Freight Performance Measurement Using GPS Data

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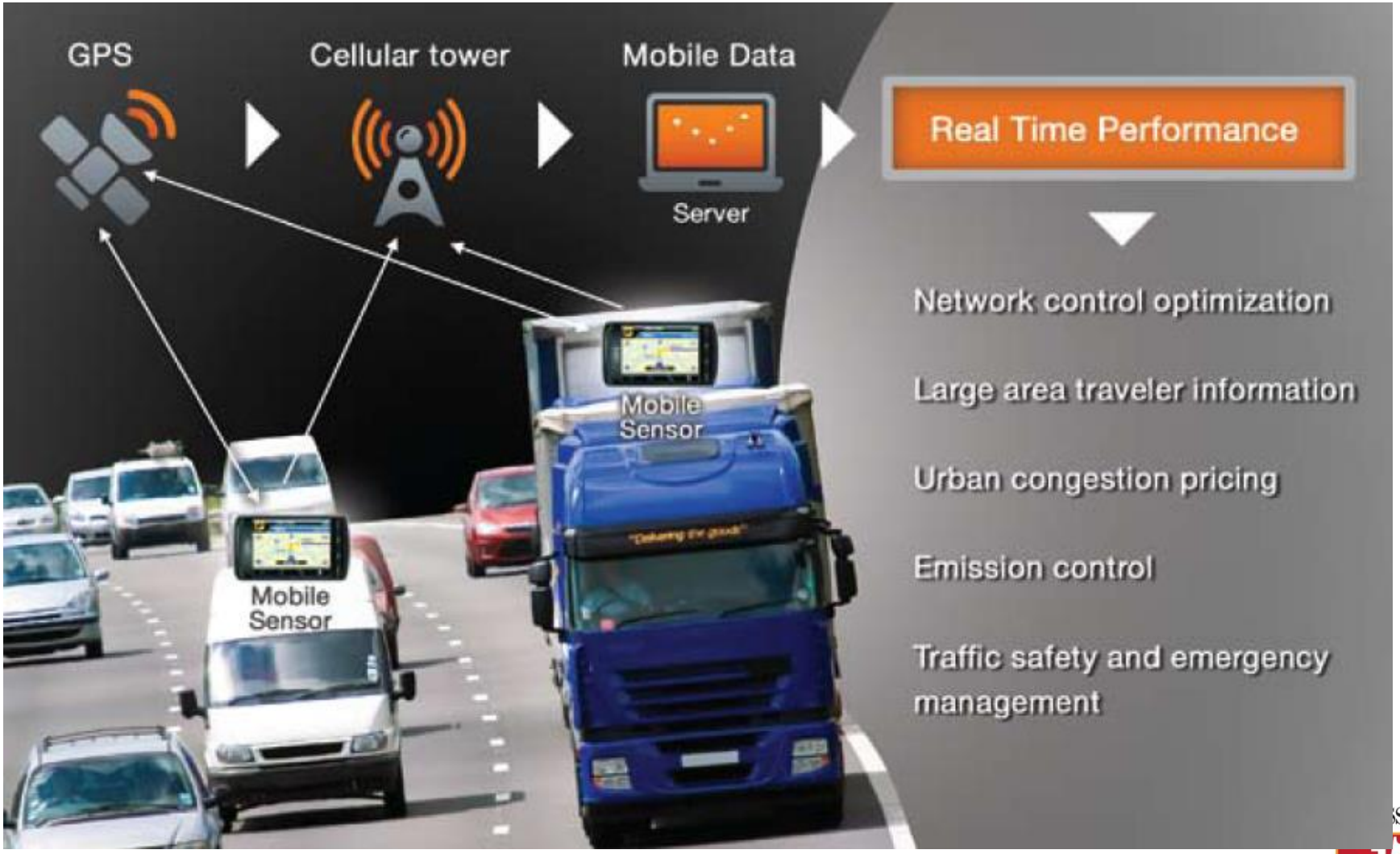
Using GPS to Measure Urban Freight Performance



Urban Freight Performance Measurement

Mobility	Energy	Environmental
Time (Total, Segment)	Vehicle Fuel Consumption	Vehicle Emissions
Service Time	Vehicle Fuel Efficiency	
Delivery Stops		
Speed		

Case Study

- 57 delivery trucks;
- 1 warehouse;
- 5 truck centers;
- 155 stores in Manhattan.

- Duration of data (Jan.1, 2012-Dec. 31, 2012)
- 11640 delivery tours in 2012;

Event-based GPS Data in 2012

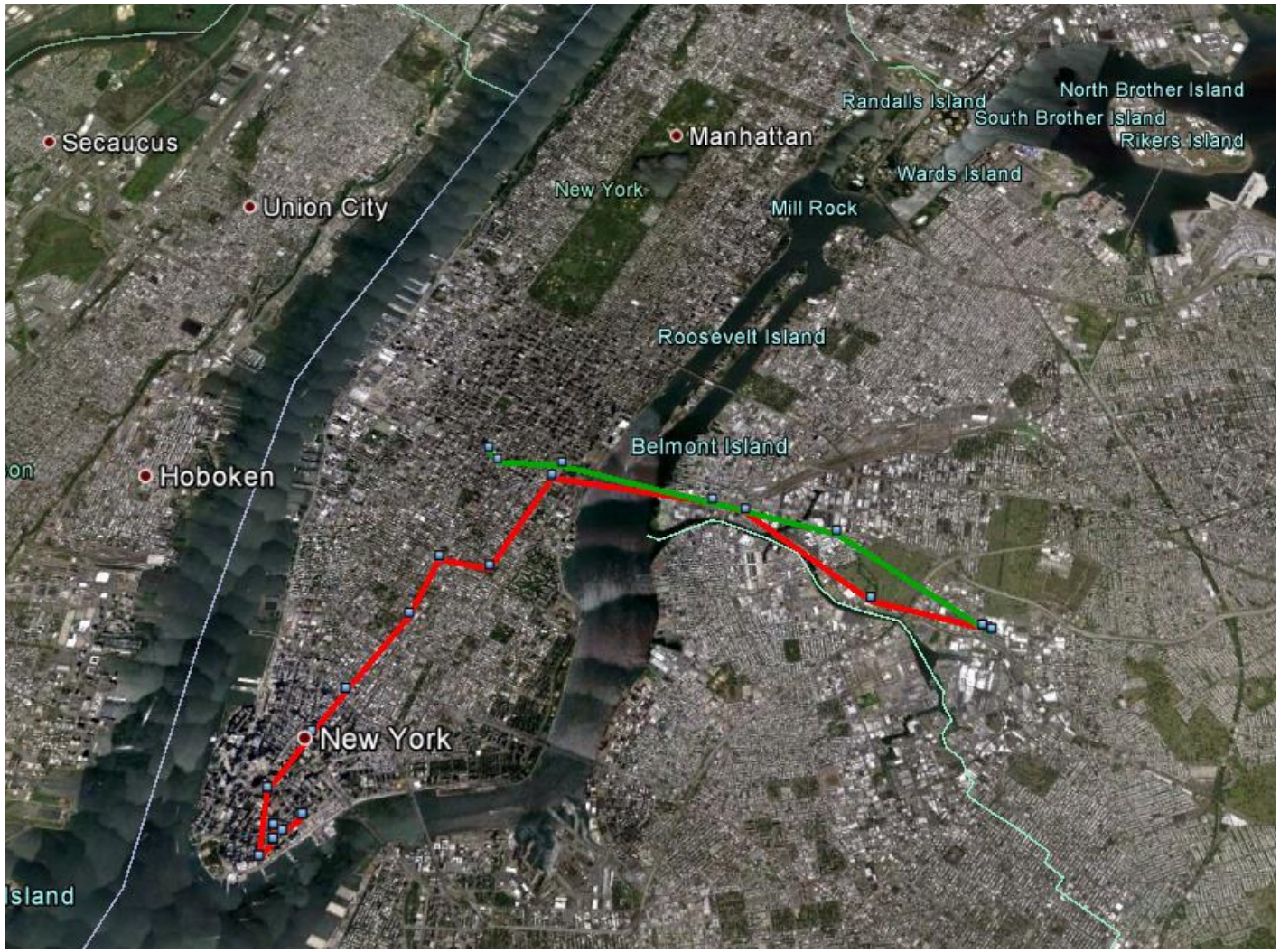
Label	Date / Time	Address	Latitude	Longitude	Event
928	4/3/2012 21:50	521 Park Ave, New York, NY, 10065	40.763525	-73.9692138	Travel Stop
928	4/3/2012 21:50	1 Central Park S, New York, NY, 10019	40.76478	-73.9737944	Travel Start
928	4/3/2012 21:55	937 7th Ave, New York, NY, 10019	40.76668	-73.9790527	Drive
928	4/3/2012 22:00	98 W 53rd St, New York, NY, 10019	40.761666	-73.9790111	Drive
928	4/3/2012 22:03	65 W 56th St, New York, NY, 10019	40.763447	-73.9769638	Travel Stop
928	4/3/2012 22:04	65 W 56th St, New York, NY, 10019	40.763447	-73.9769638	Ignition Off
928	4/3/2012 22:04	70 W 57th St, New York, NY, 10019	40.763825	-73.9768972	Ignition On
928	4/3/2012 22:06	68 W 55th St, New York, NY, 10019	40.762497	-73.9772	Travel Start
928	4/3/2012 22:08	62 W 57th St, New York, NY, 10019	40.763788	-73.9768055	Travel Stop
928	4/3/2012 22:08	47 W 56th St, New York, NY, 10019	40.763569	-73.9765194	Ignition Off
928	4/3/2012 22:34	42 W 56th St, New York, NY, 10019	40.762877	-73.9767305	Ignition On

- Advantage: Engine status (Ignition off, Ignition On) and travel status (start, stop)
- Assumption: Apart from warehouse and truck centers, a vehicle will only turn the engine off for deliveries at stores. **This helps identify delivery stops.**

GPS Data Issues

- Devices may be broken
- Signal between satellite and receiver can be blocked by obstructions, especially in urban areas (like NYC)
- Devices may turn off when vehicle speed drops below some threshold (2 mph) or when signal is blocked
- **As a result**, the GPS raw data files often contain errors and incomplete tour information
- Even everything else is perfect, GPS data are very accurate on location information but poor on behavior explanations;

Incomplete Tour



Red and green lines

Two incomplete tours

Moving around at one store?

)44	1/18/2012 1:00	567 2nd Ave, New York, NY, 10016	40.743119	-73.9772305	Drive
)44	1/18/2012 1:05	567 2nd Ave, New York, NY, 10016	40.743119	-73.9772305	Drive
)44	1/18/2012 1:10	567 2nd Ave, New York, NY, 10016	40.743119	-73.9772305	Drive
)44	1/18/2012 1:13	567 2nd Ave, New York, NY, 10016	40.743119	-73.9772305	Travel Stop
)44	1/18/2012 1:14	567 2nd Ave, New York, NY, 10016	40.743119	-73.9772305	Ignition Off
)44	1/18/2012 1:15	567 2nd Ave, New York, NY, 10016	40.743119	-73.9772305	Travel Start
)44	1/18/2012 1:16	567 2nd Ave, New York, NY, 10016	40.743119	-73.9772305	Ignition On
)44	1/18/2012 1:16	567 2nd Ave, New York, NY, 10016	40.743119	-73.9772305	Travel Stop
)44	1/18/2012 1:16	567 2nd Ave, New York, NY, 10016	40.743119	-73.9772305	Ignition Off
)44	1/18/2012 1:21	567 2nd Ave, New York, NY, 10016	40.743119	-73.9772305	Ignition On
)44	1/18/2012 1:24	567 2nd Ave, New York, NY, 10016	40.743119	-73.9772305	Ignition Off
)44	1/18/2012 1:49	567 2nd Ave, New York, NY, 10016	40.743119	-73.9772305	Ignition On
)44	1/18/2012 1:51	567 2nd Ave, New York, NY, 10016	40.743119	-73.9772305	Ignition Off
)44	1/18/2012 1:57	567 2nd Ave, New York, NY, 10016	40.743119	-73.9772305	Ignition On
)44	1/18/2012 2:03	185 4th Ave, New York, NY, 10003	40.733852	-73.9894583	Travel Start
)44	1/18/2012 2:05	185 4th Ave, New York, NY, 10003	40.733852	-73.9894583	Travel Stop
)44	1/18/2012 2:19	185 4th Ave, New York, NY, 10003	40.733852	-73.9894583	Ignition Off
)44	1/18/2012 2:24	185 4th Ave, New York, NY, 10003	40.733852	-73.9894583	Ignition On
)44	1/18/2012 2:47	49th St, New York, NY, 11378	40.724483	-73.9208916	Travel Start
)44	1/18/2012 2:52	49th Ln, New York, NY, 11378	40.724827	-73.9176555	Drive
)44	1/18/2012 2:53	49th Ln, New York, NY, 11378	40.724827	-73.9176555	Travel Stop

	Store No.	Consolidated Stores with Delivery	Driver	Truck No.	Number of Dollies	Number of H.V. Cages	Manifest Time	Store Scheduled Delivery Time	DC Dispatch Time	Security Gate Dispatch Time	Store Arrival Time	Late/On Time	Store Unload Start Time	Store Departure time	Security Gate Return Time	Travel Time to Store	Travel Time to DC	Total Unload Time @ Store	Total Turn Time of Truck
					6:00 Dispatch														
14	14438			77	11	1	18:54	1:00	0:10	0:46	1:00	On time	1:20	2:10	2:47	0:14	0:37	0:50	2:01
15	14468			44	15	1	20:16	1:00	0:15	0:44	1:10	On time	1:25	2:30	2:50	0:26	0:20	1:05	2:06

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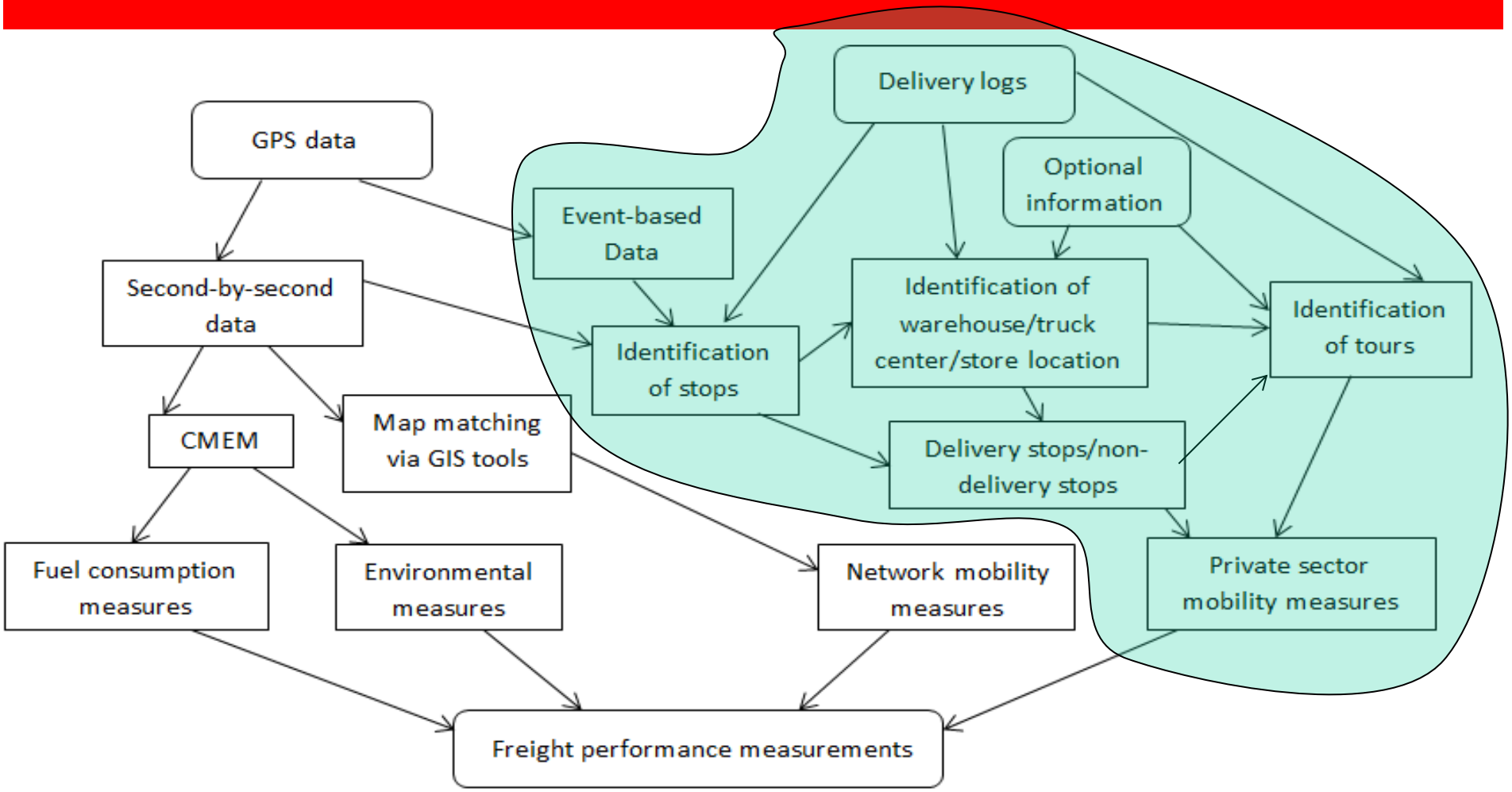
Devices Issues?

009	3/9/2012 21:39	64 W 23rd St, New York, NY, 10010	40.742275	-73.9917194	Ignition Off
009	3/9/2012 22:13	64 W 23rd St, New York, NY, 10010	40.742275	-73.9917194	Ignition On
009	3/9/2012 22:34	64 W 23rd St, New York, NY, 10010	40.742275	-73.9917194	Ignition Off
009	3/9/2012 23:31	64 W 23rd St, New York, NY, 10010	40.742275	-73.9917194	Ignition On
009	3/10/2012 1:36	64 W 23rd St, New York, NY, 10010	40.742275	-73.9917194	Ignition Off
009	3/10/2012 2:46	64 W 23rd St, New York, NY, 10010	40.742275	-73.9917194	Ignition On
009	3/10/2012 2:52	64 W 23rd St, New York, NY, 10010	40.742275	-73.9917194	Ignition Off
009	3/10/2012 4:51	64 W 23rd St, New York, NY, 10010	40.742275	-73.9917194	Ignition On
009	3/10/2012 4:59	64 W 23rd St, New York, NY, 10010	40.742275	-73.9917194	Ignition Off
009	3/10/2012 8:18	64 W 23rd St, New York, NY, 10010	40.742275	-73.9917194	Ignition On
009	3/10/2012 9:06	64 W 23rd St, New York, NY, 10010	40.742275	-73.9917194	Ignition Off
009	3/10/2012 9:09	64 W 23rd St, New York, NY, 10010	40.742275	-73.9917194	Ignition On
009	3/10/2012 10:20	64 W 23rd St, New York, NY, 10010	40.742275	-73.9917194	Ignition Off
009	3/10/2012 11:11	64 W 23rd St, New York, NY, 10010	40.742275	-73.9917194	Ignition On
009	3/10/2012 11:21	64 W 23rd St, New York, NY, 10010	40.742275	-73.9917194	Ignition Off

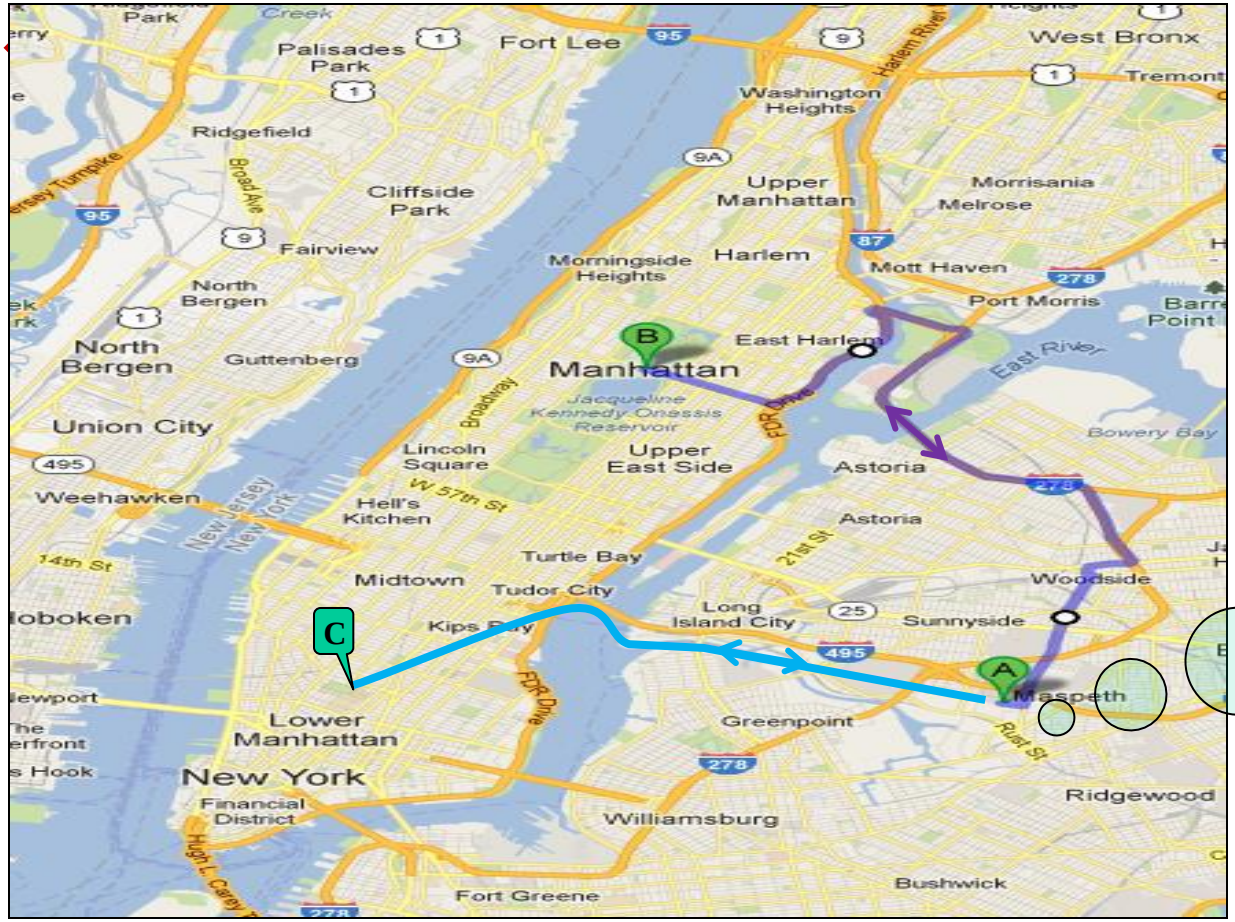
009	1/7/2012 2:45	71st Rd, New York, NY, 11375	40.720244	-73.8432444	Antenna Connect
009	1/7/2012 2:47	71st Rd, New York, NY, 11375	40.720277	-73.8433722	Antenna Disconnect
009	1/7/2012 2:47	71st Rd, New York, NY, 11375	40.720277	-73.8433722	Antenna Connect
009	1/7/2012 2:47	71st Rd, New York, NY, 11375	40.720277	-73.8433722	Antenna Disconnect
009	1/7/2012 2:47	71st Rd, New York, NY, 11375	40.720277	-73.8433722	Antenna Connect
009	1/7/2012 2:47	71st Rd, New York, NY, 11375	40.720277	-73.8433722	Antenna Disconnect
009	1/7/2012 2:47	71st Rd, New York, NY, 11375	40.720277	-73.8433722	Antenna Connect
009	1/7/2012 2:48	71st Rd, New York, NY, 11375	40.720041	-73.8430416	Antenna Disconnect
009	1/7/2012 2:48	71st Rd, New York, NY, 11375	40.720041	-73.8430416	Antenna Connect
009	1/7/2012 2:48	71st Rd, New York, NY, 11375	40.720041	-73.8430416	Antenna Disconnect
009	1/7/2012 2:48	71st Rd, New York, NY, 11375	40.720041	-73.8430416	Antenna Connect

Flow Chart of Research Process

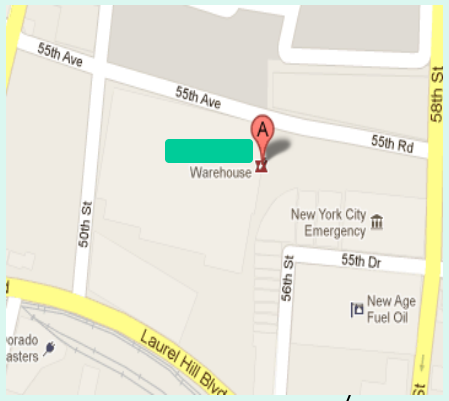


1. Warehouse Identification (Method A and B)

- Method A: The location with the highest number of stops



Every tour starts and ends at the warehouse



Results of method A

Seven out of eight locations are clustered together

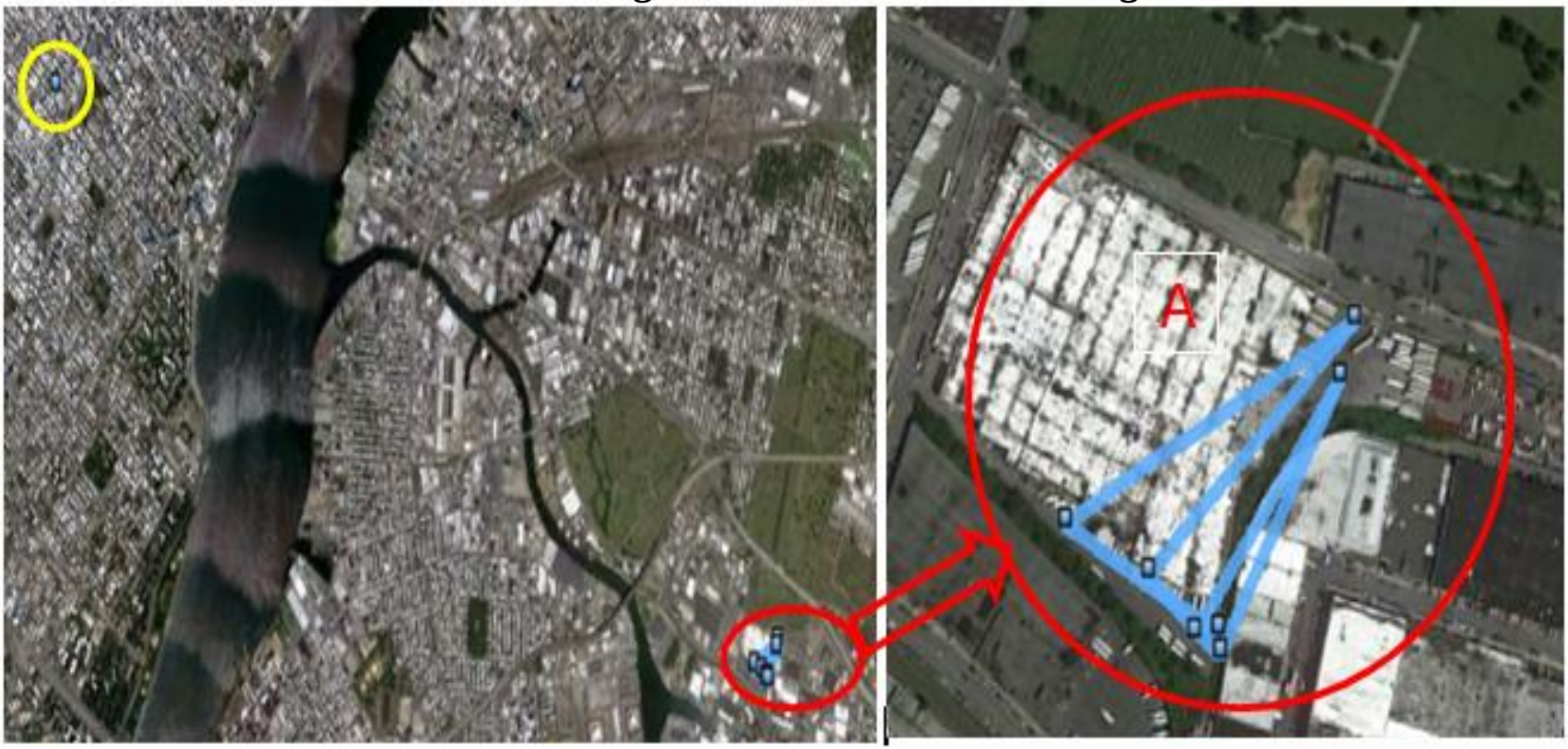


Figure1.1 The geographical distribution of stop locations with over 1000 stops in 2012

Results of method B

- Method B: Warehouse is the location with the highest number of long-duration stops.
- A truck has to load all the cargos at the warehouse for one or more deliveries.

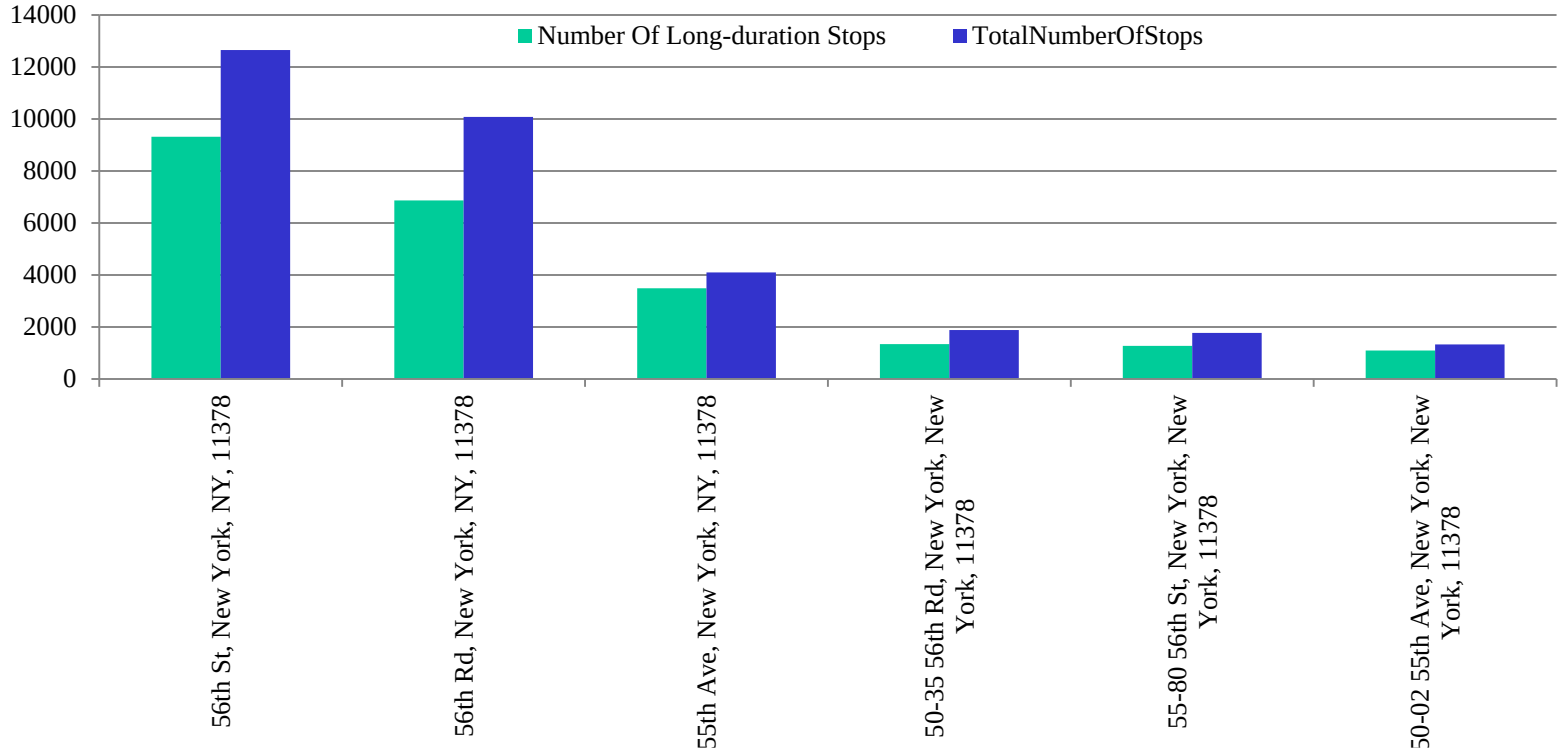
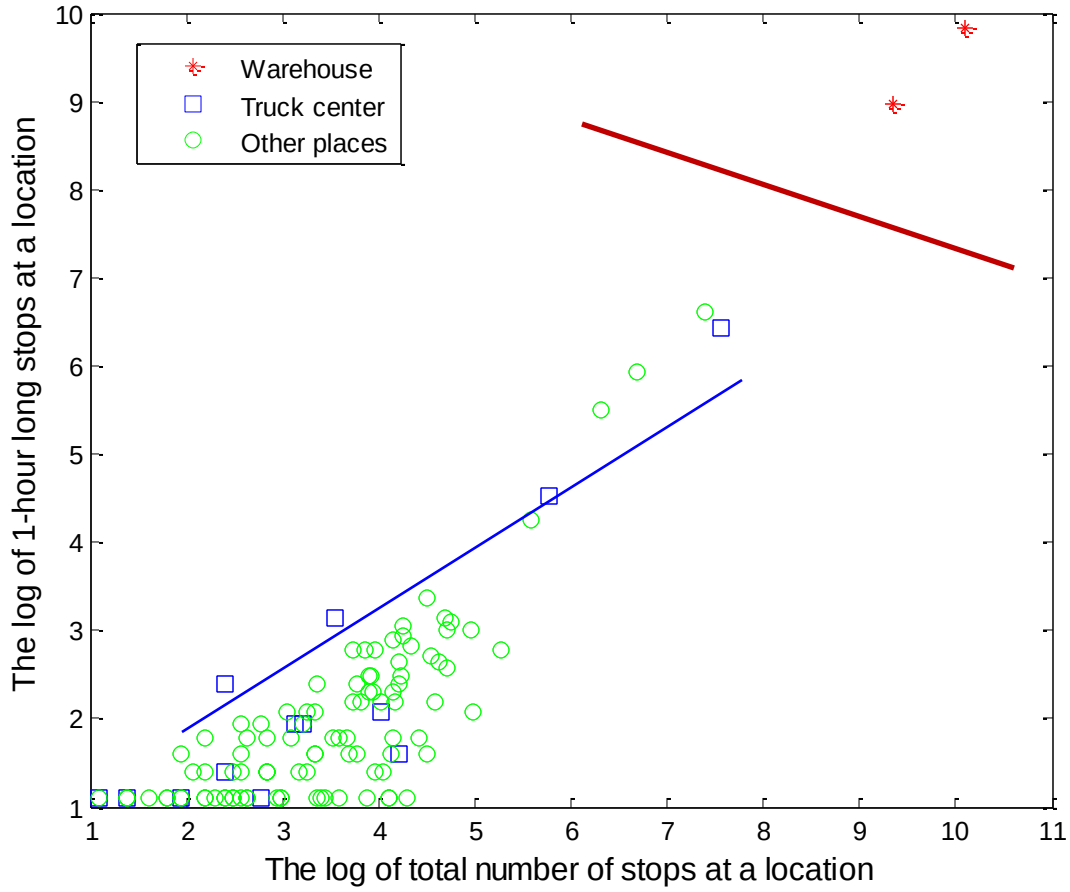


Figure 1.2 Long-duration (1hour) stop location distribution in 2012

Plot showing the classification results



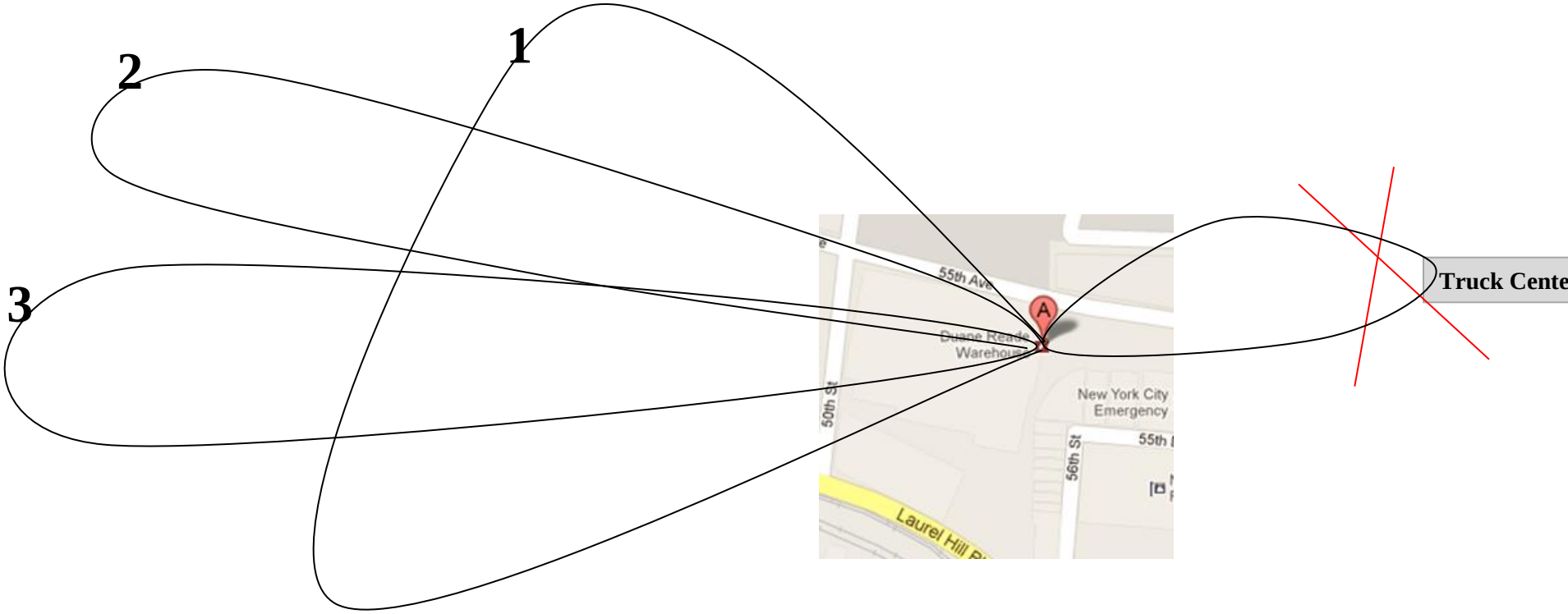
2 Truck Center Identification

- It is assumed that trucks go to truck centers for mechanical reasons;
- Stop duration at truck centers are relatively long;
- Google Earth displays the 1-hour or longer stops;

	Longitude	Latitude
Truck center 1	40.729861	-73.9412333
Truck center 2	40.824080	-74.0888638
Truck center 3	40.811658	-73.9025305
Truck center 4	40.883633	-74.068167
Truck center 5	40.731433	-73.9031166
Truck center 6	40.586050	-73.949700

3 Tour Identification

- A tour is defined as a journey starts and ends at the warehouse.



Note: Those tours stopped at truck centers are excluded.

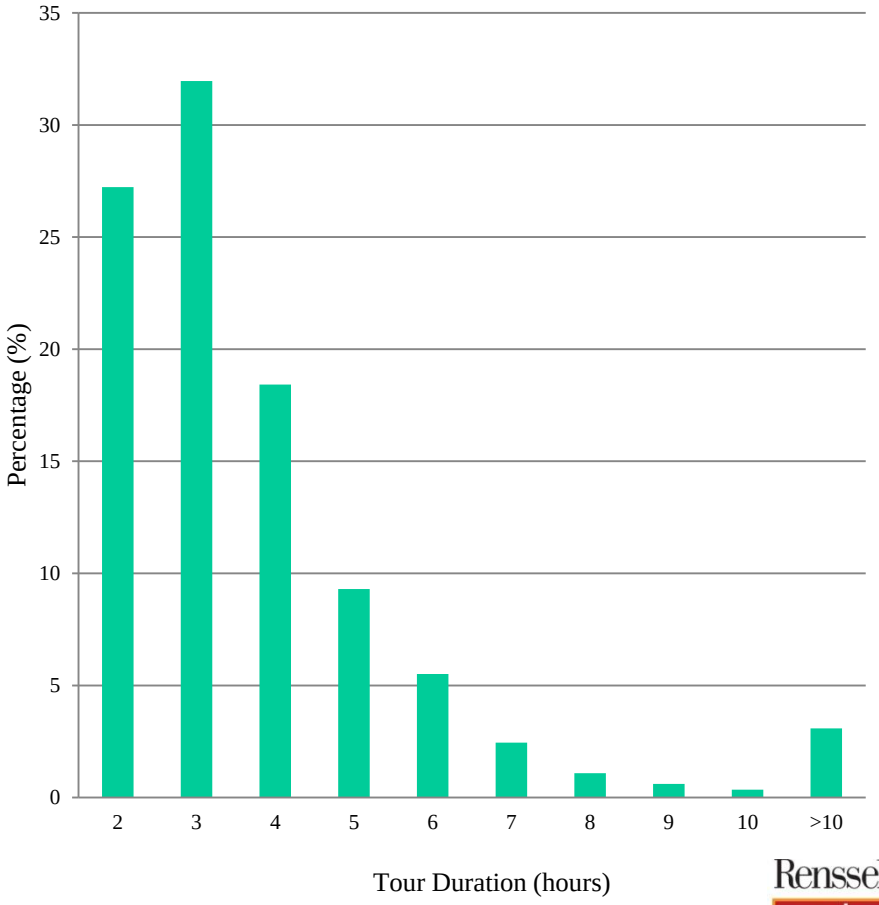
Results of tour identification

- There are 14886 tours in total in 2012;
- 3246 passing through at least one truck center or data have problems;
- 11640 tours which do not passing any truck centers;

- The average tour duration is **3.09** hours;
- the average total service time during a tour is **1.42** hours;
- the average number of delivery stops during a tour is **2.8**;
- The average service time per stop is **30** minutes;

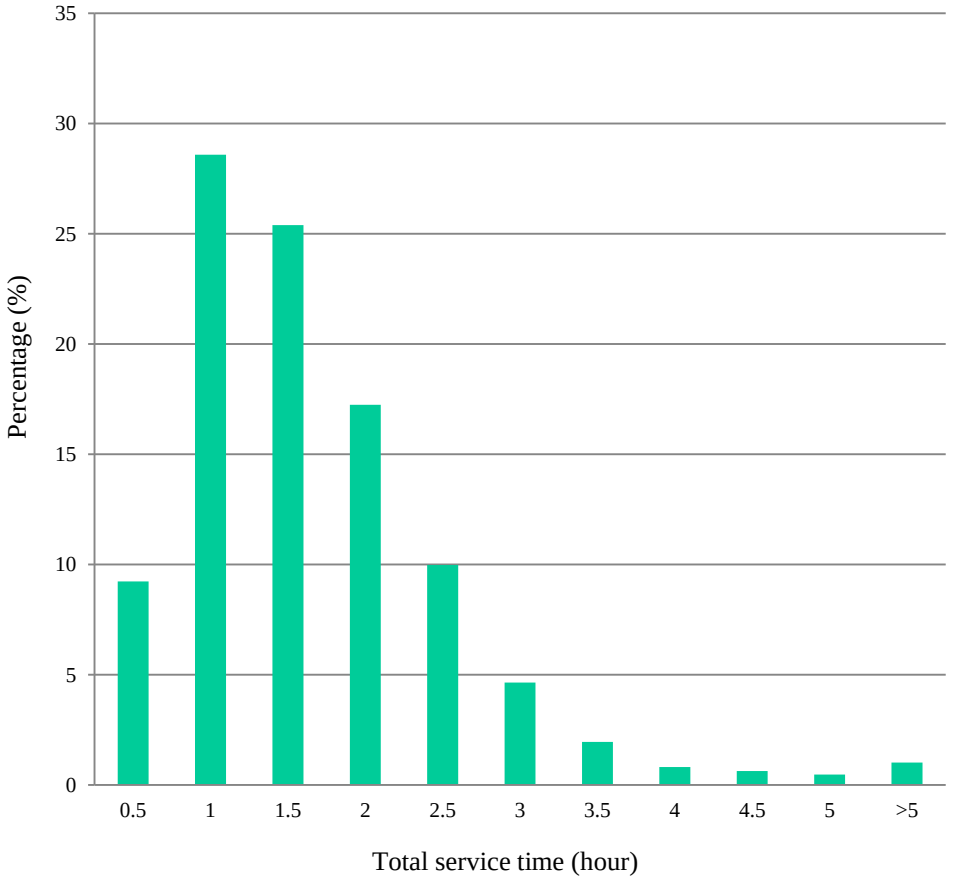
Distribution of tour duration

Tour Duration /Hour	Percentage	Accumulative Percentage
2	27.97	27.97
3	32.84	60.81
4	18.93	79.73
5	9.55	89.29
6	5.64	94.93
7	2.45	97.38
8	1.04	98.42
9	0.50	98.92
10	0.22	99.14
>10	0.86	100.00



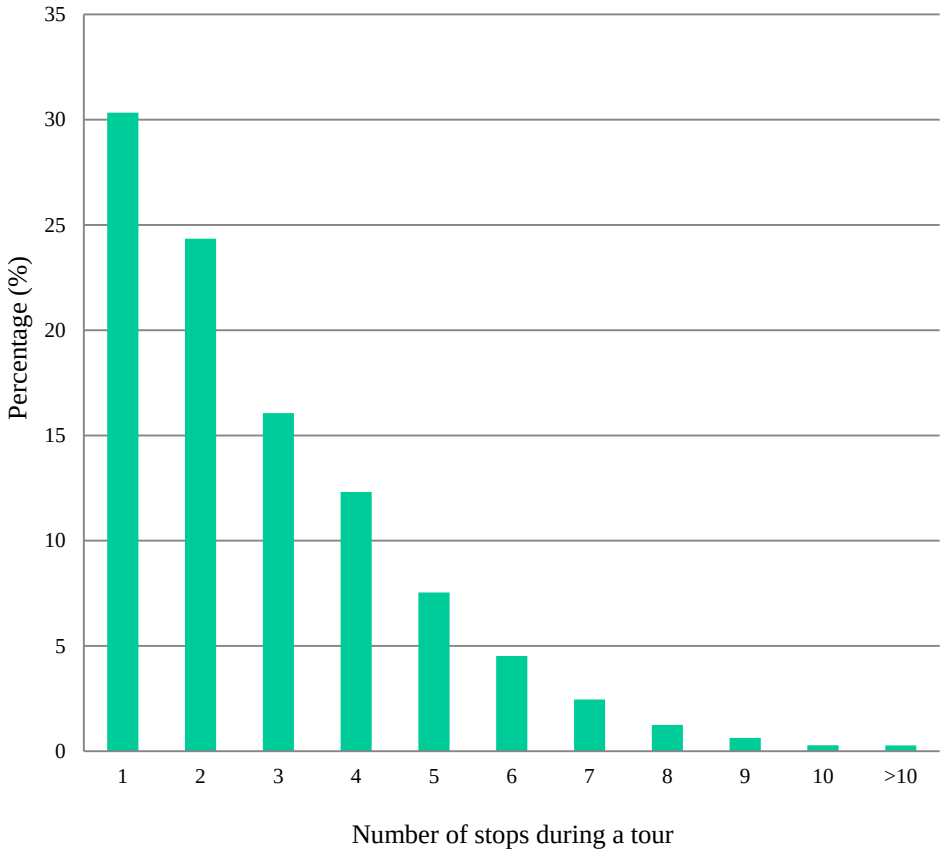
Service time (at a stop) distribution

Total Service Time	Percentage	Accumulative Percentage
0.5	9.24	9.24
1	28.59	37.83
1.5	25.40	63.22
2	17.24	80.46
2.5	9.98	90.45
3	4.65	95.09
3.5	1.96	97.05
4	0.82	97.87
4.5	0.64	98.51
5	0.47	98.98
>5	1.02	100.00

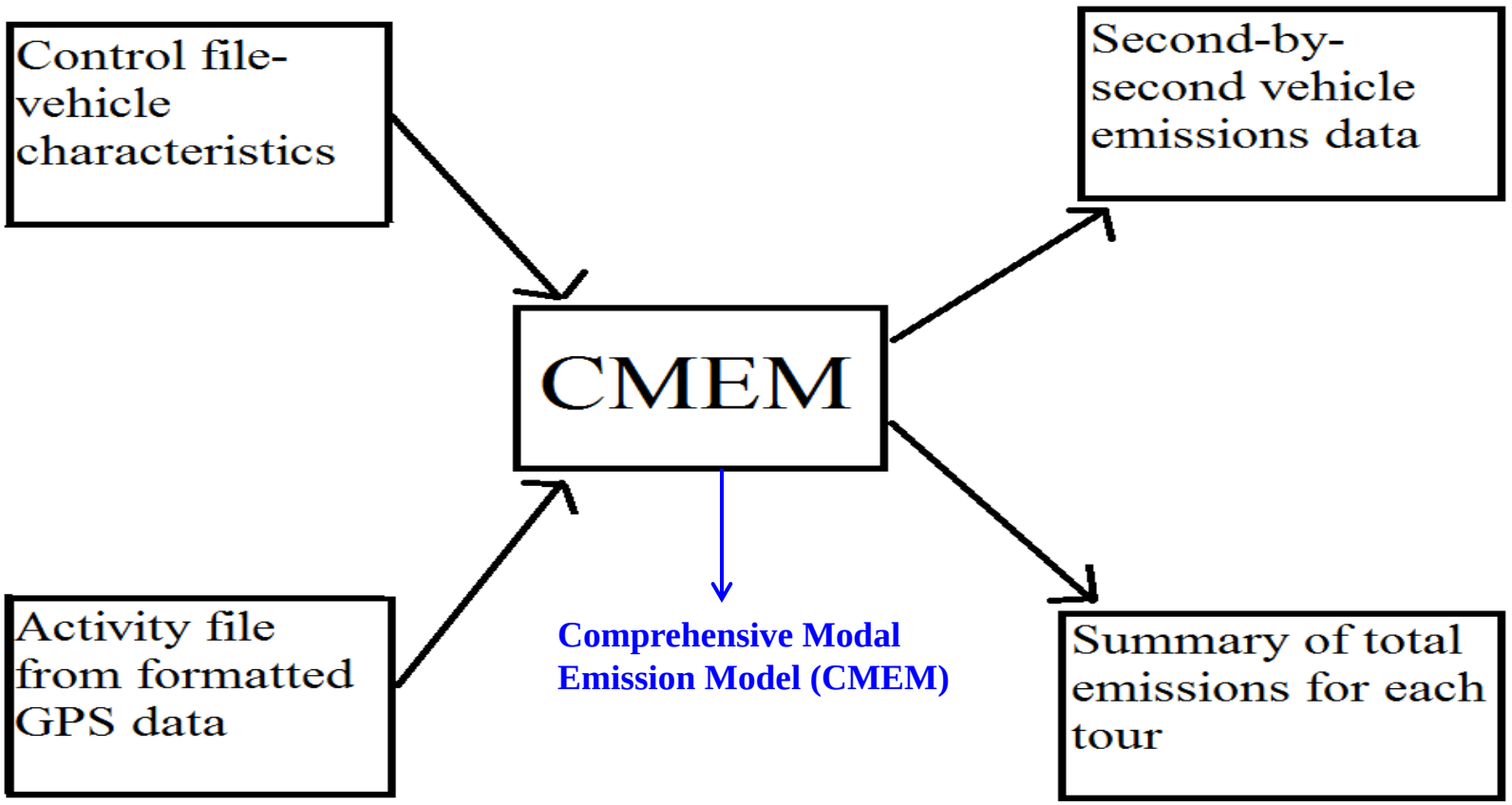


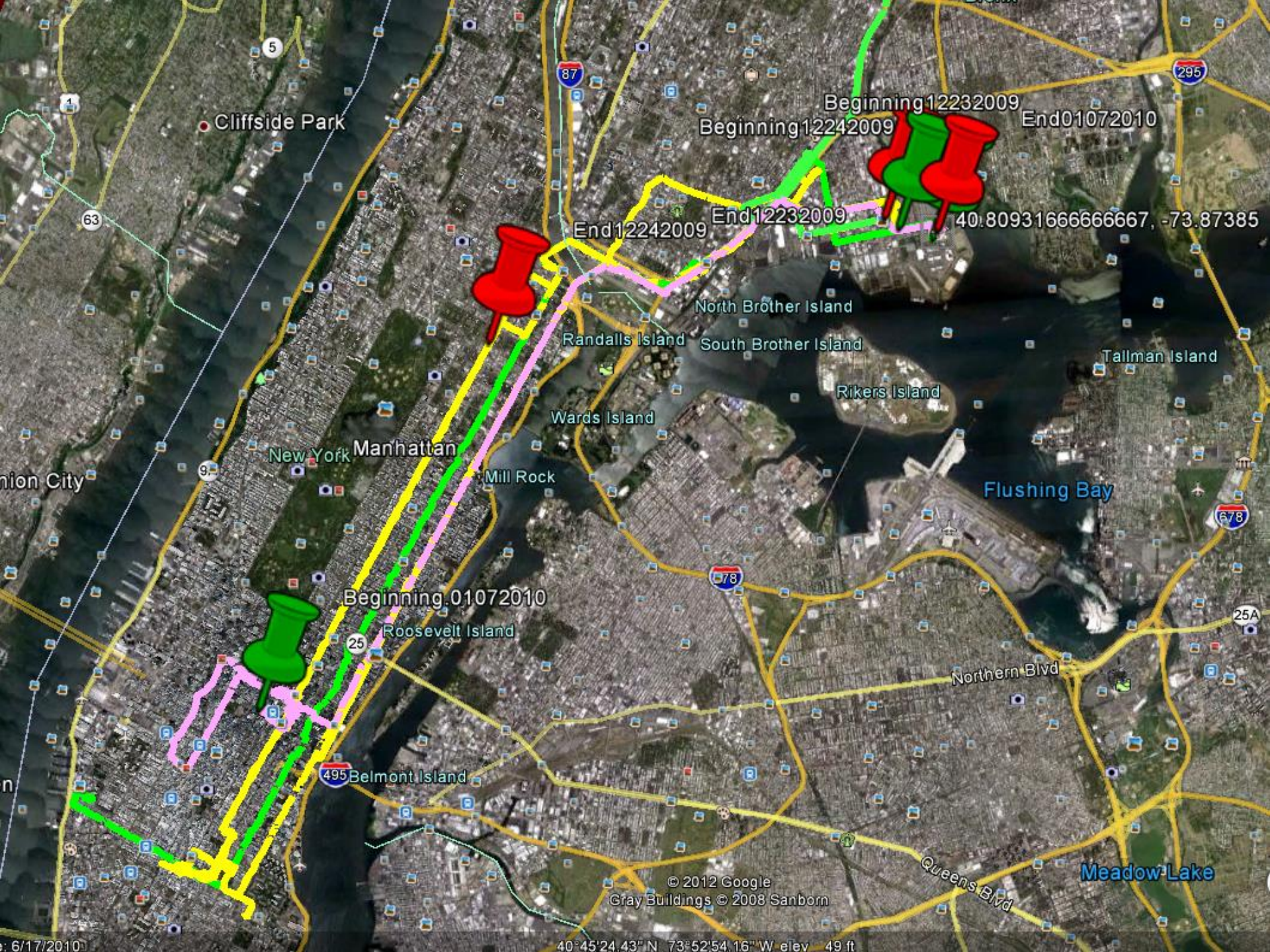
Distribution of number of stops during a tour

Number of Stops	Percentage	Accumulative Percentage
1	30.34	30.34
2	24.35	54.68
3	16.06	70.74
4	12.31	83.05
5	7.54	90.59
6	4.52	95.11
7	2.46	97.57
8	1.25	98.81
9	0.63	99.44
10	0.28	99.73
>10	0.27	100.00



Vehicle Emissions and Fuel Consumption




Beginning12232009
End01072010
Beginning12242009
End12232009
End12242009
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Cliffside Park
North Brother Island
Randalls Island
South Brother Island
Tallman Island
Rikers Island
Wards Island
New York
Manhattan
Mill Rock
Flushing Bay
Beginning.01072010
Roosevelt Island
Northern Blvd
Belmont Island
Queens Blvd
Meadow Lake
© 2012 Google
Gray Buildings © 2008 Sanborn
40°45'24.43" N 73°52'54.16" W elev 49 ft

Second by Second Emission/Fuel File

time	velocity	thcgs	tcogs	tnoxgs	fuelgs	tco2
1	6.11	0.007390	0.072551	0.000578	0.433584	1.236446
2	6.61	0.008992	0.104943	0.007976	0.632965	1.812619
3	7.11	0.008721	0.103174	0.007821	0.631849	1.812777
4	7.61	0.008484	0.101914	0.007780	0.633852	1.821913
5	8.65	0.010279	0.139453	0.016354	0.879909	2.537415
6	9.69	0.010272	0.144082	0.017700	0.929400	2.687167
7	10.73	0.010255	0.148672	0.019048	0.982191	2.847481
8	11.52	0.009289	0.134884	0.016355	0.915157	2.659764
9	12.31	0.009189	0.137322	0.017218	0.955195	2.783286
10	13.11	0.009070	0.139408	0.018012	0.995968	2.909754
11	13.66	0.008115	0.124492	0.015083	0.915951	2.682589
12	14.22	0.007944	0.124787	0.015466	0.943474	2.770014
13	14.78	0.007769	0.124882	0.015811	0.971848	2.860469
14	13.78	0.024088	0.060115	0.002151	0.483937	1.359206
15	12.77	0.004503	0.059145	0.002087	0.483674	1.426185
16	11.77	0.004392	0.058176	0.002057	0.483411	1.427249
17	11.47	0.004974	0.057208	0.002072	0.483148	1.425964
18	11.17	0.004177	0.056243	0.002054	0.482885	1.429344
19	10.86	0.004074	0.055279	0.002052	0.482623	1.430375
20	10.53	0.003973	0.054317	0.002051	0.482360	1.431396
21	10.20	0.003874	0.053357	0.002049	0.482098	1.432407
22	9.86	0.003777	0.052399	0.002048	0.481835	1.433407
23	9.72	0.003299	0.042178	0.000000	0.395066	1.175827
24	9.57	0.003204	0.040893	0.000000	0.388785	1.158242
25	9.42	0.003113	0.039642	0.000000	0.382552	1.140744
26	9.41	0.003167	0.041914	0.000000	0.410438	1.225456
27	9.39	0.003096	0.041157	0.000000	0.409586	1.224182
28	9.38	0.003026	0.040402	0.000000	0.408712	1.222833
29	8.23	0.010994	0.046717	0.002091	0.480270	1.412946
30	7.08	0.003164	0.045775	0.002035	0.480009	1.440098
31	6.03	0.003084	0.044835	0.002033	0.479748	1.441016
32	7.06	0.004383	0.076225	0.010600	0.830669	2.500526
33	8.09	0.004252	0.074599	0.010838	0.843163	2.543159
34	9.13	0.004217	0.074955	0.011670	0.880182	2.660154
35	8.95	0.008958	0.028910	0.000000	0.355148	1.050893
36	8.78	0.002159	0.027915	0.000000	0.348913	1.055686
37	8.61	0.002102	0.027022	0.000000	0.343633	1.040534
38	7.71	0.002478	0.036942	0.002023	0.477528	1.448430
39	6.82	0.002415	0.036030	0.002011	0.477268	1.449252
40	5.93	0.002353	0.035122	0.002008	0.477008	1.450063
41	6.26	0.002520	0.039706	0.003598	0.552939	1.683169
42	6.60	0.002446	0.038473	0.003454	0.552287	1.683294
43	6.93	0.000157	0.002356	0.001172	0.707226	2.239307
44	7.27	0.000157	0.002350	0.000060	0.706277	2.236307
45	7.60	0.000158	0.002359	0.000060	0.707581	2.240429
46	7.94	0.000159	0.002387	0.000061	0.711916	2.254132
47	9.64	0.000461	0.008477	0.003967	1.354857	4.283150
48	11.33	0.000539	0.010111	0.004560	1.482400	4.684925
49	13.03	0.000627	0.011966	0.005196	1.615790	5.104868
50	13.67	0.000372	0.006617	0.000348	1.194128	3.776494

```
Input Files
Control File:  sample-ctr
Activity File: C:\Users\Eric\

Using calculated acceleratior

VEHICLE_CATEGORY = 17

FuelType not specified
   Defaulting to 'Gasoline' ba


Condition Parameters
Tsoak       =          50
SH          =       80.00

Vehicle Parameters
Ed          =        3.42
Masslb      =     3937.50
Trlhp       =       17.99
S           =       33.56
Nm          =        2953
Qm          =      193.78
Zmax        =      149.98
Np          =        4603
Idle        =      850.00
ng          =           4
Sload       =        5.97

Calibrated Parameters
K_0         =      0.2152
Edt3        =      0.1000
CO          =      3.7651
aCO         =      0.0856
aHC         =      0.0100
rHC         =      0.0043
aNO1        =      0.0293
aNO2        =      0.0400
FRNO1       =     -0.4067
FRNO2       =      0.7421
MAXCO       =     99.9832
MAXHC       =     99.9423
MAXNO       =     99.8352
bCO         =      0.0559
cCO         =      1.2399
bHC         =      0.0189
cHC         =      0.3027
bNO         =      0.5541
cNO         =      2.3004
Lamb_0      =      1.2180
lam_m       =      0.2373
Pscale      =      1.2686
maxhc       =      0.0689
hc_jk       =      0.6545
r_R         =      0.5422
spd_th      =     14.4083
rO2         =     41.6012
COB1        =     28.2663
HCB1        =     18.8802
NOB1        =     15.1104
lam_cold    =      1.1144
CSHC        =      3.9831
CSNO        =      3.9917
CSNO        =      3.9917
Tlamb       =   100.1827
id          =      0.1242
Csoak_co    =   176.7746
Csoak_hc    =      0.0115
Csoak_no    =   399.9964
Bcat_co     =    30.6649
Bcat_hc     =   239.9966
Bcat_no     =      7.1501
Edt1        =      0.8882
NH3_b       =   100.0000
NH3_s1      =      2.0000
NH3_s2      =      3.4000
NH3_i       =      0.0450


Distance Traveled
550.87 miles


Fuel Use
7.6060      (grams/mile)


Engine Out Emissions
ECO2 =     14.8935 (grams/mile)
EHC  =      0.0829 (grams/mile)
ECO  =      5.6983 (grams/mile)
ENOx =      0.3323 (grams/mile)


Tailpipe Out Emissions
TCO2 =     15.6380 (grams/mile)
TCO  =      5.3149 (grams/mile)
THC  =      0.0409 (grams/mile)
TNOx =      0.0487 (grams/mile)

NH3  =      0.0000 (grams/mile)

CO2  =   8614.5015 (grams)
CO   =   2927.8350 (grams)
HC   =     22.5429 (grams)
NOx  =     26.8275 (grams)
```

Performance Measure Results

Performance Measure	Tour 1	Tour 2	Tour 3
Tour Duration	29762 seconds	3765 seconds	3660 seconds
Traffic Stops	29	18	7
Average Segment Time	2611 Seconds	3765 seconds	1316 seconds
Average Speed (MPH)	11.01	12.21	15.91
Delivery Stops	2	1	1
Average Service Time	10963 seconds	Unknown+	1029 seconds
Complete Tour?	Yes	No	No
CO2 (grams)*	18268	8358	7701
Fuel (gallons)*	2.14	0.96	0.90
Fuel Efficiency (MPG)*	10.31	11.30win	12.86

Summary and Future Research

- GPS data are very valuable for urban freight performance measurement (for both mobility and environmental related measures)
- Caution should be made when using GPS data: the data may be incomplete and/or contain errors, and more importantly, there is no behavioral explanations on why certain things happened.
- Data mining techniques are very helpful to process/ clean GPS data, which should also properly integrate well-established transportation knowledge/principles

- Thanks

- Questions or Comments?