1. Problem Statement

- **Background**

Growing concerns with environmental issues have led to the consideration of alternatives to urban mobility. Among available options, electric vehicles (EV) have been considered in advantage in terms of sustainability as well as emission of pollutants. This work using Gorubi optimizer and K-means to optimize the EV charging station allocation in New York City.

At present, there are three levels of chargers in the EV market. As is shown in figure 1, the charging time, construction and labor costs are different according to the chargers' level. Through investigating, there are 361 charging stations, each charging station averagely has 1-3 chargers of different levels, most of them has 2 chargers and the level 2 charger is the most general. In addition, New York City has 6551 registered EV on the road.

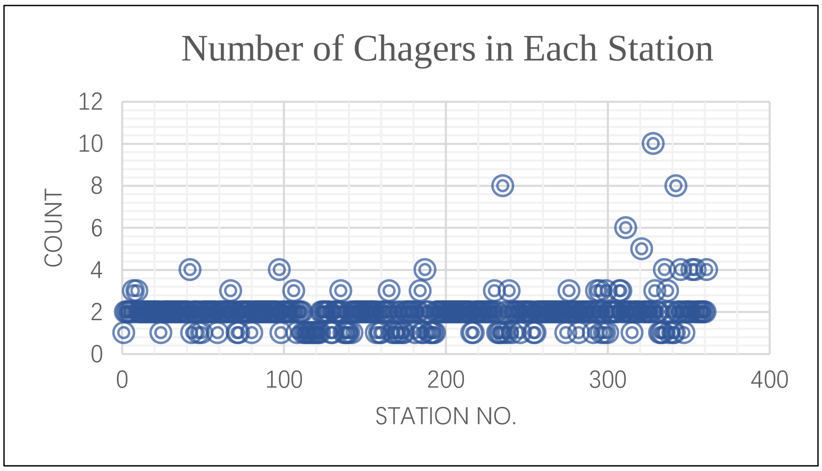


Figure 1 The Number of Chargers in Each Station

Table 1 charger levels and their corresponding construction investment

Level	*Charging Time*	*Construction Cost*	*Labor Cost*
Level 1	8-12 hours	$300-600	$1,000 - $1,700
Level 2	4-6 hours	$500-700	$1,200 - $2,000
Level 3	30 min for 80%	$2,300-6000	$2,300 - $6,000

- **Data Resources and data pre-processing**

The following datasets are collected form the Electric Vehicle Station Locator Website (https://www.nyserda.ny.gov/All-Programs/Programs/Drive-Clean-Rebate). And NYC Open Data Website (https://data.cityofnewyork.us/widgets/i8iw-xf4u)

1. EV Users shapefile

   As you can see in Table 2, I only have the number of EVs on the road in each zip code area. To get the locations of the EV users, I created random points within each zip code boundary according to the third column in ArcGIS software.

   Table 2 Registered EVs in New York City

Utility	*ZIP Code*	*EVs on the Road*
Consolidated Edison Company	10001	41
Consolidated Edison Company	10002	32
Consolidated Edison Company	10003	69
Consolidated Edison Company	10004	70
Consolidated Edison Company	10005	14
Consolidated Edison Company	10006	9
Consolidated Edison Company	10007	153

   After this step, I got a shapefile and the geometry information of the EV users' position. As is shown in Table 3.

   Table 3 the geometry information of the EV users

GET_FID	CID	ZIPCODE	PO_NAME	POPULATION	AREA	STATE	COUNTY	CTY_FIPS	ev_regis_1	geometry
0	0	11436	Jamaica	18681.0	2.269930e+07	NY	Queens	081	Consolidated Edison Company	POINT (1042878.753199248 184593.5188203277)
1	0	11436	Jamaica	18681.0	2.269930e+07	NY	Queens	081	Consolidated Edison Company	POINT (1039875.386117198 187297.2242258743)
2	0	11436	Jamaica	18681.0	2.269930e+07	NY	Queens	081	Consolidated Edison Company	POINT (1040235.167471389 187980.9175596923)

2. Zip Code Boundary of NYC shapefile

   This is a shapefile dataset, I can draw the map of NYC zip code boundary using GeoPandas.

   Table 4 Zip code boundary of NYC

	ZIPCODE	PO_NAME	POPULATION	AREA	STATE	COUNTY	CTY_FIPS	OID_	Utility	EVs_on_the	zipcode_1
0	11436	Jamaica	18681.0	2.269930e+07	NY	Queens	081	352	Consolidated Edison Company	3	11436
1	11213	Brooklyn	62426.0	2.963100e+07	NY	Kings	047	277	Consolidated Edison Company	8	11213
2	11212	Brooklyn	83866.0	4.197210e+07	NY	Kings	047	276	Consolidated Edison Company	10	11212

3. Present Charging Stations shapefile

   Table5 NYC charging stations Map

ity	ZIP	Latitude	Longitude	Location	F__of_Leve	F_of_level	Super_chag	number_of	Service_ab	geometry
ɔrk	10001	40.747217	-73.989896	(40.7472165, -73.9898959)	0.0	1.0	None	1.0	16.0	POINT (987049.6889537015 211507.9295838565)
ɔrk	10001	40.748789	-73.989915	(40.748789, -73.989915)	0.0	2.0	None	2.0	32.0	POINT (987044.3306818638 212080.8412137982)

2. Optimization Model

- **Assumption:**

1. Each station can only install one specific level of charger, and each charger can only serve one user only.
2. The user can only go to the assigned station.
3. Each station would install 2 chargers.

- **Python Packages**

Gorubi

- **Optimizer:**

Minimize $C = \sum_j \sum_m F_m X_{jm} + \sum_i \sum_j Z_{ij} d_{ij}$(minimize the total planning cost, including the initial construction investment of charging stations and the users' charging cost in the later use.)
Constrain:

a) $\sum_j Z_{ij} = 1, \forall i \in I$ <u>(the user in demand point i can only go to one appointed charging station at one time)</u>

b) $Z_{ij} \leq X_{jm}$ (prerequisite conditions to make a candidate point into function)

c) $\sum_i Z_{ij} \leq \sum_m A_m X_{jm}, \forall j \in J$ (the charging demand quantity at one station must not exceed its maximum service ability.)

d) $\sum_m X_{jm} \leq 1, \forall j \in J$ (a candidate point must be constructed as only one of the levels.)

e) $\sum_j \sum_m X_{jm} = P$ (the constraint of total amount of charging stations to be constructed)

f) $X_{jm} \in \{0,1\}, \forall j \in J, m \in M$; $Z_{ij} \in \{0,1\}, \forall i \in I, j \in J$ (give the feasible zones for the decision-making variables.)

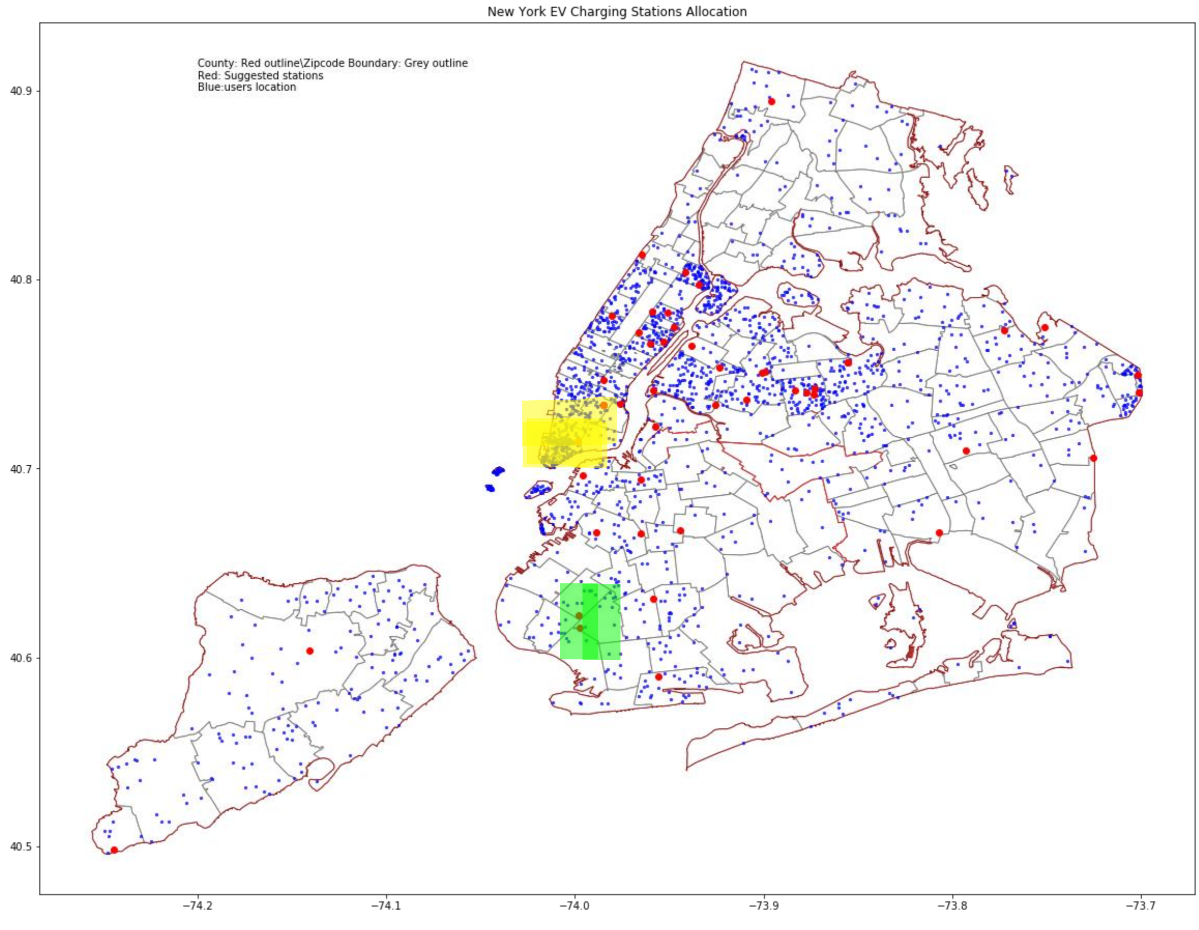
Where:

1) I&i: the set and index of demand point.
2) J&j: the set and index of charging stations.
3) m: the level of the station = {1,2,3}.
4) Fm: the initial install cost of a charger in level m.
5) Am: the serving ability of a station in level m at candidate point j= the number of serving EV daily.
6) dij: the distance from the demand point I to the candidate point j.
7) P: the quantity of station to be constructed.
8) Xjm = {0,1}: whether j is chosen as a level m station.
9) Zij = {0,1}: whether user at demand point i receives service at candidate point j.

Table 5. charger levels and their corresponding construction investment

Level m	*Am:Service ability /(vehicles/day)*	*Construction Cost (Fm)*
Level 1	8*2=16	$300*2=600
Level 2	16*2=32	$500*2=1000
Level 3	32*2=64	$2,300*2=4600

3.Results



As is shown in above figure, the red points are the suggested 50 charging stations. Among them, 2 are chose to be constructed as level 2 stations, and 2 stations are level 3, the left will be level 1 charging stations. This output may have some unreasonable things, for example, in the yellow area, there are many EV users, but only one level 1 charging station. In addition, in the Green area, there are two charging station that are very close, but the density of users is lower than most position.

4. Limitation and Next Step

Because the limitation of my computer's memory, I have to narrow my dataset. I randomly choose a subset of the present users' position dataset, which may lead to the inaccuracy of my output. In addition, the level 2 charging stations is most universal in the real world, but in my model, level 1 charging station has a primacy. This is probably because in my model, I also optimized the construction cost other than the locations of charging stations, and level 1 charging station has the lowest cost.

Next step, I want to optimize my model based on the population density, zoning and the use of home charging. In this model, I did not take into account the use of household chargers, nor did I consider whether the construction position was allowed in the actual situation and whether it met the requirements for the construction of charging stations.