53	42.27	32.21	22.03
5AM	1.33	8.35		17.43				50.50	31.84	45.88		13.06
6AM	4.37	7.46		13.95		12.72			31.53	41.70		11.76
7AM	4.12	8.95	13.69	12.74	33.90	22.58	28.77	22.15	27.01	46.48		10.67
8AM	3.79	10.79	8.54	11.36		21.76	23.38	20.27	28.51	37.67	46.38	11.86
9AM	4.56	12.01	10.24	15.89		18.75	24.54	27.54	26.13	37.41	51.67	14.65
10AM	6.28	9.28	11.16	13.93	23.84	22.68	24.52	23.12	25.11	34.59	41.60	14.78
11AM	7.25	9.29	15.01	13.34	17.68	24.27	21.48	37.49	23.22	37.84	32.82	13.85
Noon	5.50	9.58	15.22	14.44		26.72	19.74	39.33	27.58	30.31	39.68	12.68
1PM	6.05	11.66	12.72	16.62	22.29	22.56	18.35	26.50	26.26	36.93	26.39	13.04
2PM	6.61	8.98	11.40	17.41		22.89	22.51	20.58	26.32	31.92	40.11	13.54
3PM	6.27	8.03	13.82	18.04	15.42	13.04	24.95	22.94	29.78	28.83	41.46	11.63
4PM	5.73	5.59	10.05	14.74	16.85	16.33	18.51		24.32	32.72		11.40
5PM	5.79	8.55	10.43	15.79	17.18		19.34	15.96	21.60	46.83		12.04
6PM	5.09	5.80		17.93		11.59		22.87	13.87	42.60		9.54
7PM	4.84	8.09		22.98					25.26	47.35		15.58
8PM	4.19	10.59		19.74					46.51	50.95		15.02
9PM		18.75		26.50	19.30	28.10		31.13	39.46	44.74		29.89
10PM		7.35		19.37	15.36		29.48	28.76	38.99	58.91		23.89
11PM	22.89	12.29								58.07		38.97
Average	5.86	9.43	12.20	14.60	18.49	20.58	21.96	25.76	26.56	36.03	37.01	13.19



# Analysis by Origin and Time of Arrival at the Port: CO<sub>2</sub> (g/mile)

Port Working Hours

Arrival Time at the Port	Elizabeth NJ	Newark NJ	Bayonne	Carteret NJ	I-280	West of Hudson	I-287	East of Hudson	I-78	I-95 South	NY North	Average
Midnight		1768.71		1281.10					1352.78	1200.45		1369.35
1AM		1571.50						1170.94	1281.05			1296.33
2AM	1966.79	1733.68		1303.58			1274.31	1179.47	1186.71	1224.44		1312.73
3AM		1795.74		1237.17		1407.22			1321.10	1185.70		1361.75
4AM		2031.27		1256.49					1492.91	1258.95	1295.08	1401.01
5AM	3206.20	1828.91		1495.91				1170.65	1329.19	1208.99		1565.48
6AM	2566.11	2114.11		1609.69		1446.74			1310.38	1245.60		1712.17
7AM	2633.69	1958.25	1983.99	1666.43	1281.26	1364.01	1409.22	1345.22	1312.70	1232.38		1788.47
8AM	2681.14	1819.58	1903.68	1830.97		1419.80	1399.96	1444.08	1315.69	1261.60	1239.73	1714.09
9AM	2504.60	1678.67	1884.31	1570.24		1491.21	1424.10	1362.28	1396.62	1275.86	1185.50	1570.33
10AM	2223.60	1844.49	1770.39	1665.71	1531.71	1406.20	1377.71	1424.18	1486.08	1289.30	1201.33	1583.21
11AM	2032.06	1920.30	1504.51	1627.08	1403.66	1344.27	1509.20	1256.07	1377.44	1284.53	1223.82	1600.51
Noon	2292.25	1894.51	1606.13	1723.40		1327.55	1499.37	1227.97	1338.26	1338.23	1245.40	1672.28
1PM	2207.29	1736.84	1884.83	1535.69	1407.78	1354.87	1472.91	1414.24	1367.87	1284.08	1298.53	1635.27
2PM	2059.23	1807.40	1714.79	1514.69		1408.53	1396.69	1439.04	1370.08	1294.25	1246.92	1580.57
3PM	2128.43	2021.72	1639.64	1524.55	1401.43	1525.04	1435.18	1451.91	1395.78	1330.34	1255.00	1692.51
4PM	2144.77	2249.30	1888.96	1574.78	1683.81	1783.69	1709.47		1417.26	1291.09		1679.31
5PM	2222.67	1838.62	1731.49	1443.82	1512.61		1449.92	1681.26	1464.64	1204.76		1644.56
6PM	2273.08	2255.26		1442.77		1684.42		1496.97	1770.83	1347.05		1805.10
7PM	2514.01	1858.75		1370.28					1380.41	1208.41		1504.27
8PM	2518.61	1684.18		1271.49					1301.13	1303.61		1525.17
9PM		1507.45		1336.19	1337.00	1262.32		1322.75	1236.20	1248.46		1321.28
10PM		1877.46		1511.72	1503.92		1288.47	1315.86	1229.15	1245.69		1374.73
11PM	1598.22	1397.13								1265.01		1293.01
Average	2205.11	1864.80	1711.97	1606.98	1453.74	1417.43	1459.92	1378.95	1374.20	1283.36	1239.81	1626.36





# Final Remarks

- Fuel consumption and emissions on a per mile basis are about 13% in average higher in urban areas
- Emissions and fuel consumption vary with traffic conditions along the day, giving opportunities for demand management strategies that aim to shift time of travel
  - In NYC, vehicles produce 25% more emissions per mile in the most congested time of the day (5PM) in comparison to the least congested time of the day (3AM)
- The case of the Port of Elizabeth shows the potential reduction in fuel consumption and emissions if vehicles could arrive at the port at less congested times of the day
  - Vehicles could reduce emissions up to 33% by switching the arrival time to the port
  - Similar gains could be obtained with other Large Traffic Generators located in urban areas



Thank you!

