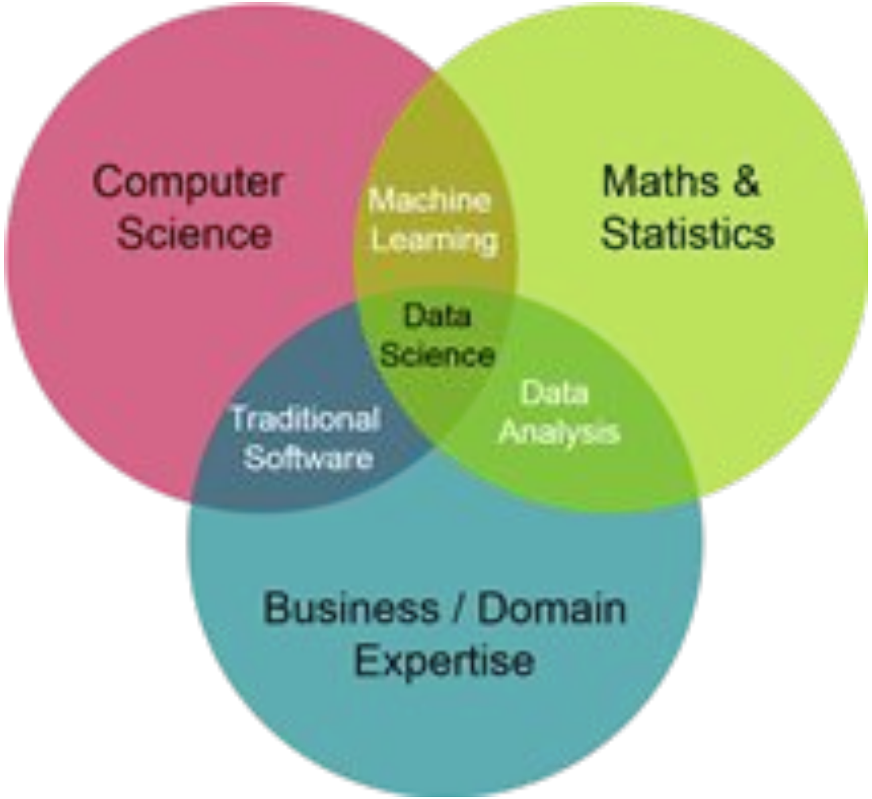
Big Data and Math Modeling:

Using Python to Analyze The NYC Subway System

Lauren Shareshian

What is Data Science?



Tons of Data Science education is popping up

From the expensive bootcamps:

Metis: https://www.thisismetis.com/

Galvanize: https://www.galvanize.com

UCSD: https://bootcamp.extension.ucsd.edu/data/

To the free online materials:

UC Berkeley: http://data8.org/

What is Big Data?

- Volume - Lots of it
- Velocity - New data continuously coming in
- Variety - Data comes in all types of formats

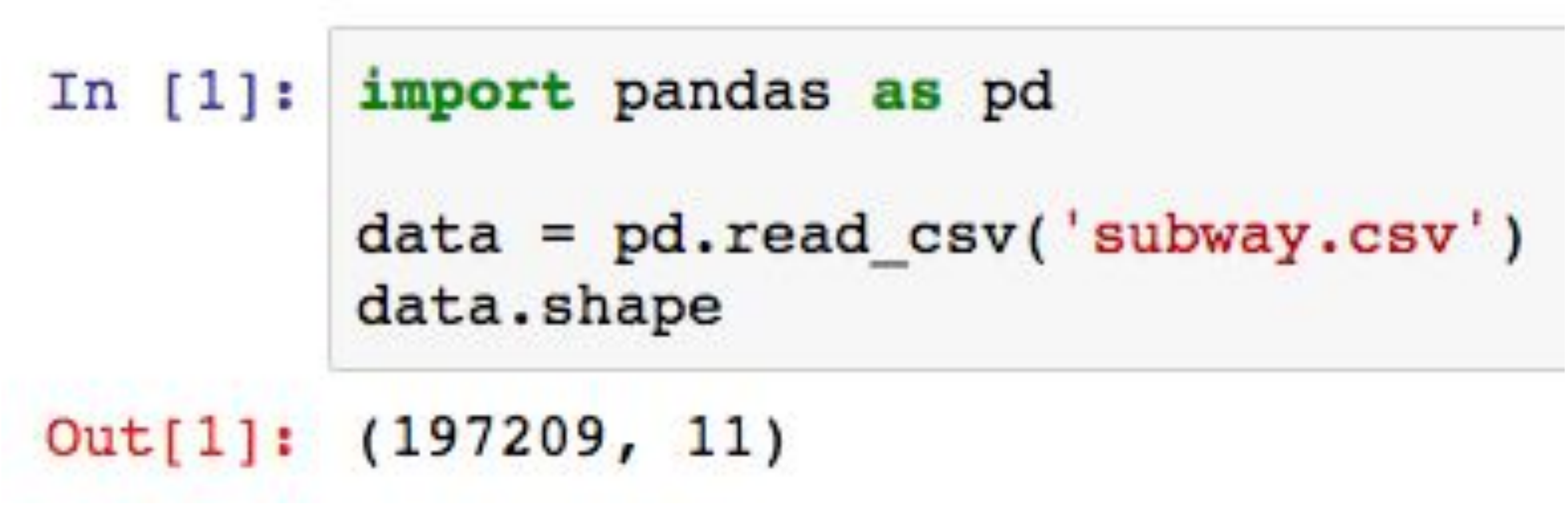
"Big data" refers to the **use of analytics to extract value** from data, and seldom to a particular size of data set.

MTA NYC Subway Data Set

- Publicly available
- Published weekly
- Info on entries/exits through every turnstile in 4 hour intervals

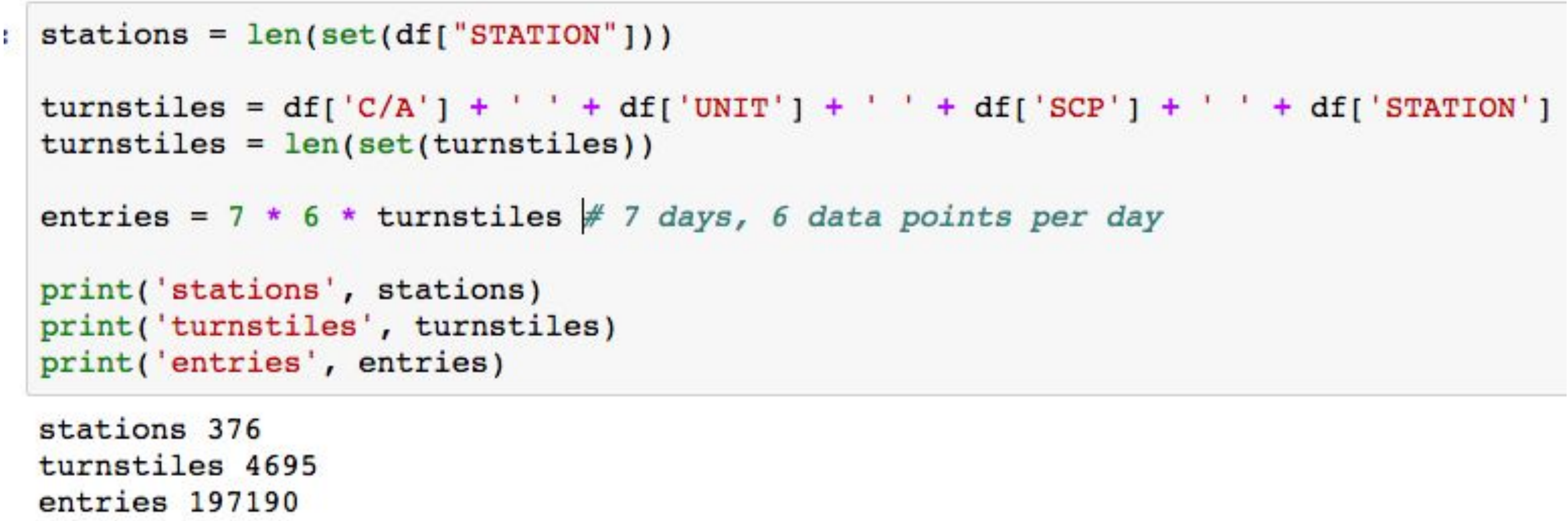
http://web.mta.info/developers/turnstile.html

How big is the data set?



```
In [1]: import pandas as pd

        data = pd.read_csv('subway.csv')
        data.shape

Out[1]: (197209, 11)
```

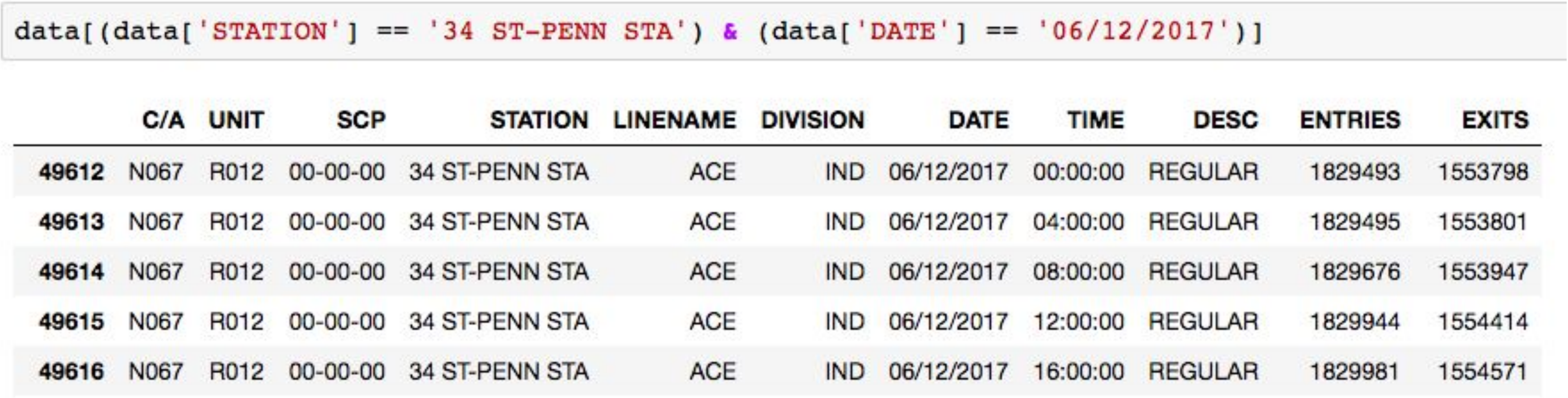
How do we get 197,209 entries?



```
stations = len(set(df["STATION"]))

turnstiles = df['C/A'] + ' ' + df['UNIT'] + ' ' + df['SCP'] + ' ' + df['STATION']
turnstiles = len(set(turnstiles))

entries = 7 * 6 * turnstiles # 7 days, 6 data points per day

print('stations', stations)
print('turnstiles', turnstiles)
print('entries', entries)
```

```
stations 376
turnstiles 4695
entries 197190
```

What does the data set look like?



```
data[(data['STATION'] == '34 ST-PENN STA') & (data['DATE'] == '06/12/2017')]
```

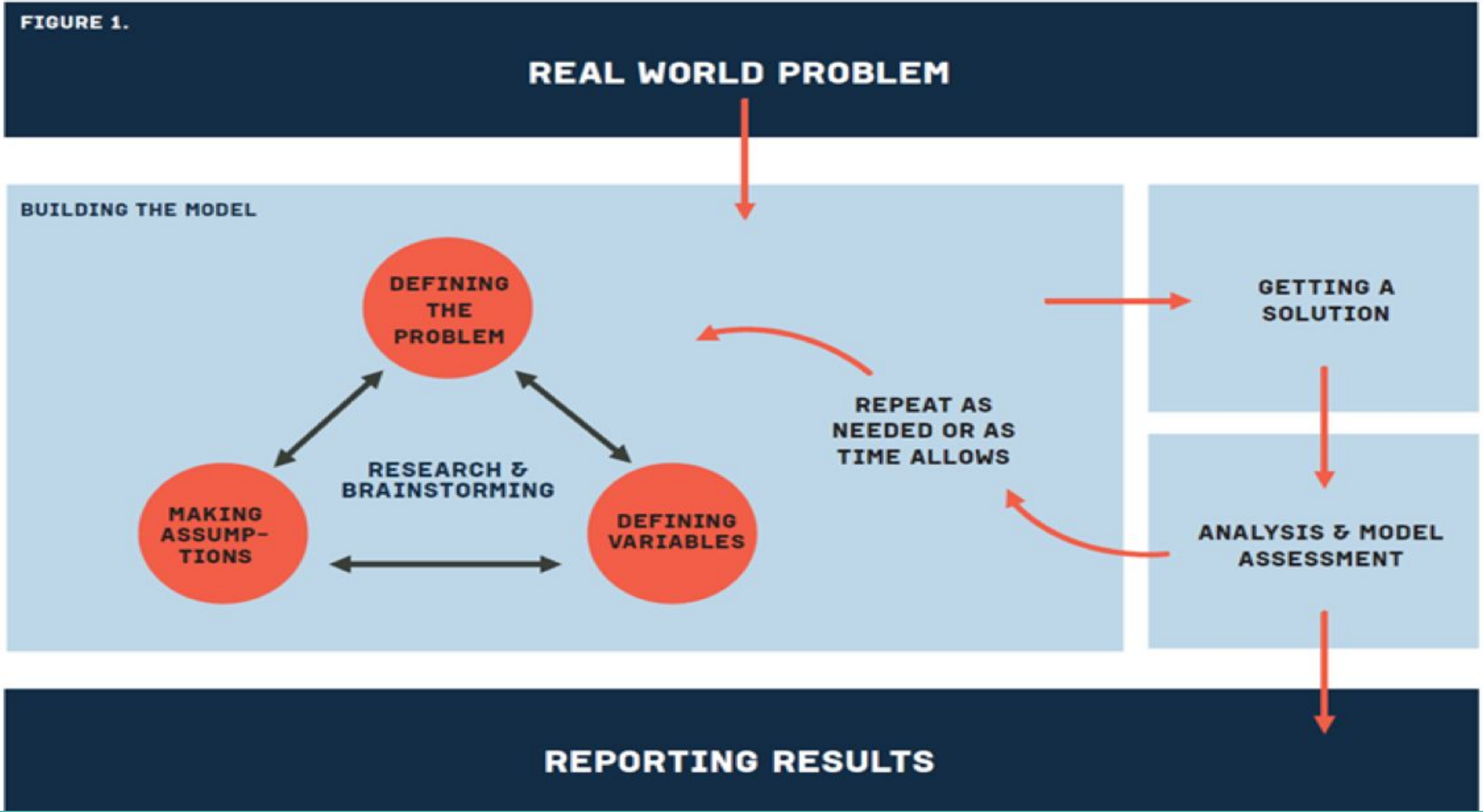
	C/A	UNIT	SCP	STATION	LINENAME	DIVISION	DATE	TIME	DESC	ENTRIES	EXITS
49612	N067	R012	00-00-00	34 ST-PENN STA	ACE	IND	06/12/2017	00:00:00	REGULAR	1829493	1553798
49613	N067	R012	00-00-00	34 ST-PENN STA	ACE	IND	06/12/2017	04:00:00	REGULAR	1829495	1553801
49614	N067	R012	00-00-00	34 ST-PENN STA	ACE	IND	06/12/2017	08:00:00	REGULAR	1829676	1553947
49615	N067	R012	00-00-00	34 ST-PENN STA	ACE	IND	06/12/2017	12:00:00	REGULAR	1829944	1554414
49616	N067	R012	00-00-00	34 ST-PENN STA	ACE	IND	06/12/2017	16:00:00	REGULAR	1829981	1554571

How does this relate to math modeling?

From this data set we can ask questions that are:

- Interesting
- Purposeful (**extracts value**)
- Collaborative
- Allow for a variety of solutions
- Open ended

FIGURE 1.



REAL WORLD PROBLEM

BUILDING THE MODEL

DEFINING THE PROBLEM

MAKING ASSUMPTIONS

DEFINING VARIABLES

RESEARCH & BRAINSTORMING

REPEAT AS NEEDED OR AS TIME ALLOWS

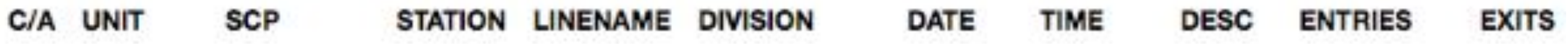
GETTING A SOLUTION

ANALYSIS & MODEL ASSESSMENT

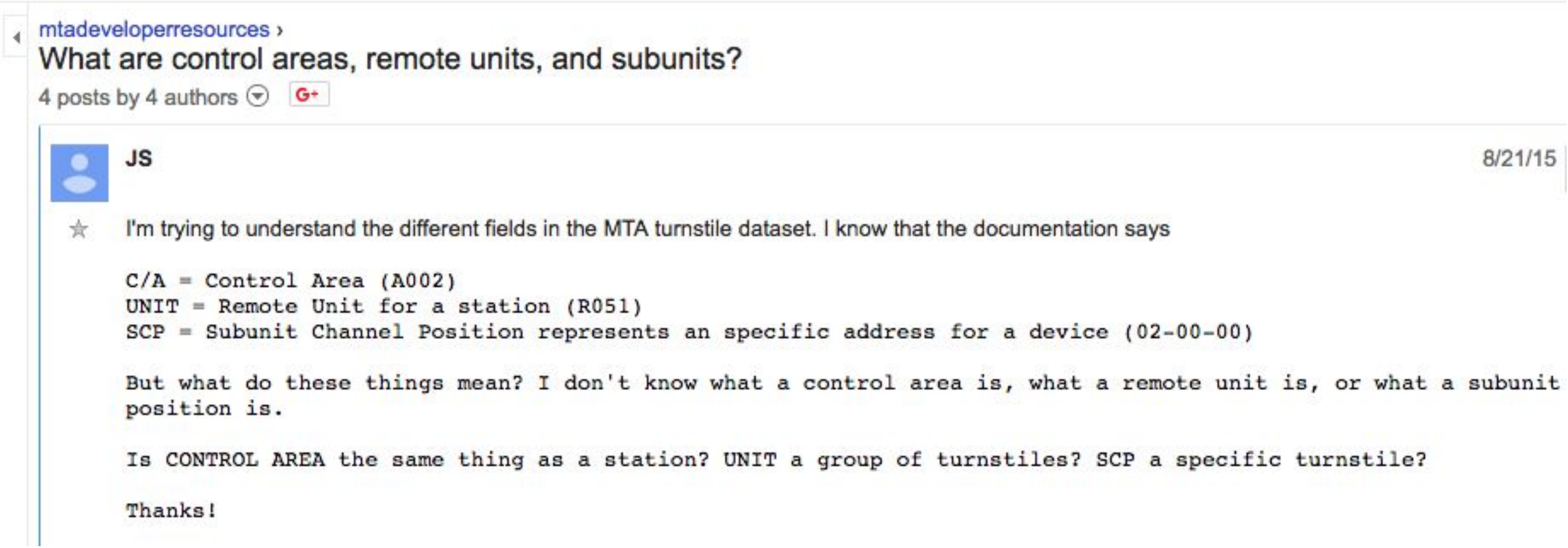
REPORTING RESULTS

What are those variables?

Skills developed: Research skills, resourcefulness



C/A	UNIT	SCP	STATION	LINENAME	DIVISION	DATE	TIME	DESC	ENTRIES	EXITS



mtadeveloperresources ›

What are control areas, remote units, and subunits?

4 posts by 4 authors

JS 8/21/15

I'm trying to understand the different fields in the MTA turnstile dataset. I know that the documentation says

```
C/A = Control Area (A002)
UNIT = Remote Unit for a station (R051)
SCP = Subunit Channel Position represents an specific address for a device (02-00-00)
```

But what do these things mean? I don't know what a control area is, what a remote unit is, or what a subunit position is.

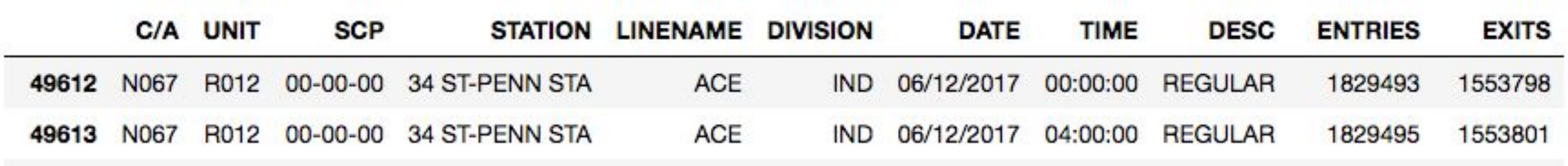
Is CONTROL AREA the same thing as a station? UNIT a group of turnstiles? SCP a specific turnstile?

Thanks!

What are those variables telling me?

Skills developed: Number Sense

Did 1,829,493 people enter through a Penn Station turnstile at midnight?



	C/A	UNIT	SCP	STATION	LINENAME	DIVISION	DATE	TIME	DESC	ENTRIES	EXITS
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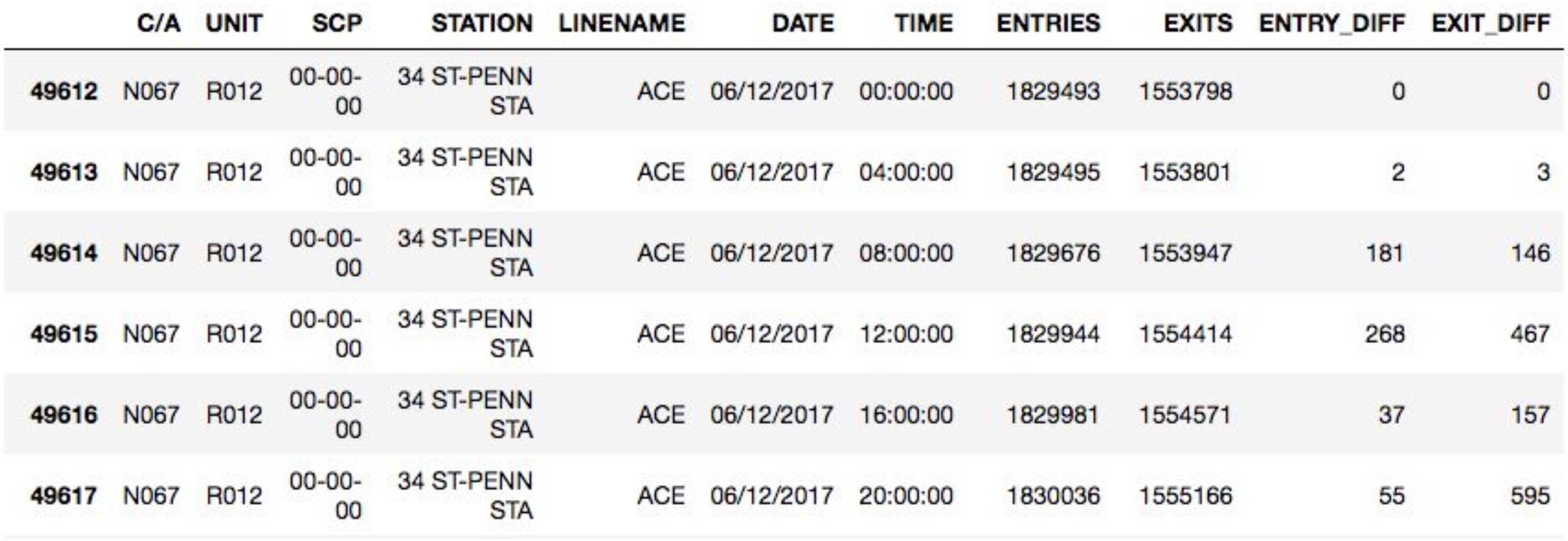
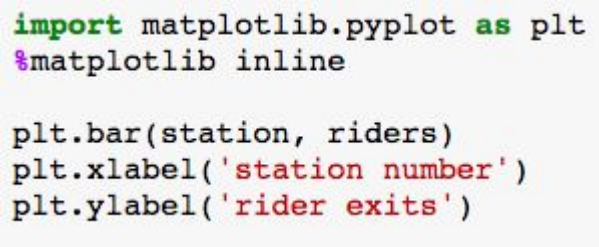
49613	N067	R012	00-00-00	34 ST-PENN STA	ACE	IND	06/12/2017	04:00:00	REGULAR	1829495	1553801

Put the data in a form we can work with



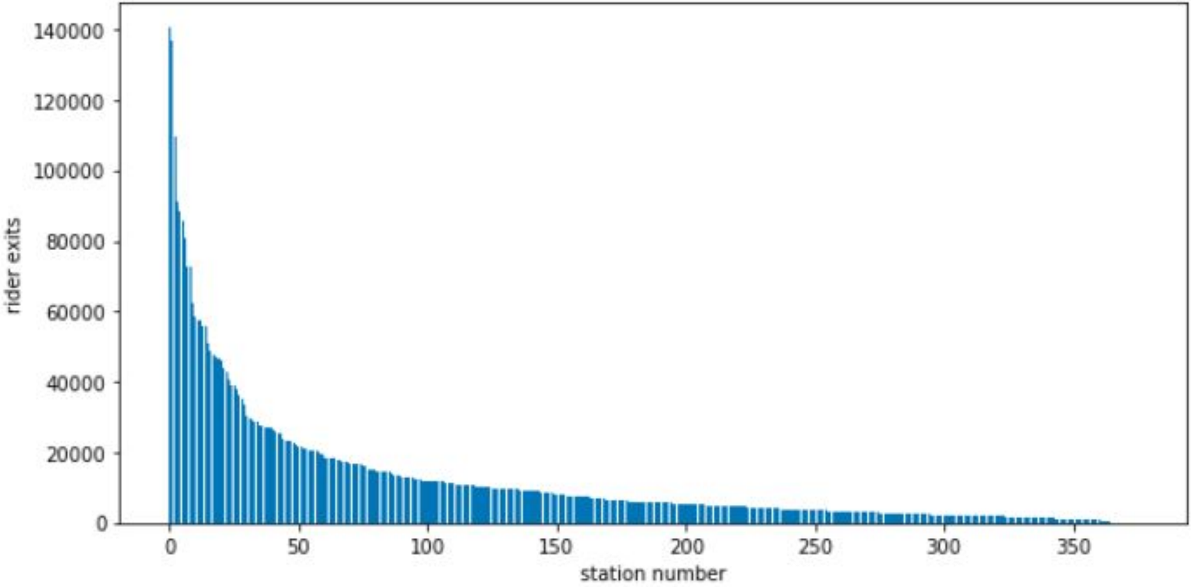
	C/A	UNIT	SCP	STATION	LINENAME	DATE	TIME	ENTRIES	EXITS	ENTRY_DIFF	EXIT_DIFF
49612	N067	R012	00-00-00	34 ST-PENN STA	ACE	06/12/2017	00:00:00	1829493	1553798	0	0
49613	N067	R012	00-00-00	34 ST-PENN STA	ACE	06/12/2017	04:00:00	1829495	1553801	2	3
49614	N067	R012	00-00-00	34 ST-PENN STA	ACE	06/12/2017	08:00:00	1829676	1553947	181	146
49615	N067	R012	00-00-00	34 ST-PENN STA	ACE	06/12/2017	12:00:00	1829944	1554414	268	467
49616	N067	R012	00-00-00	34 ST-PENN STA	ACE	06/12/2017	16:00:00	1829981	1554571	37	157
49617	N067	R012	00-00-00	34 ST-PENN STA	ACE	06/12/2017	20:00:00	1830036	1555166	55	595

Riders on Monday, June 12, 2017

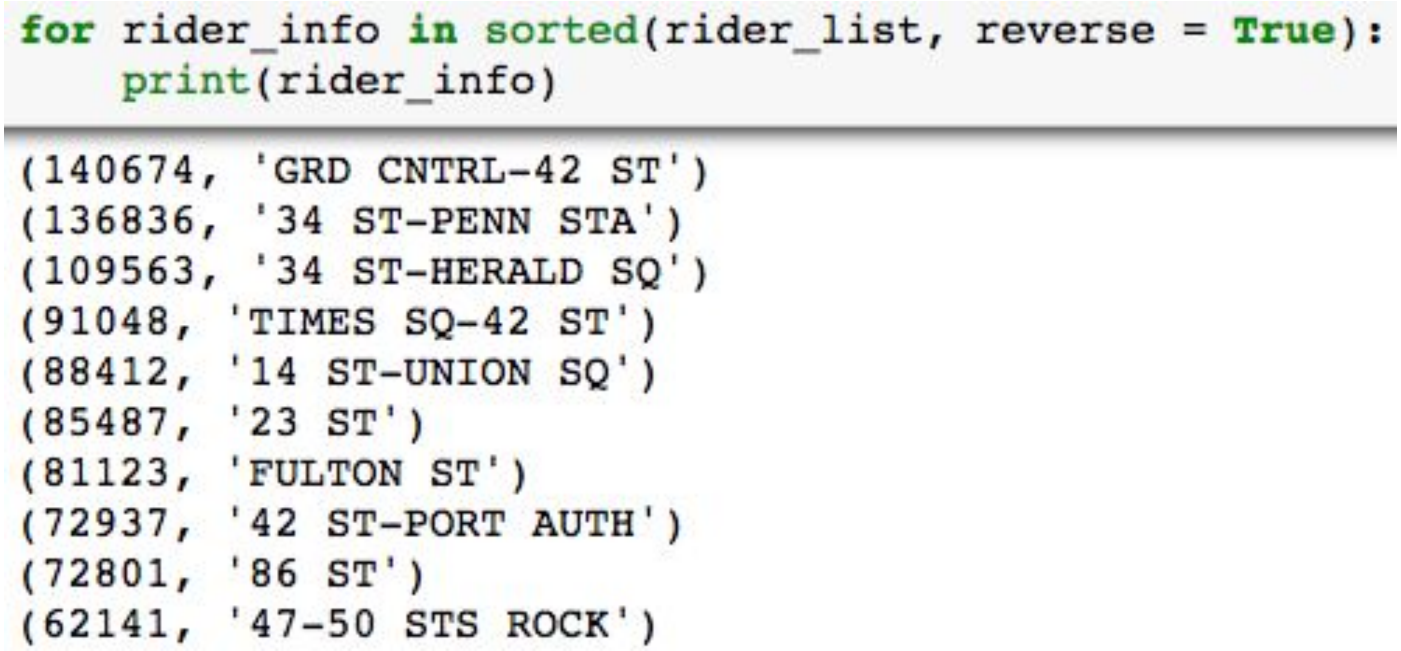


```
import matplotlib.pyplot as plt
%matplotlib inline

plt.bar(station, riders)
plt.xlabel('station number')
plt.ylabel('rider exits')
```



What were the busiest stations?



```
for rider_info in sorted(rider_list, reverse = True):
    print(rider_info)
```

```
(140674, 'GRD CNTRL-42 ST')
(136836, '34 ST-PENN STA')
(109563, '34 ST-HERALD SQ')
(91048, 'TIMES SQ-42 ST')
(88412, '14 ST-UNION SQ')
(85487, '23 ST')
(81123, 'FULTON ST')
(72937, '42 ST-PORT AUTH')
(72801, '86 ST')
(62141, '47-50 STS ROCK')
```

Modeling Task

Coding Chicks has an annual gala this summer. Please help us **optimize the placement** of our street teams in the subway. Our goal is to gather the most contact info from those who will **attend the gala and donate**.

We have **ten volunteers** to advertise in the subway for **four hours each** per day (in one four-hour shift or in 2 two-hour shifts). They can help **seven days** in a row, so we plan on doing all of our advertising during one seven-day blitz.

Please give us a clear, detailed presentation outlining your suggestions. **We will hire the most compelling business solution.**

Lots of complexity to consider

1. Focusing on where women in technology are located.

2. Focusing on where wealthier donors are located.

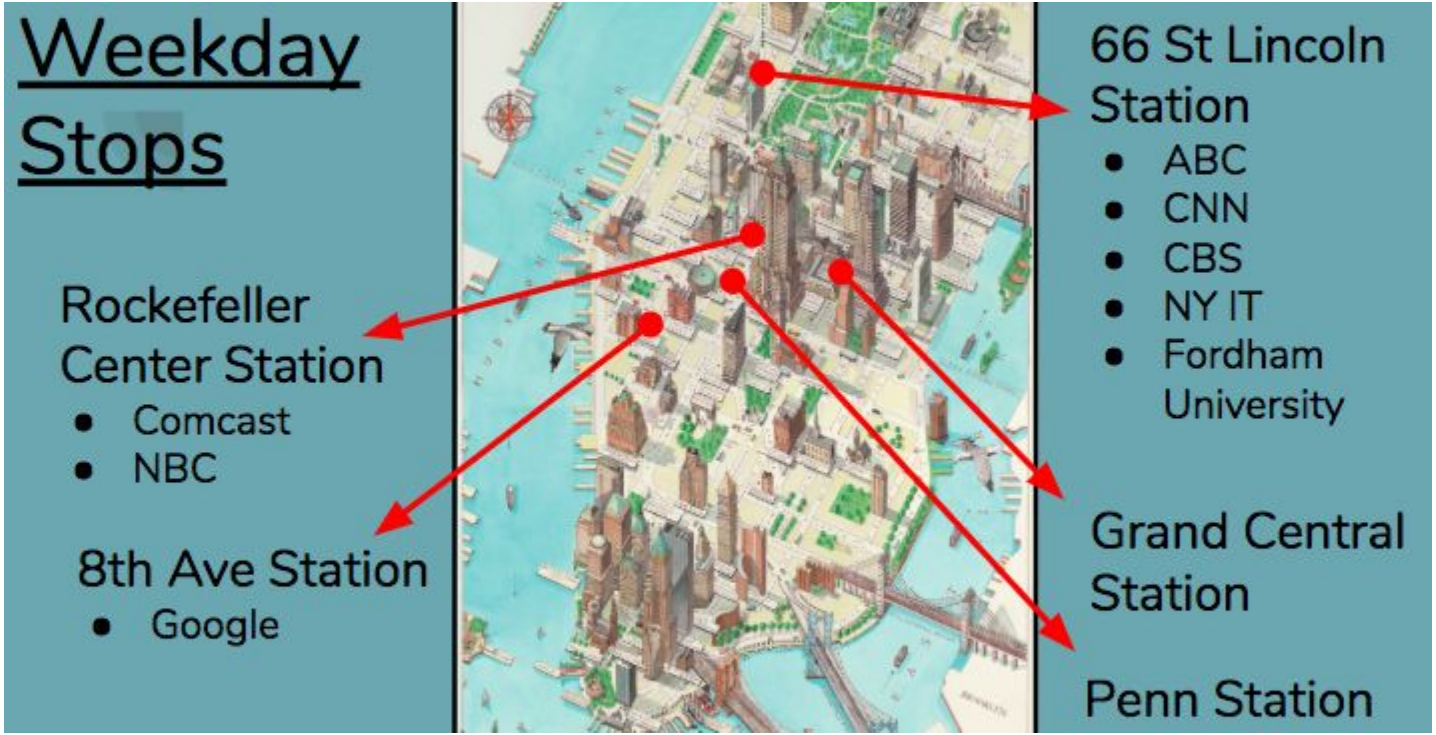
3. Differentiating between weekday and weekend placement.

4. Differentiating between what subway turnstile entries versus exits tell you.

5. Differentiating between morning and evening placement.

6. Differentiating between tourist and commuter stops.

Student Work #1: Focusing on tech hubs



Weekday Stops

Rockefeller Center Station

- Comcast
- NBC

8th Ave Station

- Google

66 St Lincoln Station

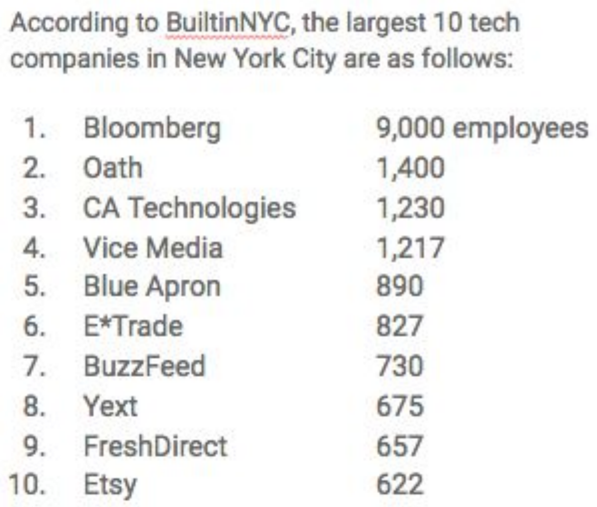
- ABC
- CNN
- CBS
- NY IT
- Fordham University

Grand Central Station

Penn Station

Student Work #2: Focusing on tech hubs

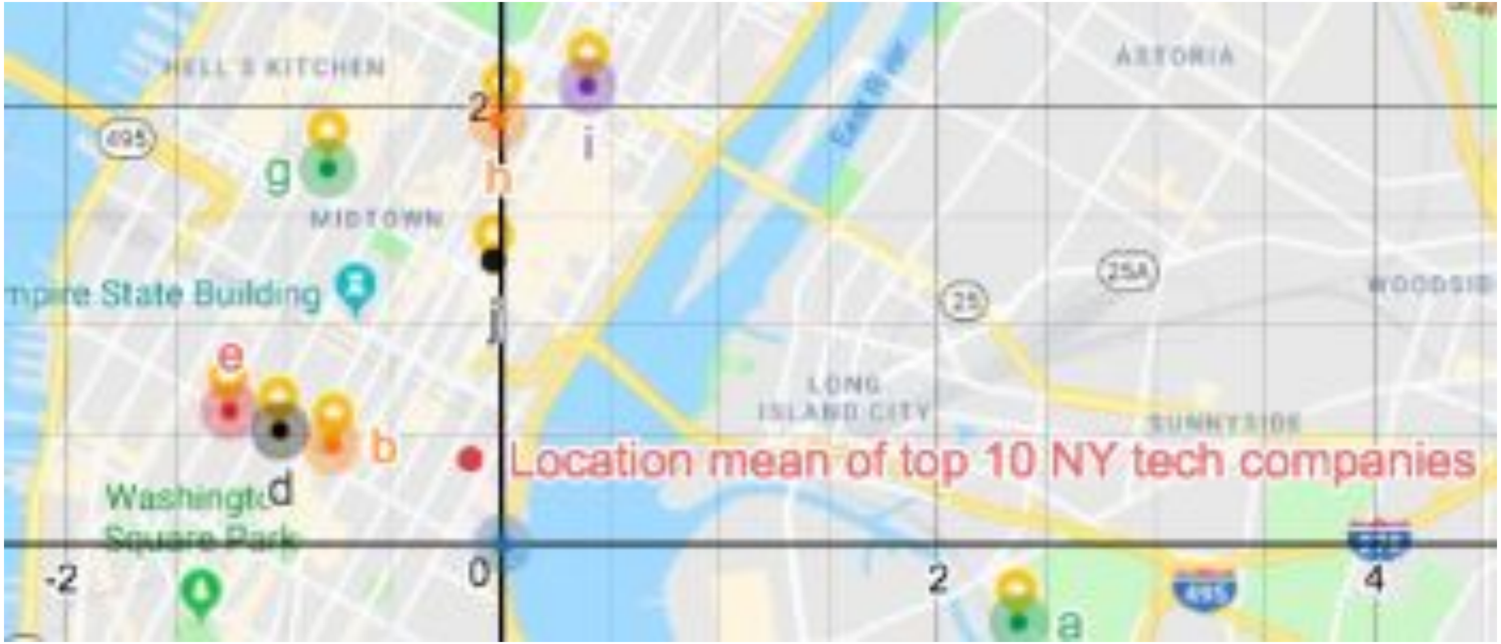
Initial Research



According to BuiltinNYC, the largest 10 tech companies in New York City are as follows:

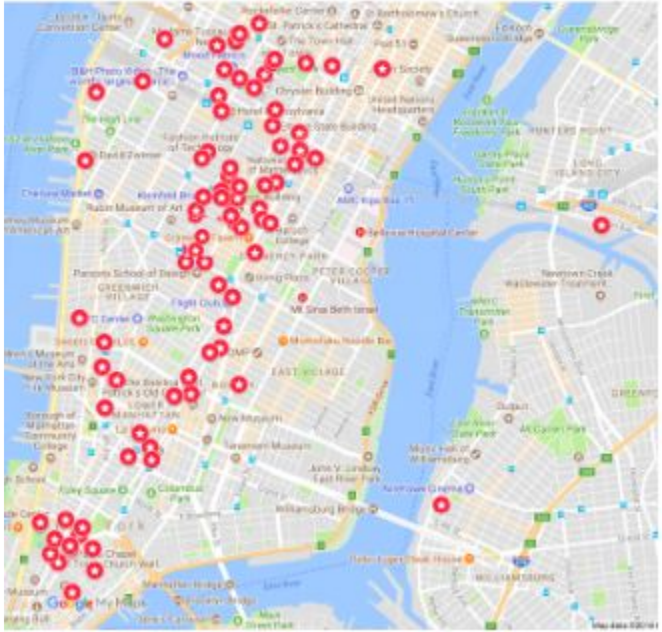
1.	Bloomberg	9,000 employees
2.	Oath	1,400
3.	CA Technologies	1,230
4.	Vice Media	1,217
5.	Blue Apron	890
6.	E*Trade	827
7.	BuzzFeed	730
8.	Yext	675
9.	FreshDirect	657
10.	Etsy	622

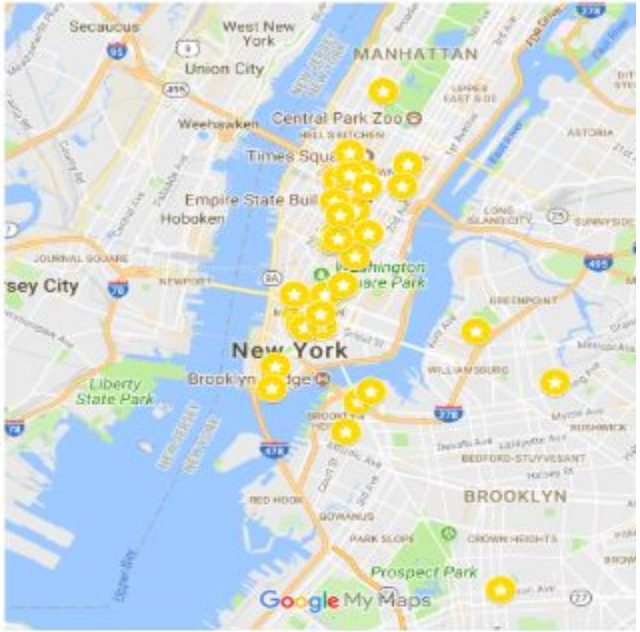
Student Work #2: Focusing on tech hubs



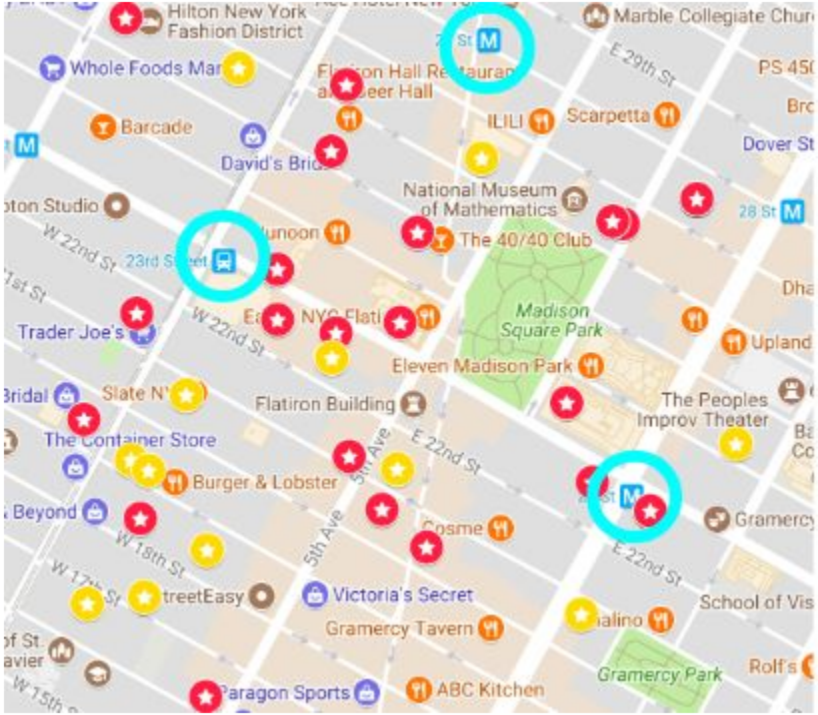
Student Work #3: Focusing on tech hubs

Established VS Startups





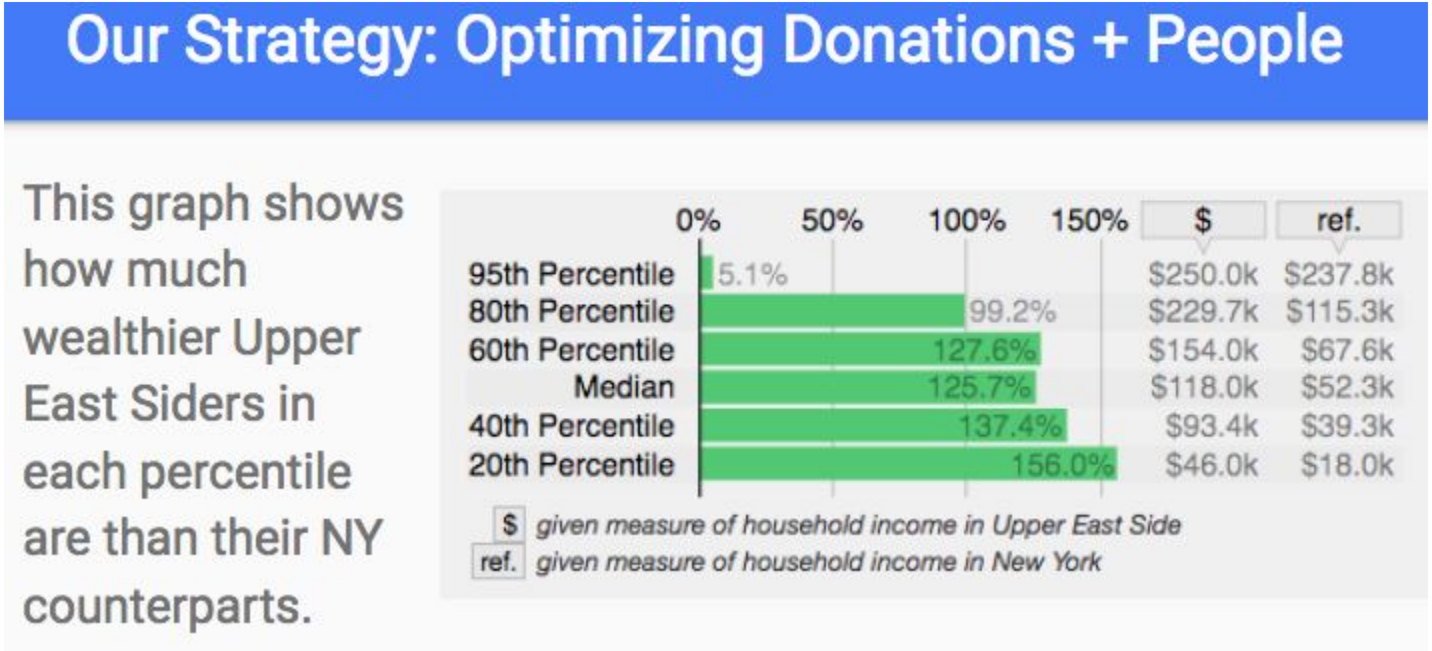
Student Work #3: Focusing on tech hub



STATIONS

- 23rd St
- 28th St

Student Work: Focusing on Wealthier Donors



Our Strategy: Optimizing Donations + People

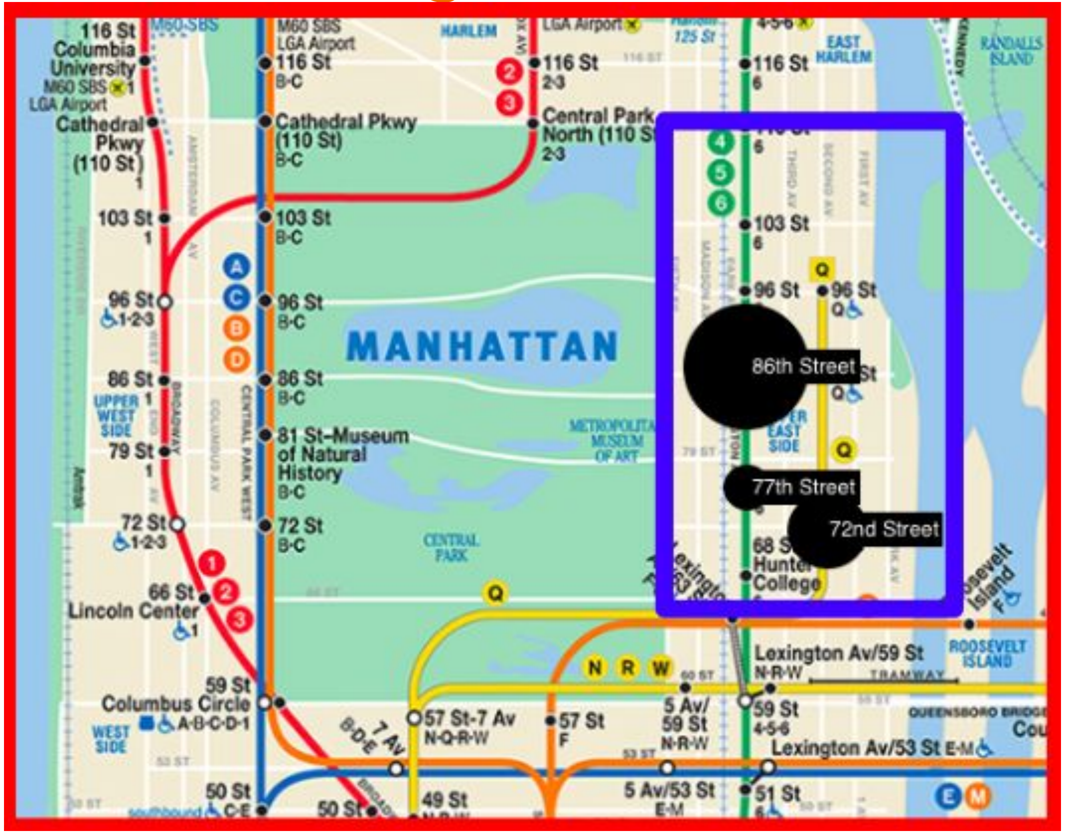
This graph shows how much wealthier Upper East Siders in each percentile are than their NY counterparts.

0%
50%
100%
150%
$
ref.
95th Percentile 5.1% $250.0k $237.8k
80th Percentile 99.2% $229.7k $115.3k
60th Percentile 127.6% $154.0k $67.6k
Median 125.7% $118.0k $52.3k
40th Percentile 137.4% $93.4k $39.3k
20th Percentile 156.0% $46.0k $18.0k

$ *given measure of household income in Upper East Side*

ref. *given measure of household income in New York*

Student Work: Focusing on Weekends



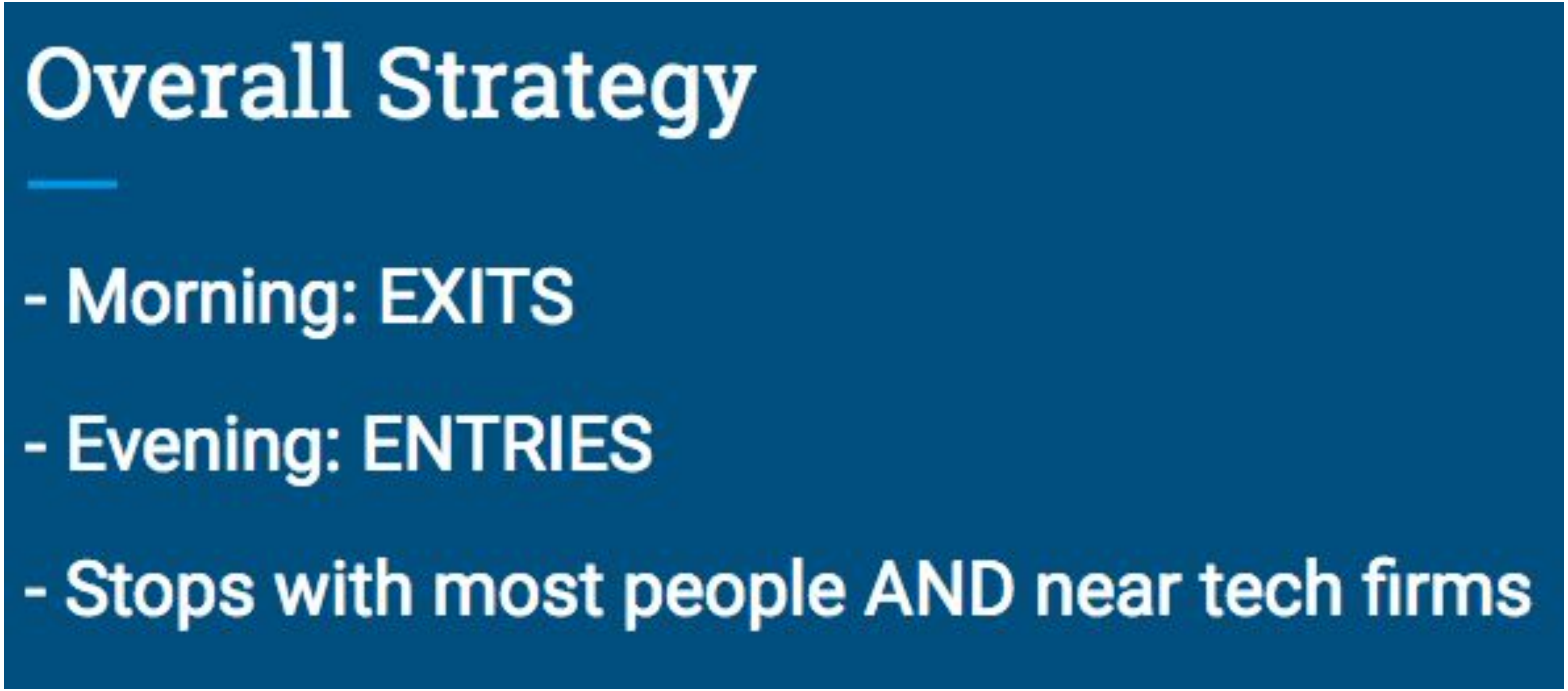
Huge Debate: Subway entrances vs. exits

- What about the stations that have separate entrances and exits?

- **Targeting entrances:** riders will have time to read pamphlets on train
- But will they be in too much of a rush to make the train?

- **Targeting exits:** riders won't be in a rush to make the train
- But will they not be willing to stay and chat?

Student work: Subway entrances vs. exits



Overall Strategy

- Morning: EXITS

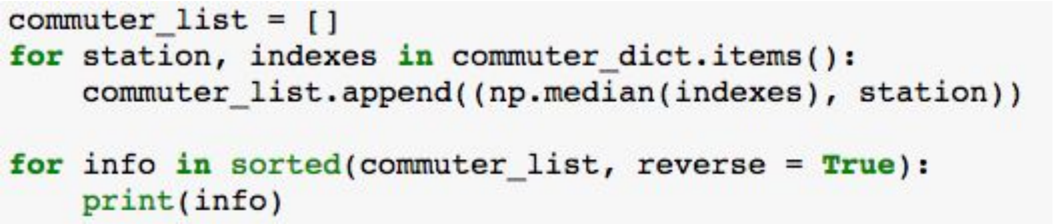
- Evening: ENTRIES

- Stops with most people AND near tech firms

Student Work: Finding commuter stops

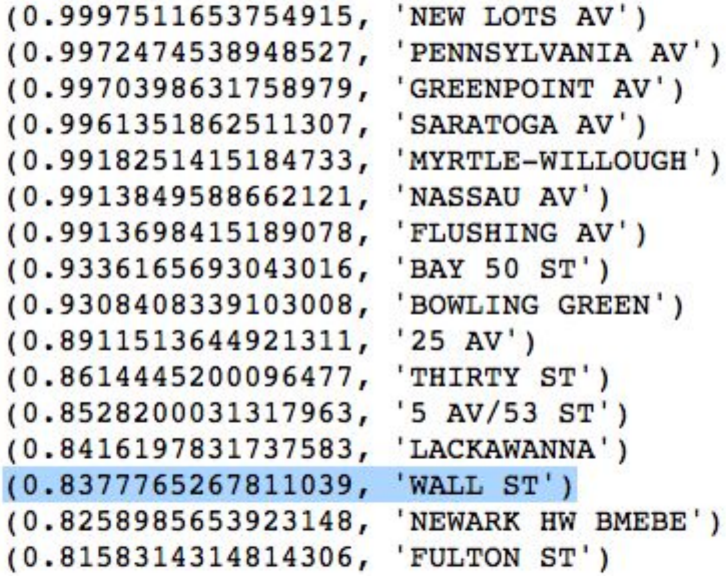
$$\text{CommuterIndex} = \frac{\text{Weekday Avg}}{\text{Weekday Avg} + \text{Weekend Avg}}$$

Top commuter exits



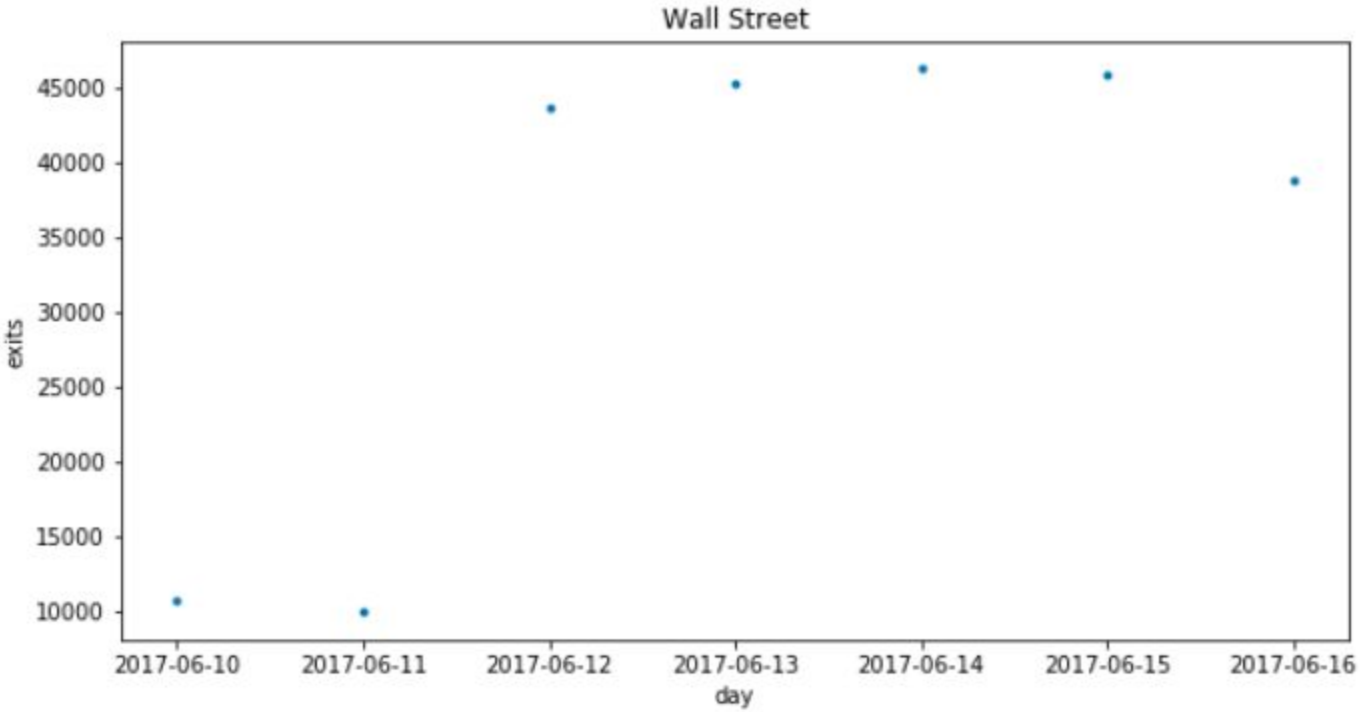
```
commuter_list = []
for station, indexes in commuter_dict.items():
    commuter_list.append((np.median(indexes), station))

for info in sorted(commuter_list, reverse = True):
    print(info)
```

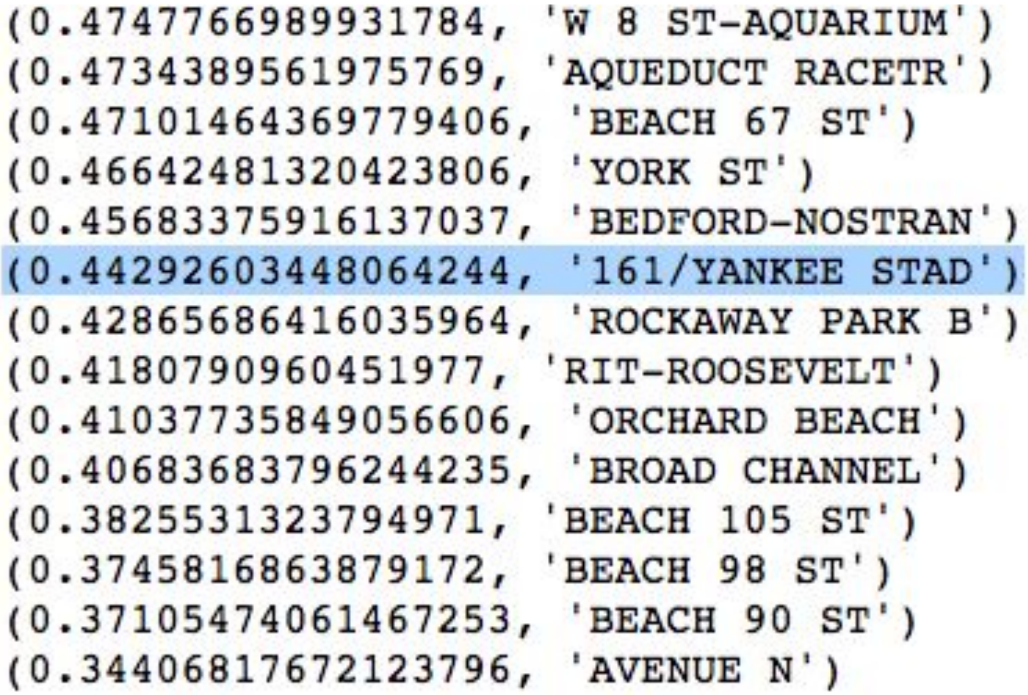


```
(0.9997511653754915, 'NEW LOTS AV')
(0.9972474538948527, 'PENNSYLVANIA AV')
(0.9970398631758979, 'GREENPOINT AV')
(0.9961351862511307, 'SARATOGA AV')
(0.9918251415184733, 'MYRTLE-WILLOUGH')
(0.9913849588662121, 'NASSAU AV')
(0.9913698415189078, 'FLUSHING AV')
(0.9336165693043016, 'BAY 50 ST')
(0.9308408339103008, 'BOWLING GREEN')
(0.891513644921311, '25 AV')
(0.8614445200096477, 'THIRTY ST')
(0.8528200031317963, '5 AV/53 ST')
(0.8416197831737583, 'LACKAWANNA')
(0.8377765267811039, 'WALL ST')
(0.8258985653923148, 'NEWARK HW BMEBE')
(0.8158314314814306, 'FULTON ST')
```

Commuter exit example: Wall Street

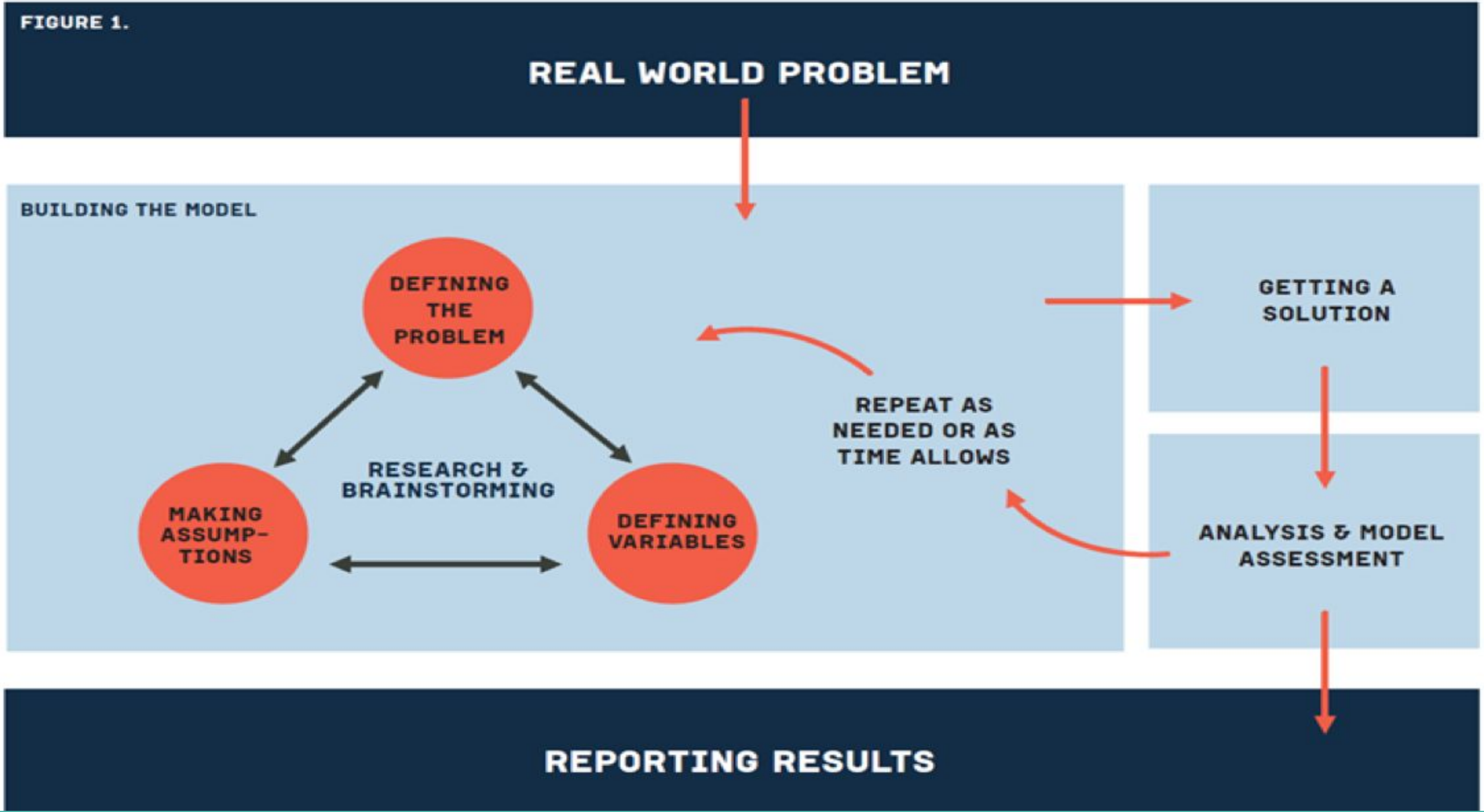


Tourist Heavy Exits



```
(0.4747766989931784, 'W 8 ST-AQUARIUM')
(0.473438956197576, 'AQUEDUCT RACETR')
(0.47101464369779406, 'BEACH 67 ST')
(0.46642481320423806, 'YORK ST')
(0.45683375916137037, 'BEDFORD-NOSTRAN')
(0.44292603448064244, '161/YANKEE STAD')
(0.42865686416035964, 'ROCKAWAY PARK B')
(0.4180790960451977, 'RIT-ROOSEVELT')
(0.41037735849056606, 'ORCHARD BEACH')
(0.40683683796244235, 'BROAD CHANNEL')
(0.3825531323794971, 'BEACH 105 ST')
(0.3745816863879172, 'BEACH 98 ST')
(0.37105474061467253, 'BEACH 90 ST')
(0.34406817672123796, 'AVENUE N')
```

FIGURE 1.



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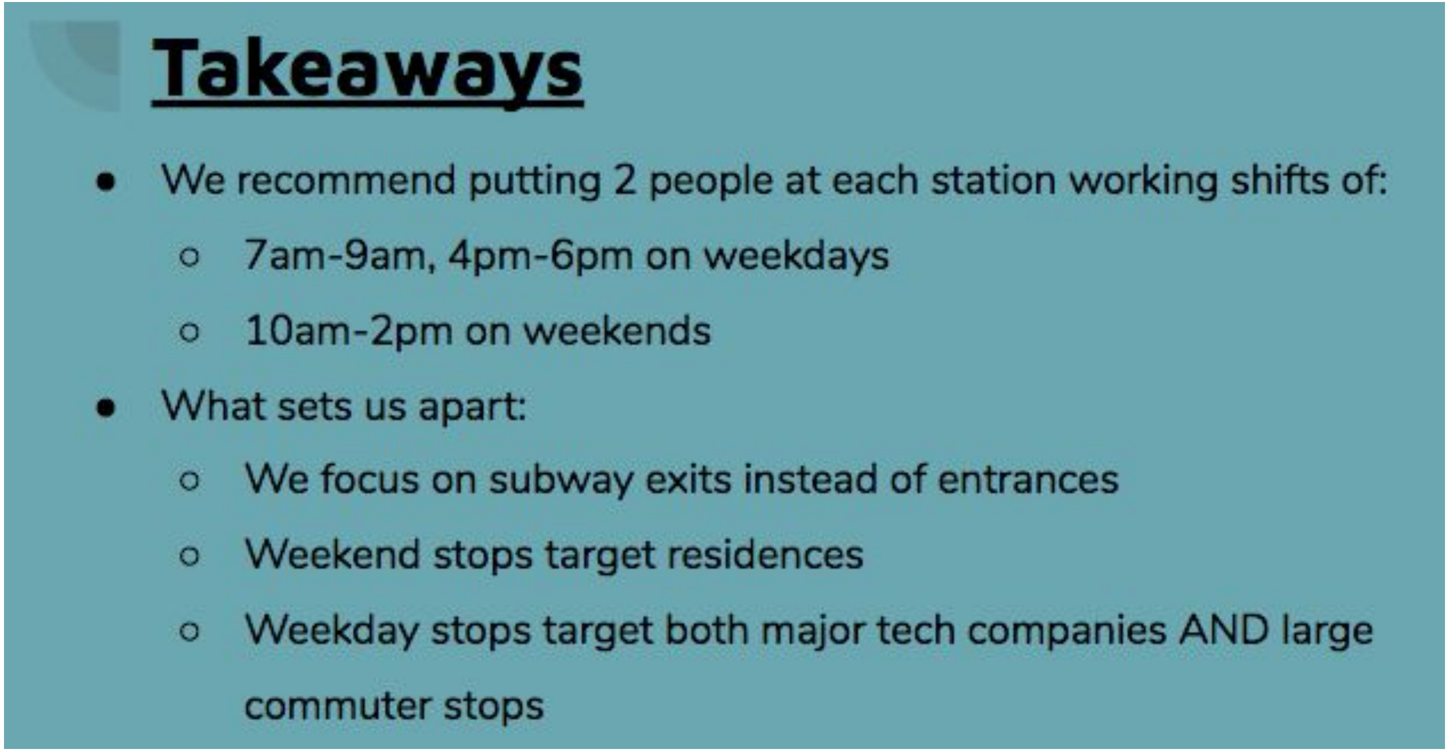
ANALYSIS & MODEL ASSESSMENT

REPORTING RESULTS

Professional Presentation Requirements

1. You need extremely clear slides and explanations.
2. YOU CANNOT HAVE TOO MUCH TEXT ON YOUR SLIDES.
3. You should create maps and charts to help visualize your suggestions.
4. Your analysis needs to be accurate and thoughtful.
5. Have at least one thing that is unique to your group, or else, why would this organization choose to hire YOUR company?

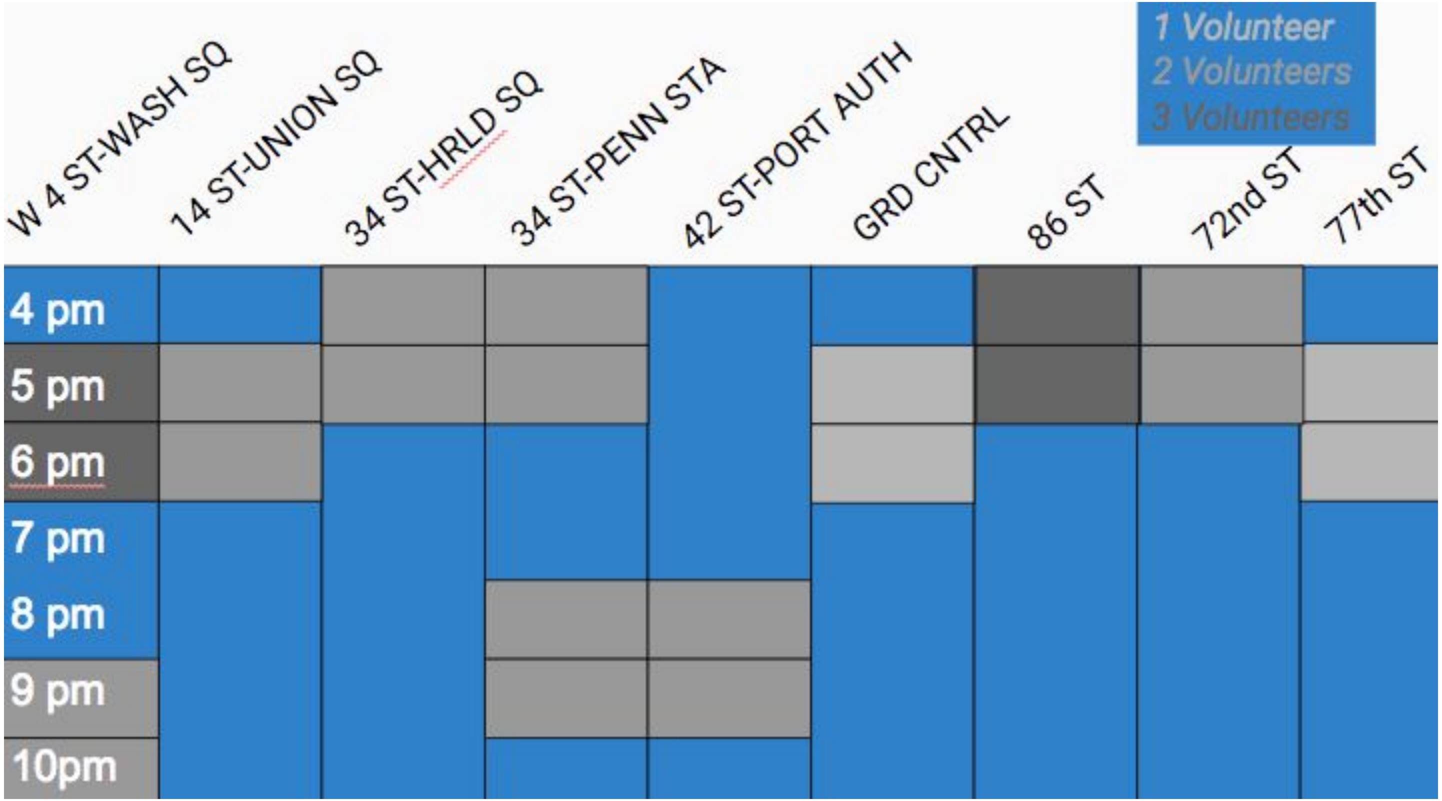
Student Work #1: Concluding summary



Takeaways

- We recommend putting 2 people at each station working shifts of:
  - 7am-9am, 4pm-6pm on weekdays
  - 10am-2pm on weekends
- What sets us apart:
  - We focus on subway exits instead of entrances
  - Weekend stops target residences
  - Weekday stops target both major tech companies AND large commuter stops

Student Work #2: Concluding summary



░ 1 Volunteer
▒ 2 Volunteers
▓ 3 Volunteers

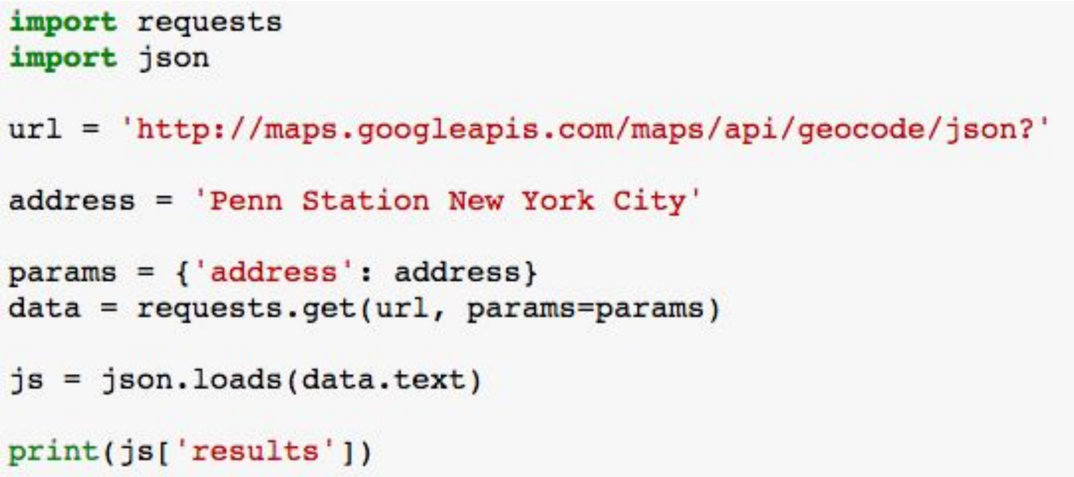
W 4 ST-WASH SQ	14 ST-UNION SQ	34 ST-HRLD SQ	34 ST-PENN STA	42 ST-PORT AUTH	GRD CNTRL	86 ST	72nd ST	77th ST
4 pm 🟦	🟦	▒	▒	🟦	🟦	▓	▒	🟦
5 pm ▓	▒	▒	▒	🟦	░	▓	▒	░
6 pm ▓	▒	🟦	🟦	🟦	░	🟦	🟦	░
7 pm 🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦
8 pm 🟦	🟦	🟦	▒	▒	🟦	🟦	🟦	🟦
9 pm ▒	🟦	🟦	▒	▒	🟦	🟦	🟦	🟦
10pm ▒	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦

Many extensions

- Graphical packages
- Google API
- Data cleaning

Extension #1: Animations

Extension #2: Working with Google Maps API

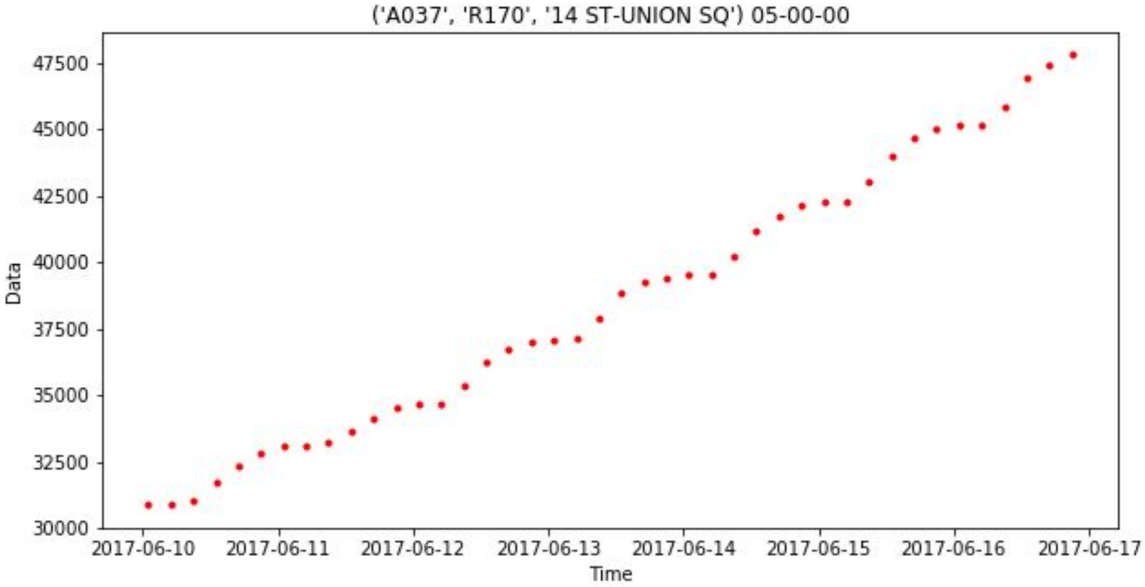


```
import requests
import json

url = 'http://maps.googleapis.com/maps/api/geocode/json?'

address = 'Penn Station New York City'

params = {'address': address}
data = requests.get(url, params=params)

js = json.loads(data.text)

print(js['results'])
```

coln Tunnel
HELL'S KITCHEN
Le Bernardin
Times Squar
Rockefeller C
MIDTOWN
10th Ave
W 34th St
2nd Ave
The High Line
Empire State Buildin
W 14th St
E 23rd St
eum
n Art
Bellevue H
ed Pig
Webster Hall
Washington
Square Park
Winery
EAST VILLAGE
LOWER
MANHATTAN
E Houston St
Canal St
Brooklyn Brew
TRIBECA
Grand St
New York
FDR Drive
Manhattan Bridge
S

Extension #3: Data Cleaning

If the data is correct, the count at each turnstile should be monotonically increasing like this:

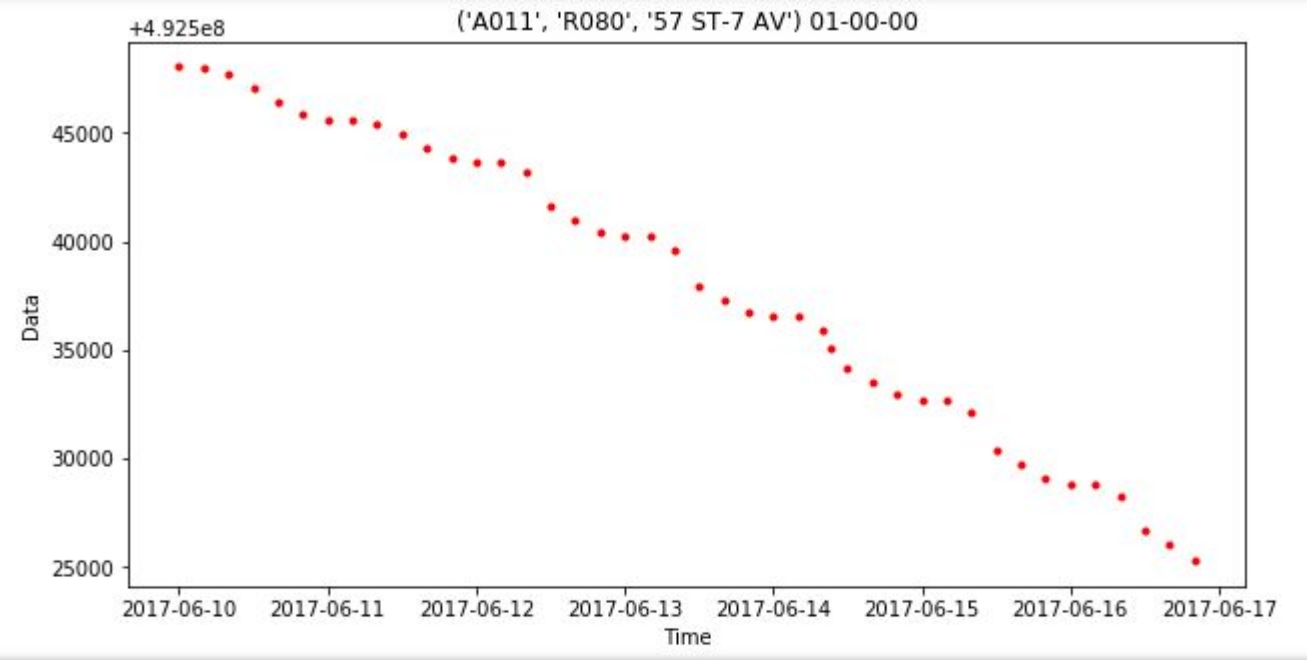


Type of Errors

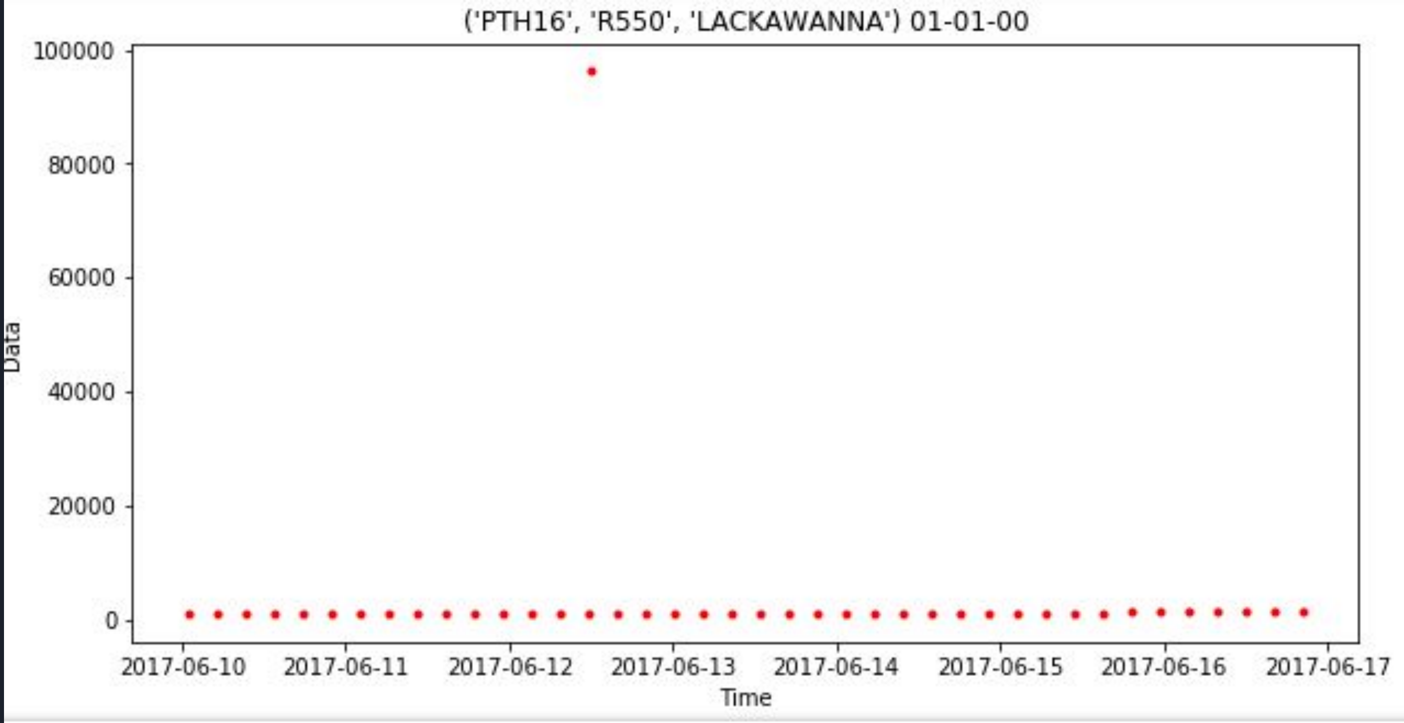
59 turnstiles have incorrect data, in 3 types

1. Monotonic Decreasing
2. Garbage Values
3. Turnstile Resets

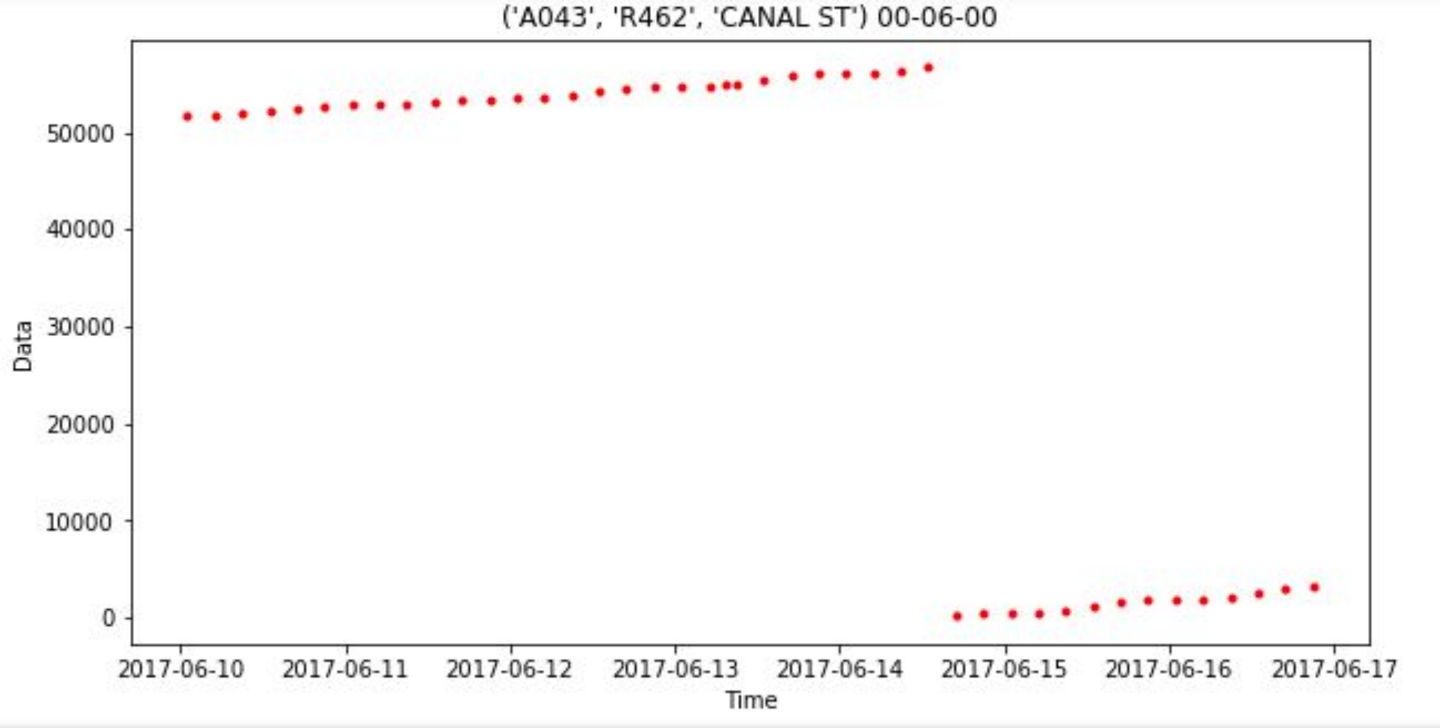
Monotonic Decreasing



Garbage Value



Turnstile Reset



Tech required for data analysis

- Python 3.6 in a Jupyter Notebook (www.anaconda.com/download/)

- matplotlib (plotting)
- **pandas (spreadsheets)**
- NumPy (arrays, math functions, linear algebra)

Free Resources

- UC Berkeley Foundations of Data Science:
  http://data8.org/

- Think Stats 2e & Think Python 2e, Allen B. Downey
  http://greenteapress.com/wp/think-stats-2e/
- Python For Everyone, Charles Severance:
  https://www.py4e.com/html3/
- My course materials:
  https://github.com/laurenshareshian/Python_Course_Lessons
- Google “pandas tutorials”

Thanks!

Lauren Shareshian

Oregon Episcopal School

shareshianl@oes.edu