Gaps in Electric Vehicle Charging Infrastructure(in New York)

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SIADS 591 & 592 Project Report
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Motivation

In the next decade, the number of electric vehicles (EVs) on our roads will likely rise substantially, and we believe the bulk of the charging of these vehicles will take place at home. But charging away from home or a workplace will also be key to support EV growth. Such on-the-go charge-ups will also need to be as easy and convenient as refueling a traditional, internal combustion engine (ICE) vehicle today.

While EVs account for less than 2% of new vehicle registrations in the US, and much less than 1% (IHS, 2021) of all vehicles on the road today, the underlying economics of EV ownership are improving. State and federal regulators are incentivizing adoption, signaling that EV penetration will likely increase steadily over the next decade and beyond. California—often a bellwether for other states—has moved to ban new ICE cars from 2035. We expect that, by then, EV ownership will be economically viable for most people.

So, are we ready for EV future? Well, while EV registrations are growing at a near exponential rate in NY, the charging infrastructure does not adequately supply this demand. The ranges of EVs are increasing greatly, but the availability and speed of charging has not kept up.

NY state has provided a $4,000 tax credit to businesses to install new chargers. Additionally, New York City (NYC) has begun installing curbside public stations to meet the demand. This motivated us to seek to identify gaps in this infrastructure and propose specific sites for development to fill these gaps.

Key Factors

EV Registration Trend

EV Charging Station Infra

EVs on Road

EV Charging Sessions

Underserved Areas

Data Sources

Electric Vehicle Charging Stations

Description: Electric Vehicle Charging stations dataset will be key driver for the project to understand the current infrastructure of EV Charging stations across US and Canada. This dataset contains alternate EV Charging stations details for the past 10 years.
Size: ~16 MB. The dataset contains all US and Canada EV Charging Station records.
Source: US Department of Energy (Alternate Fuels Data Center).
Format: CSV
Access Method: Downloaded via AFDC Advanced filters section of the tool

US Geographical Shapes

Description: The 2019 cartographic boundary shapefiles are simplified representations of selected geographic areas from the U.S. Census Bureau's Master Address File / Topologically Integrated Geographic Encoding and Referencing (MAF/TIGER) Database (MTDB). ZIP Code Tabulation Areas (ZCTAs) are approximate area representations of U.S. Postal Service (USPS) ZIP Code service areas.
Size: 101.7 MB
Source: data.gov
Format: Shape Files (.shp)
Access Method: Downloaded from data.gov

NY State Vehicle Registrations

Description: This dataset contains the file of vehicle, snowmobile and boat registrations in NYS. This dataset contains all types of vehicles registered from 2019 to 2021, but we will be using only passenger vehicles including Internal Combustion Engine (ICE) vehicles, Hybrid and Electric Vehicles.
Size: 1.41 GB
Source: data.ny.gov
Format: CSV
Access Method: Data export from data.ny.gov

NY EV Charging Sessions

Description: New York State EV Charging Session details from 2019 to 2021 such as charging levels, duration, connectors.
Size: 30 MB
Source: nyserda.ny.gov
Format: Excel (xlsx)
Access Method: Downloaded from nyserda.ny.gov

NY State Traffic

Description: Locations of short-duration traffic counts collected from 2015 through 2019 on roads in New York State.
Size: 17 MB
Source: gis.ny.gov
Format: gdb
Access Method: Downloaded from gis.ny.gov

Data Manipulation - EV Registrations & Charging Stations

Electric Vehicle Registration

New York state vehicle registrations were contained in a very large data frame consisting of over 12 million rows. Because there was so much data to process, we used Spark to load and extract from the dataset. We mostly relied on SQL statements to query the database and narrow the size of the file. The dataset included all registrations in the last 2 years, as well as the make of the vehicle, vehicle type, zip code in which the vehicle was registered, fuel type of the vehicle, and other information.

In order to visualize the number of registrations for EV's by make and year, we used a group by SQL statement and converted the results to a Pandas dataframe. We also grouped the EVs by body type to determine how body type registrations varied over time. 7-day average registrations for EV's were calculating by grouping the dataset by date, then using the pandas method "rolling" along with the mean. We used this method to generate a rolling mean number of registrations for both conventional and electric vehicles.

Next, we sought to compare various zip codes in terms of electric vehicle registrations by year. This relied on grouping the number of registrations for EV vehicles by Zip Code, then using the GeoPandas tool to read shapefiles of US Zip Codes. This geographic dataset was then combined with the registration by Zip Code using the Pandas merge method. The resulting merged geographic dataset was then plotted using the Folium package.

Electric Vehicle Charging Stations

Electric Vehicle Charging stations dataset is the key driver for the project to understand the current infrastructure of EV Charging stations across US and Canada. This dataset contains alternate EV Charging stations details for the past 10 years.

We used Pandas libraries to extract, load, transform the datasets into various dataframes for manipulation. Using Pandas read_csv module, the csv file was loaded into dataframe. First, We have filtered the dataset to have charging stations in US using country column. We had to map state code to state names using map function. Then the dataset was grouped by State name to sum the number of charging stations in each state. Similarly, the dataset was narrowed down to have only New York state dataset. We grouped the datasets using different key columns such as Year Opened, City, Facility Types to visualize the top 10 cities, year over year growth on the charging station, most preferred location.

We used the geometric data had to have its FIPS codes mapped to county names with the FIPS crosswalk data, and the charging station data had to have ZIP codes mapped to county names with the US Zip Code data. Afterwards, the geometric and charging station data were merged and had the information available for the interactive choropleth.

Overall, the datasets that we used are holistic and good in quality. But still we had to perform basic cleanups by handling Nulls, empty strings, incomplete data values, etc., Some of the unnecessary columns were dropped and the data frames were filtered to only use pertinent information.

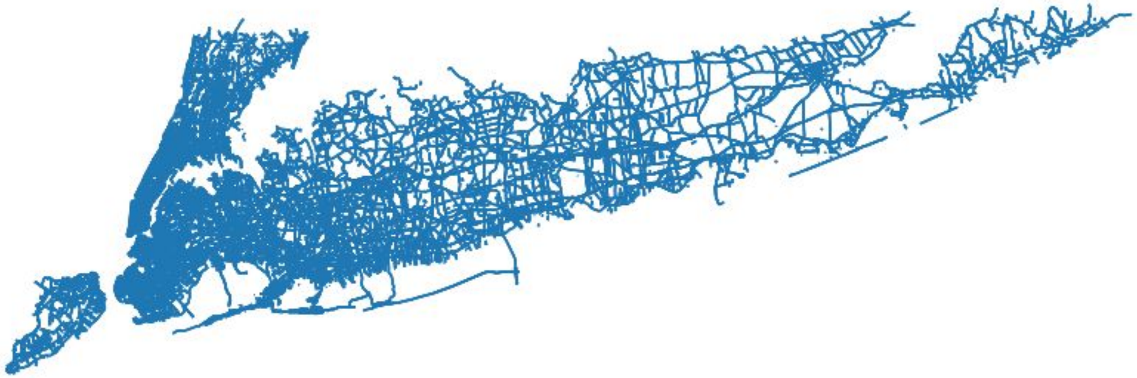
Data Manipulation - Traffic & Geographical Datasets

Traffic data for New York was available in short count form. Short counts were taken at hourly intervals based on factor group. In this case, we focused on factor group 30, which included all commuter vehicles. We also narrowed the counting time to between 7 and 10 AM, deemed morning rush hour. We narrowed to this time so that we could gauge traffic based on the number of registrations by Zip code. We assumed that vehicle owners commuted to work from home during this time period. Using this time period we created a column with morning rush hour traffic.

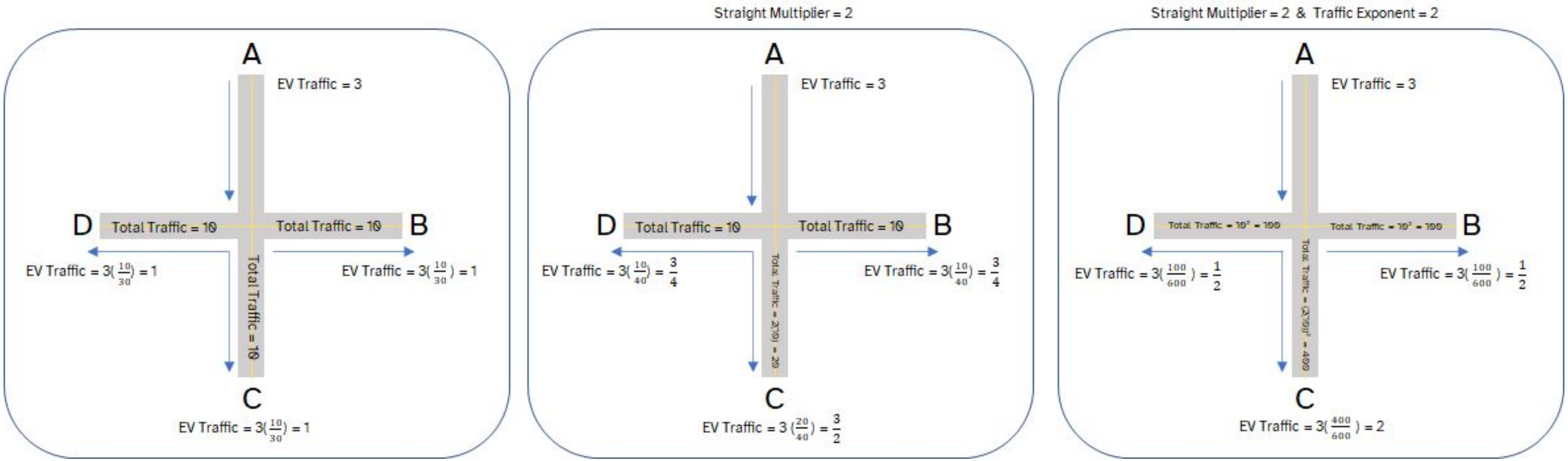
The traffic data also had varying geometries, one with point geometries indicating the location of each station, and one indicating the lines for routes. In order to visualize traffic and estimate traffic from EVs, we used the shapefile containing line geometries. This shapefile along with all other shapefiles used in this analysis were loaded using the GeoPandas package, which converts shapefiles to usable dataframes that can be manipulated in Pandas. The traffic database had fairly comprehensive coverage of the NYC metro area. A map of these routes is shown on the right. However, some stations did not have data from the most recent reporting year. For this reason, we extracted the counts from the most recent year available for each station.

The database also contained a parameter labeled “Federal Direction”. This parameter described the direction of the road, either North, South, East, West, or bidirectional. For the purposes of this analysis we excluded stations labelled as bidirectional. This enabled us to simplify labelling and provide differing measurements of traffic based on time of day. We also narrowed the routes to those with a station latitude below 41.5°N. We assumed this to be the furthest north that NYC metro extends and thus the northern edge of traffic into the city.

The traffic geometries were then combined with Zip Code shapefiles. This was accomplished by first combining the line segment shapefile with the point shapefile for stations. The points were aligned with Zip Codes using the Shapely method “contains”, which takes a polygon and finds if that polygon contains a point. In this case, the polygons were the Zip Code shapes, and the points were the locations of the traffic stations. We created a python file containing a function that used this method and merged the Zip Code dataframe with the station location dataframe.



Data Manipulation - Traffic Calculation Algorithm



In order to calculate the number of EVs on the road throughout the city of New York we developed an algorithm that estimated trip data. This algorithm relied on traffic data and basic probability concepts. Shown above is a simplified version of this algorithm. EV traffic at the starting point was based on the NY registration data by Zip code, including all makes of EVs. The most heavily trafficked segments were then chosen for each Zip code, and these were used to seed the algorithm.

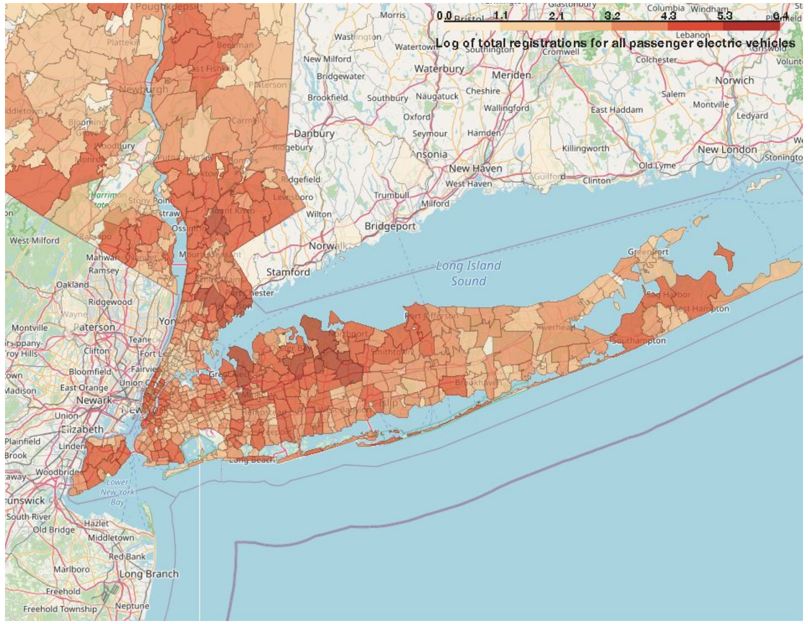
The basic formulation of the algorithm involves estimating the traffic along each segment of the road at each intersection based on the traffic at each direction flowing away from the originating station and direction. We created two parameters to adjust traffic at each intersection. First was the straight multiplier, which adjusts preference to traffic flowing in the same direction as the previous segment. The second parameter, the traffic exponent, adjusts preference for more highly trafficked segments by raising the traffic to an exponent. The algorithm was run until routes reached a certain ratio of initial traffic, in our case 0.5%.

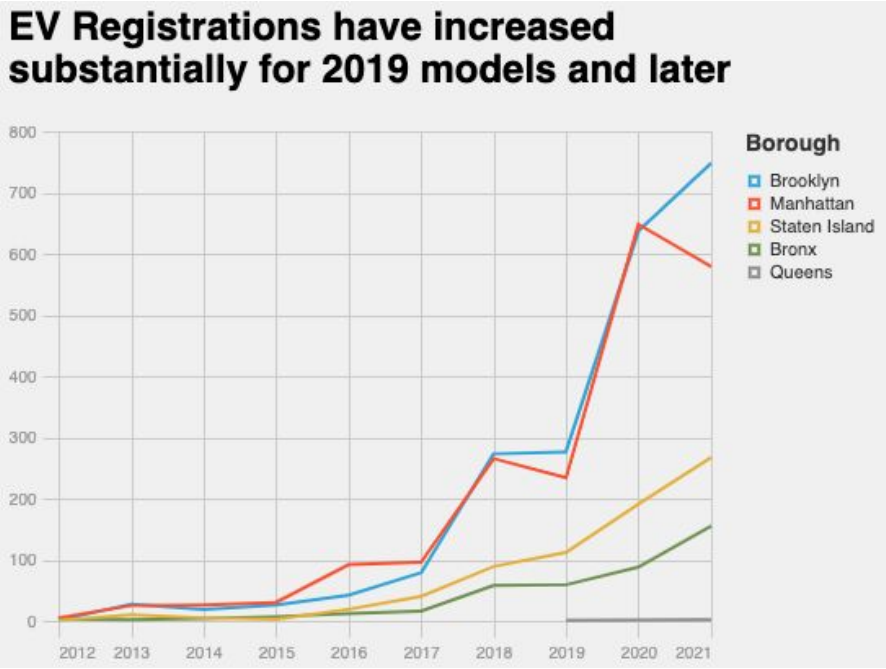
In order to choose the best parameters for evaluation, we developed three evaluation parameters; one which evaluated how straight the routes were, one which evaluated how heavily trafficked routes were, and one which evaluated the distance from the seeds that the routes travelled. Using three randomly chosen seeds and various values for the straight multiplier and traffic exponent we found that a straight multiplier and traffic exponent of 2 performed best. We then ran this algorithm using those parameters for the 100 Zip codes in the NYC metro with the most EV registrations.

Analysis - EV Vehicle Registration

The US big 3 automakers are chasing Tesla's dominance in the EV space. Specifically, in 2021, 11,225 EVs were registered as Teslas. The next highest number of registrations by make in that year were 1,188 vehicles by Chevrolet.

While Teslas are the most commonly registered EVs in NY, registrations of EVs from other manufacturers are increasing at a greater rate than for Tesla. This rate, however, reduced substantially in the latter part of 2021, owing largely to chip shortages. The 7-day average of new registrations decreased from 48.7 on June 30, 2021 to 18 on July 31, 2021. Over the same time period registrations of conventional vehicles grew, albeit at a much slower rate, and plateaued around April 2021. The 7-day average of new conventional vehicle registrations reached 21,366 on April 1, 2021, and reduced slightly to 17, 600 on June 1, 2021. By comparison, over the same time period, the 7-day average for new electric vehicle registrations increased from 33.28 to 44.43.





Suburbans and four-door sedans were by far the most commonly registered EV body types, with very similar trends in number of registrations. Registrations of suburbans reduced from 82.4 on June 3, 2021 to 19.6 on July 31, 2021, again likely owing to the chip shortage. The next most common body type was sedans. The 7-day average number of new registrations for sedans peaked at 8.3 on March 3, 2021. The average then dropped considerably to 1.3 on July 31, 2021.

For non-Tesla vehicles the number of new registrations by vehicle model year increased greatly for Ford from 2020 models to 2021 models. Specifically, the number of new registrations increased from 1 for 2020 Ford models to 661 for 2021 models. Ford thus was the most registered make for 2021 non-Tesla models. Chevrolet models, on the other hand, reduced substantially in number of registrations from 2020 to 2021, with 823 registrations for 2020 models and 381 registrations for 2021 models.

Total EV registrations by NYC borough and by Zip Code are shown on the right. EV registration for Brooklyn were highest in 2021 , with Manhattan having the second most. Additionally, the Zip codes in the NYC metro with the highest number of EV registrations are in the suburbs, specifically Westchester and Suffolk counties. This means that areas outside of the city proper need to be considered as a basis for traffic for infrastructure development.

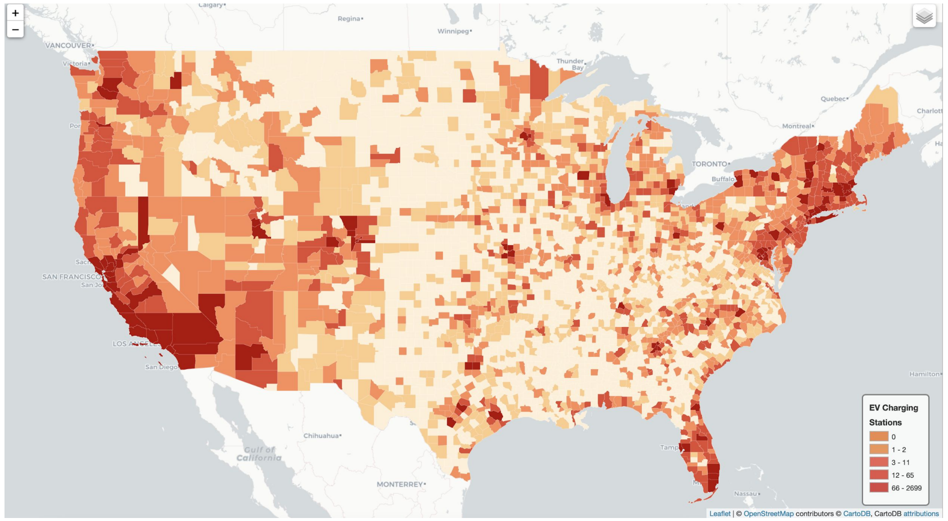
Analysis - EV Charging Stations

The charging model for EVs is very dissimilar to that for fossil fuel vehicles, with charging time dependent on charger type and battery capacity. Therefore it's not as simple as adding EV charging stations to gas stations. The user's charging behavior will vary depending on where they live, where they work, and their travel patterns. Other than at home or at the workplace, charging also occurs at individual charging stations at different parking lots. There are lots of logistical questions to answer, but what is clear is that publicly accessible EV charging infrastructure will need to be expanded.

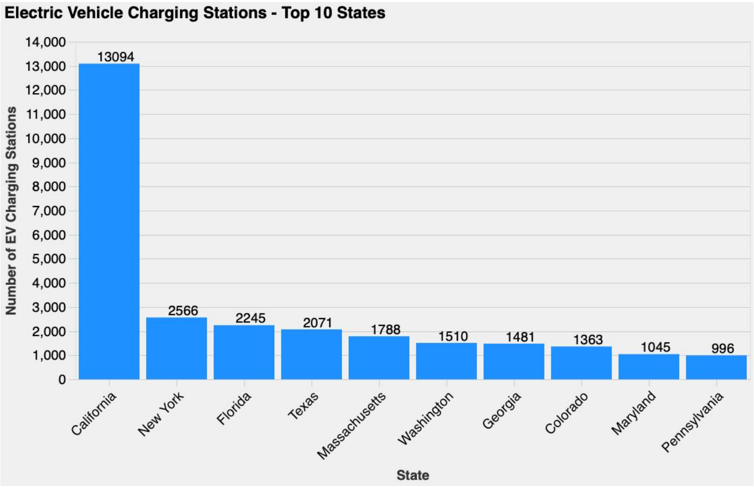
One of the biggest barriers to EV adoption is America's charging network. There are roughly 136,400 gas stations in the U.S., but just around 43,000 EV charging stations, according to the Department of Energy. And it takes about 10 minutes to fill the car with a tank of gas but about 45 minutes to fully charge an EV, sometimes longer.

We have used folium and geopandas libraries to create a choropleth which is interactive and shows the number of charging stations in each US county.

EV Charging Stations by State



Based on the color distribution, the states/counties with darker color has relatively more EV Charging stations. California tops in the list as there are more number of EV vehicles on the road and the EV Charging Infrastructure is more complete. New York state is at second place which has just around 2500 charging station which drawn our interest to explore the EV infrastructure in NY state.



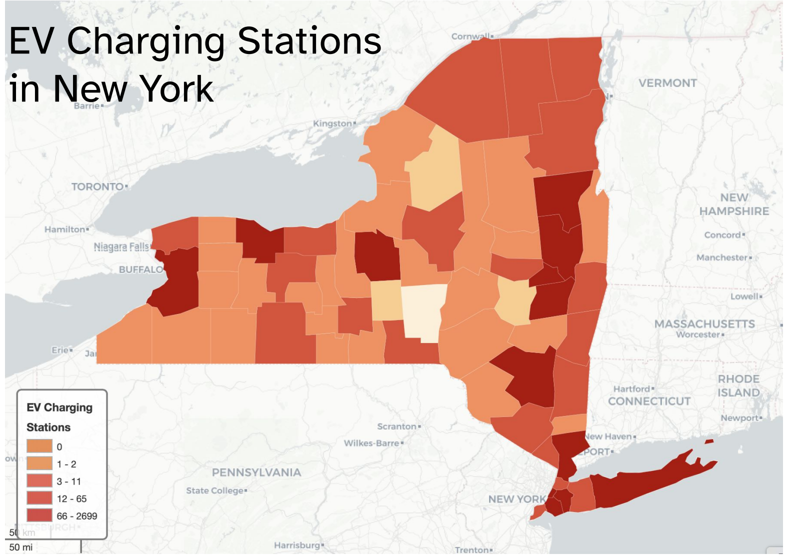
If we remember there was only one electric vehicle model in production in the U.S. in early 2008 - the Tesla Roadster. Even then, only 27 vehicles were delivered to customers by September of that year. Also, there were only 430 chargers in existence across the country in 2008.

As expected, the number of charging stations are increasing Year by year, In 2019 there were only 4000 EV charging stations and 10,000 more stations were added in 2020. In another 9 months, more than 16,000 stations are added and more to come for the rest of the year.

Based on the EV Charging Stations dataset, the facilities where EV Charging stations installed are Hotels, Car Dealership, Shopping malls, Office Buildings, Parking lots and Government Facilities. Hotels are having more EV Charging stations installed from various EV networks.

California's push to decarbonize transportation made the state to top in the list, similar actions are proposed in other states, especially in New York. Our scope for this project is to analyze the EV charging infrastructure in New York state and identify the possible gaps based on the EV vehicles on the road.

Analysis - New York EV Charging Infrastructure



Stakeholders of EV Infrastructure

We can bucket the EV Charging stations in the current NY infrastructure into three categories.

Standalone EV charging providers: The EV Charging companies are building charging capacity in advance of demand, absorbing losses and counting on the eventual rise in EV adoption. These players often seek to play in numerous EV-charging use cases such as installing home chargers and at-work charging networks, setting up charging points at commercial locations (such as parking lots at hotels or retail centers) and building roadside, fast-charging stations. Companies like ChargePoint, EV Connect, Greenlot are major contributors to this category.

Vehicle OEMs: Vehicle OEMs are investing in charging networks across the US to drive demand for their vehicles. Some may offer charging for free as an incentive to buy the car. Tesla is leading this segment with planed EV infrastructure for their EV vehicles.

State and local governments: EV adoption feeds into numerous state and municipal government environmental and sustainability goals. Some are either investing directly or subsidizing EV charging infrastructure development within their jurisdictions. Typically, though, these charging networks are Level 2 roadside or parking lot solutions.

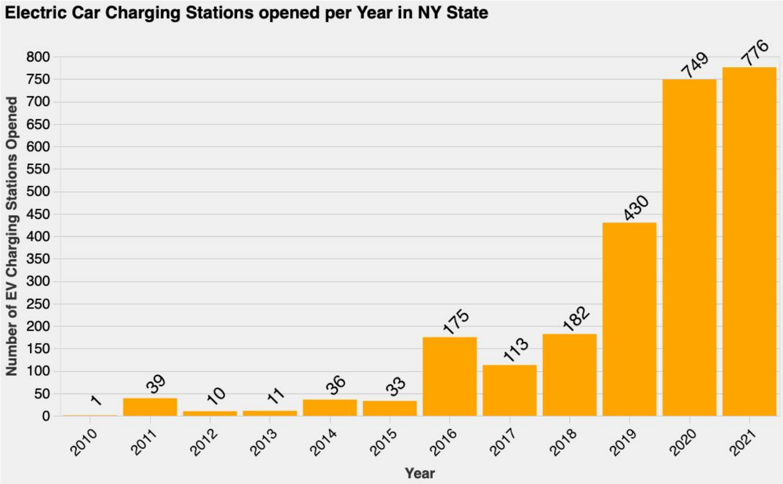
EV Network	Station Count
ChargePoint Network	1422
Tesla Destination	480
EV Connect	262
Non-Networked	161
Blink Network	78
Tesla	52
LIVINGSTON	29
eVgo Network	23
SemaCharge Network	16
Electrify America	15
Greenlots	10
Volta	9
FLO	6
OpConnect	2
AMPUP	1

In New York State, ChargePoint Network has 1422 charging stations with most level 2 port and 35 DC Fast Charge ports. Next, Tesla take the second place with 532 charging stations and 161 Non Networked which are Government owned stations.

New York city tops in number of charging stations with 330, Buffalo with 132, Albany with 118, Rochester with 115 and Brooklyn has 73 made it to top 5 cities with most number of EV Charging stations.

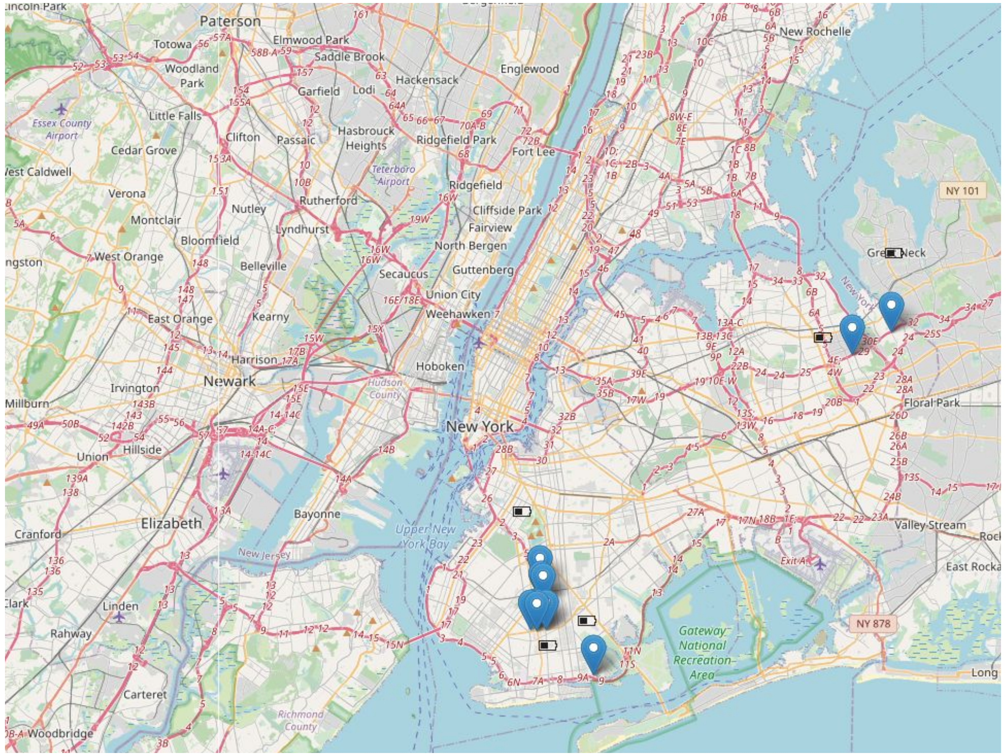
The number of EV charging stations in New York are increasing exponentially Year over year. NY is adding almost 500+ new charging stations every year.

As per Electrifying New York plan, NYC will expand its network of city-operated DC fast chargers by over 80 plugs by 2025. Currently, there are 117 DC fast chargers located throughout the city. These fast chargers are capable of producing an 80% charge in 30 to 60 minutes, depending on the vehicle. All city municipal parking lots and garages will have 20% of their parking spots equipped with L2 chargers by 2025, and 40% by 2030.



The Electrifying New York plan, including its ambitious vision for a new network of public EV chargers, will play a key role in reducing climate-changing greenhouse gases, lowering the risk of respiratory illnesses, reducing noise, and ending our reliance on fossil fuels.

Analysis - Gaps in EV Charging Infrastructure



After running the trip prediction algorithm for the top 100 Zip codes we combined the traffic by route and adjusted traffic by the number of routes per Zip code. Resulting from this was estimated traffic in roads in NYC based on EV registration data and traffic data. We chose the top 1,000 stations based on estimated traffic. Initially we did not filter the number of stations chosen in order to have a more complete dataset. However, this yielded processing times that were too long when combined with the other steps.

We then created polygons surrounding the line segments for routes and generated 10 randomly selected points within these polygons. Because not all land is zoned for commercial development like charging stations, we used NYC's zoning geometric database to determine which of these points were within an area zoned for commercial development.

Using this process we found 150 potential locations. We then used the existing charging infrastructure and found the distance of each of these points to the closest existing charging station. This distance as well as the adjusted traffic counts based on registration and traffic data were used as the basis for evaluation of these potential locations.

Summary

In order to evaluate these locations based on their distance to an existing charging station and their adjusted estimated traffic counts, we created an algorithm that estimates superiority. This algorithm used the data frame as well as evaluation columns as inputs, then determined to how many other locations each location was superior. A location was superior to another location if it had greater or the same distance from a charging station and greater or the same adjusted traffic. Using this information we created a variable, percent superior, that estimated the percent of other locations to which each location was superior. We sorted in descending order based on this metric and selected the top 10 locations. We then used reverse geocoding to find the address of each location based on their latitude and longitude. Our chosen locations are shown on the map above. Current charging stations are shown as half empty batteries. Some of the locations were repetitive as they are close to each other. However, some businesses may be more willing to install charging stations than others.

Statement of Work

Andrew Bakert

- Environmental Domain Knowledge
- Data Source Research and Selection
- NY EV Registrations
  - Data Cleaning and Manipulation
  - Exploratory Data Analysis
  - Data Visualization
- NY Traffic
  - Data Cleaning and Manipulation
  - Exploratory Data Analysis
  - Data Visualization
- Traffic Calculation Algorithm
- Final Report Writing

Aravindh Mothilal

- Automotive Domain Knowledge
- Data Source Research and Selection
- EV Charging Stations
  - Data Cleaning and Manipulation
  - Exploratory Data Analysis
  - Data Visualization
- EV Charging Sessions
  - Data Cleaning and Manipulation
  - Exploratory Data Analysis
  - Data Visualization
- Final Report Writing

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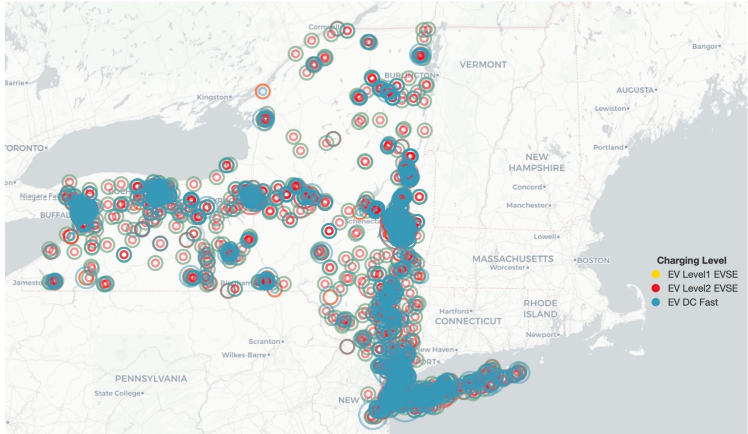
Appendix - Chosen Locations Table

Adjusted Traffic	Distance to Charging Station (ft)	Address
100	11,269	1435 Coney Island Ave, New York, New York 11230, United States
100	9,655	1071 Coney Island Avenue, Brooklyn, New York 11230, United States
95	5,774	3939 Shore Parkway, Brooklyn, New York 11235, United States
159	5,338	21902 Horace Harding Expy, New York, New York 11364, United States
13	11,819	1372 Coney Island Avenue, Brooklyn, New York 11230, United States
14	10,163	56-20 Marathon Parkway, Queens, New York 11362, United States
25	7,527	1622 Ocean Parkway, Brooklyn, New York 11223, United States
24	7,978	407 Avenue P, New York, New York 11230, United States
24	7,764	511 Avenue P, Brooklyn, New York 11230, United States
25	7,352	1963 Coney Island Avenue, Brooklyn, New York 11229, United States

Appendix - NY EV Charging Options



When we are away from home, there are thousands of charging stations that you can take advantage of across New York State. This level of charging is known as Level 2 and it is at least two times faster than Level 1.

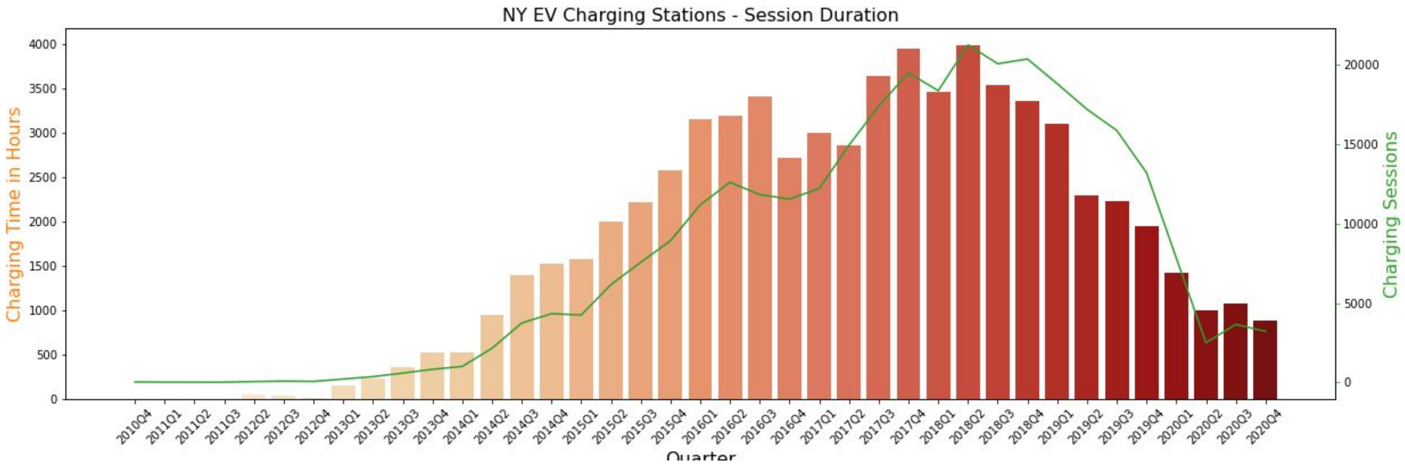
Level 2 charging stations are mainly installed at stores, office buildings, municipal parking lots, parks, hotels, theaters and hospitals. All Level 2 charging stations have a common plug that all electric cars can use, while DC fast chargers may not be compatible with every model.

DC fast charging uses direct current (DC), as opposed to households which use alternating current (AC), and can provide close to a full charge in under an hour. Only public sites can support DC fast charging and they are most often installed along major travel corridors to support long distance drivers.

Currently, there are 6471 Level 2 Charging ports and 729 DC Fast Charging ports available in New York. Most of the Level 2 ports are owned by ChargePoint and Tesla owns most of the DC Fast Charging stations.

At present, New York's charging capacity is limited for the nearly 15,000 electric vehicles registered in the city. About 1,400 level-2 charging plugs, which provide an 80% charge in four to eight hours, and 117 fast-charging plugs, which offer an 80% charge in 30 minutes to an hour, can be found across the city.

We analyzed at the Charging Session dataset to see the total charging hours for given charging session. The Charging duration was more before many of the DC Fast ports were installed, Recent years, with less number of session more charging is happening.



In the emerging EV charging market, time-starved consumers will likely value their time highly enough to pay a premium for speed. They'll look for convenient locations with the fastest charging times, and they'll be disinclined to use reservations apps. Providers targeting these consumers will build extra capacity to maximize availability and offer the fastest chargers.

Most of the public EV charging stations are opened 24/7 and they are equipped with Credit Card readers, but major network providers offer online payment, app based payment.