Contents

1 Executive Summary

Day by day, glaciers are melting, global sea levels are rising, and climate has become more extreme. The world is getting warmer as we speak. According to the National Oceanic and Atmospheric Administration, the global annual temperature has increased at an average rate of 0.07C (0.13F) per decade since 1880 and over twice that rate (+0.18C / +0.32F) since 1981. From 1900 to 1980 a new temperature record was set on average every 13.5 years (NOAA, 2017); since 1981, it has increased to every 3 years. This whole process is known as the "greenhouse effect" whereby there is an increase in greenhouse gasses such as carbon dioxide in the atmosphere. This surge of harmful gasses trap the incoming radiation from the sun which then causes a gradual rise in temperature. The most significant contributor to the greenhouse effect is from the burning of fossil fuels. Apart from large scale fossil fuel consumption like factories and generators, the internal combustion engines in cars also play a big role in contributing to this.

To promote the betterment of our planet, the world is slowly directing towards more fuel-efficient, economical vehicles. In recent years, electric cars are becoming the most popular environmentally friendly alternative with more than 1.94 million electric cars being sold worldwide in 2019 alone (Milenkovic, 2020). Out of the 5.6 million plug-in electric vehicles worldwide at the beginning of 2019, there are approximately 1.5 million electric cars in the US (Radzieta, 2019). However, only 78,544 charging outlets across the US exist (Radzieta, 2019), with a majority of those being located in high-density areas. Here at NIH Solutions, our goal is to create a more user-friendly experience for existing and future electric vehicle owners as well as providing business solutions for investors who are looking to get involved in this rapidly accelerating market.

NIH Solutions has designed a solution that utilizes machine learning and advanced algorithms to identify specific locations that charging stations can be situated at. Our product takes into account factors such as traffic, population density, profit-cost ratios and many more. The desire to promote a greener future has pushed NIH Solutions to release this first of its kind location identifier that incorporates google's api to provide a more seamless mapping experience.

2 Company Description

At NIH Solutions, the goal is to accelerate the process of mainstreaming electric vehicles to provide for a greener future. The pursuit for success is translated in everything NIH does - from empowering employees, to working efficiently with clients, to connecting communities - it strives for nothing but the best and only the best results. The company's core values are:

Dedication - We are dedicated to every client's success

Customers - We place our customers at the heart of our business.

Passion - We strive to constantly inspire and innovate in providing the best solutions.

Growth - We always embrace opportunities to learn, improve and grow with our customers.

Integrity - We honor our commitments by doing the right thing.

Pollution and global warming are widespread problems in the world and NIH Solutions is here to tackle global issues. NIH is committed to solving this issue by providing its own electric vehicle market initiative. NIH Solutions established that optimally, prioritizing customer needs, efficient cost-profit analysis, and user experience were equally important to any solution NIH delivers. Thus, after developing and testing a wide range of algorithms, unique optimization algorithms were created that represents the company's values and allow NIH Solutions to be a functional service that can be accessed by anyone at anytime in the United States. As NIH likes to say, *crucial energy starts here.*

2.1 Products and Services

Automated Charger Spot ™

NIH Solutions takes pride in making the world a better place. This is why the Automated Station Spot or ACS™ is designed with the goal to help each and every one of our clients identify the best locations to construct EV charging stations that promotes the feasibility of electric car travel.

Upon entering the dedicated website portal, every client will have the option to click on a command prompt that will redirect them to the Automated Station Spot ™ landing page. Clients will then be required to specify their city of interest, allocated budget and geographical region in the input boxes. Based on the information provided the user, Automated Station Spot will then formulate several recommended solutions. ACS™ also caters to clients that are not certain with their budget just yet, instead, clients will also be able to enter a range of budgets. Our system will generate a list of coordinates that are potential charging station locations that will be able to maximize client's profits across five years. These determined values are based off the number of chargers that are to be situated, the number of hotels and/or convenience stores constructed, the predicted demand as well as the overall cost.

On Route Navigation ™

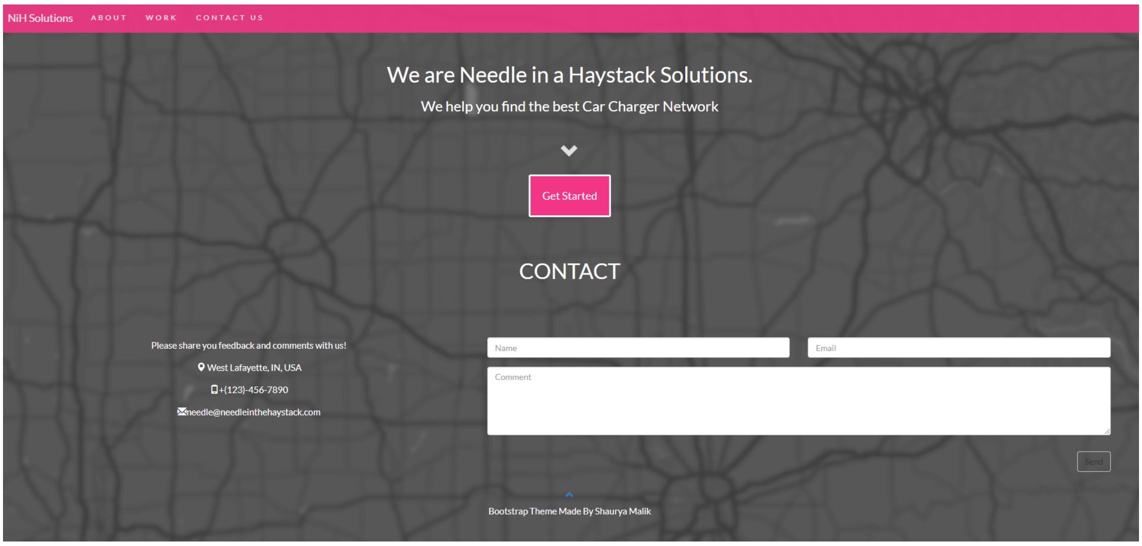
On Route Navigation™ or ORN™ is the second part of the web interface created to increase quality of user experience. By taking in the users current address and their preferences for different charging experiences: whether they want to charge on the go, charge while eating food, charge while staying overnight, charge while doing a quick shopping run, whatever may be the users preferences, ORN™ routes the user to their desired destination using the shortest path possible, thus prioritizing the user's time.

3 Website Interface

3.1 Our website

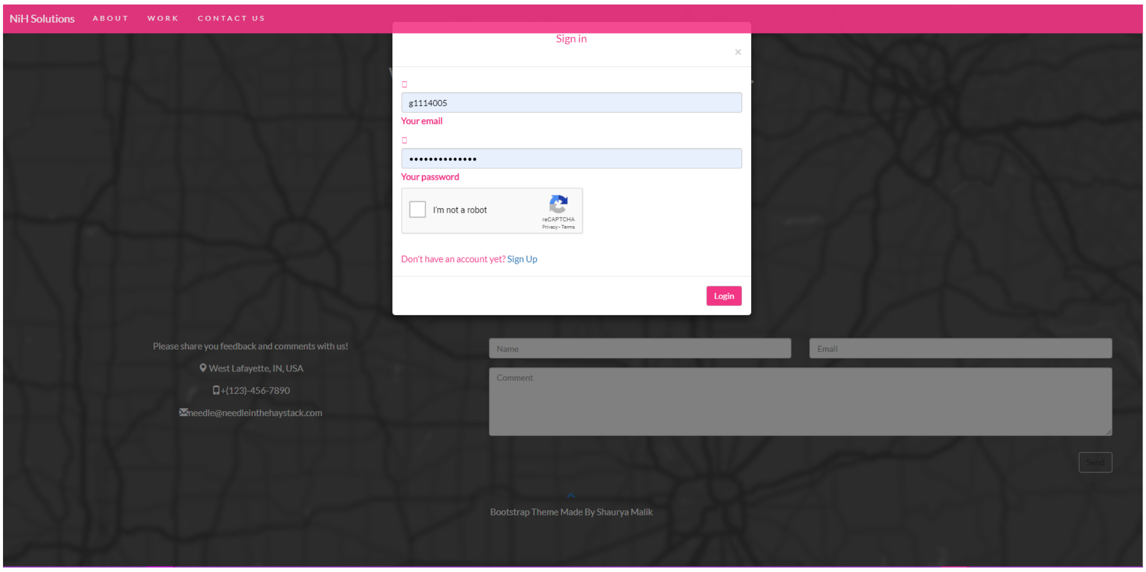
All of our services are located online, so that anyone can easily;y access them at any time. In this section we are going to go through each web page, describing exactly how to use this service effectively.

Image 1: Website Homepage



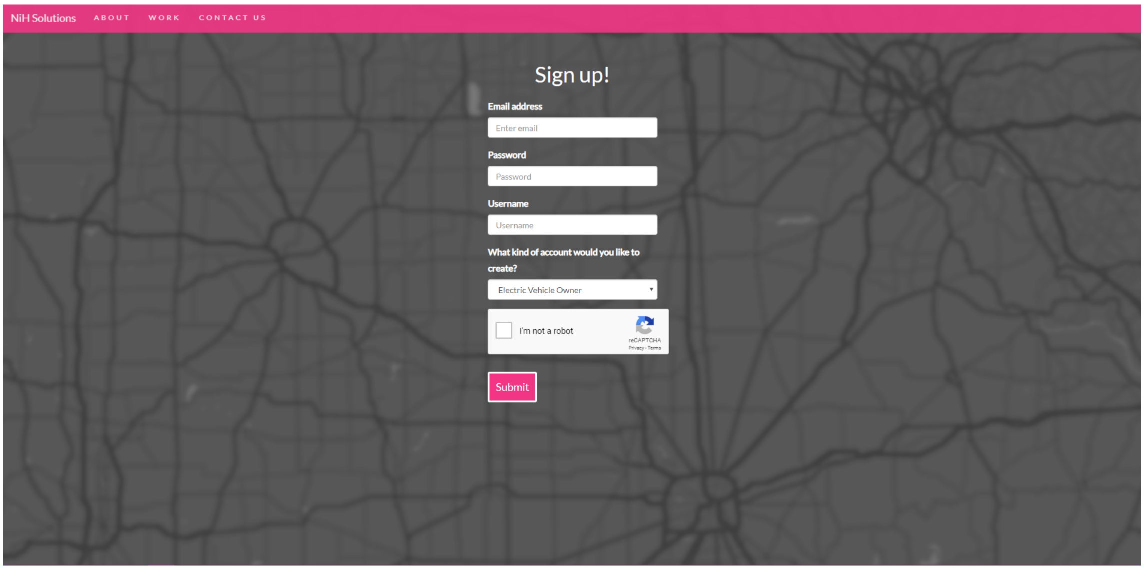
The NIH Solutions website begins with a clean and user-friendly homepage. On the top of the page, users will be able to learn more about the company, our work ethics and solutions we provide. Below that, clients will be able to fill in details to contact the customer service team directly. At the center of the page, users will be prompted to click "get-started"

Image 2: Login Page



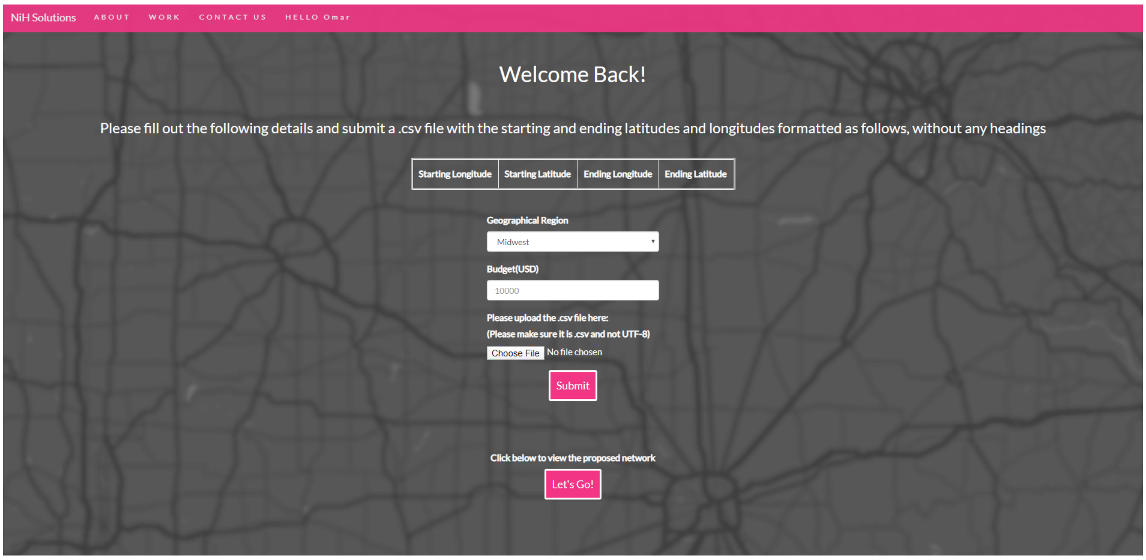
The "Sign up" function will allow users to sign-up or log-in to their existing accounts. The page will alert users if their account is already in the system. NIH has implemented high end security into their web platform and database to ensure clients' information are protected and are not vulnerable to the use of SQL injections in our login page.

Image 3: Sign up Page



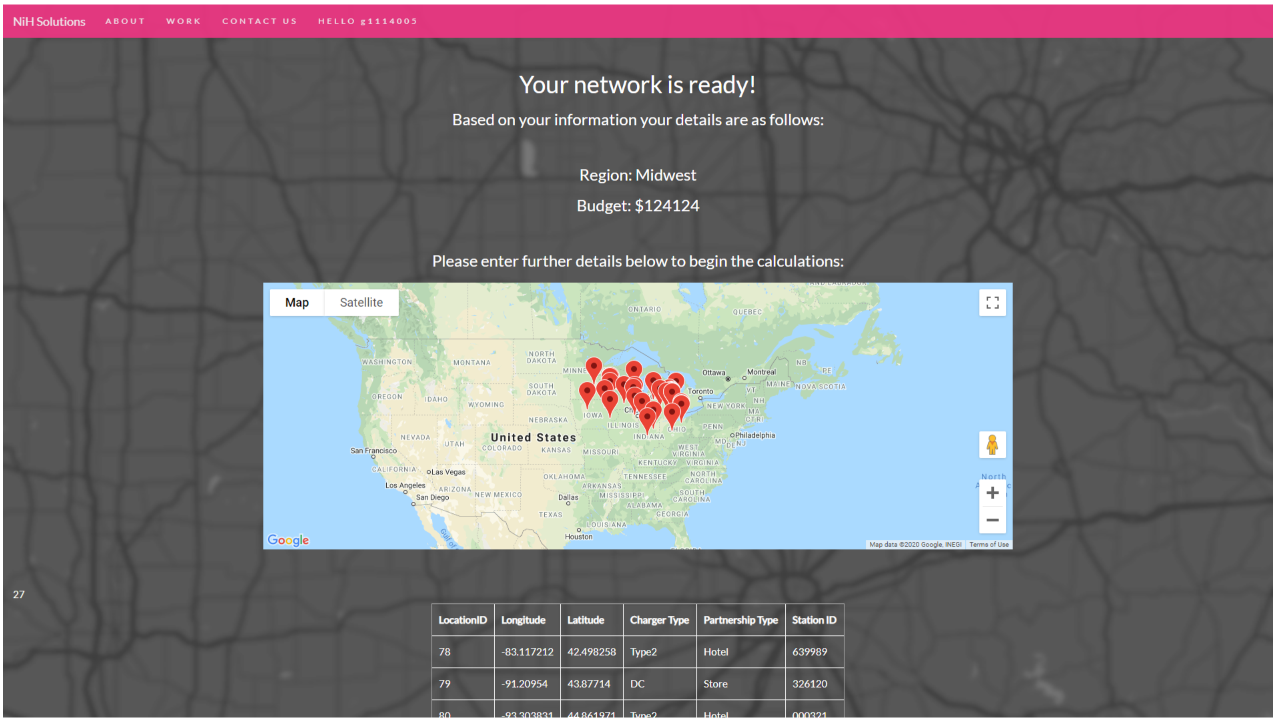
For new users, they will be required to provide their email address, password, username of choice, desired geographical region and budget. Our website platform ensures that new users are unable to create accounts using emails and usernames that are already created by existing users and prevents the submission of empty forms.

Image 4: Input Page



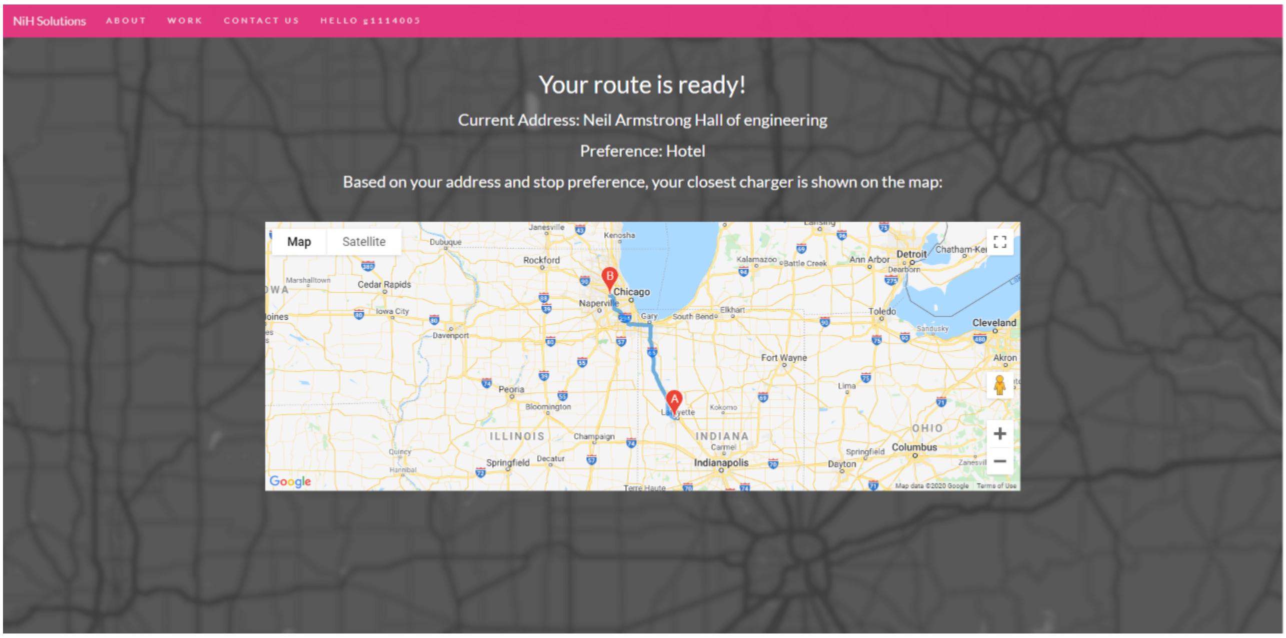
After logging in, users will be able to key in their specific geographical edges (Starting Longitude, starting latitude, ending longitude , ending latitude) that will be inputted into the Automated Station Spot.

Image 4: Mapping Page



As shown on the image above, the final solution page will indicate a map with all the individual station locations plotted with a red marker. On the side, Automated Station Spot will also output a list of all the longitude and latitudes of each individual station. With this, clients will be able to conveniently zoom in and zoom out to further analyze if the suggested charging station locations are matching their investment criteria.

Image 4: Routing Page



4 Company's Future Considerations

4.1 Future Initiatives and Plans

- Mobile Functionality (App) - With most people being active mobile users, the plan is to transfer more minute parts of the solution functionalities to mobile platforms such as IOS or Android in the form of an app. This will allow NIH to provide more value to our customers in terms of customer engagement and convenience. The app will also have specific functions that complement the website.
- Real-time Tracking - automatically updated routes based on latest data or update. Future versions of the website will have a refresh function where the user can have real-time data updated to them instantly. This ensures that every user is getting the most up-to-date routes based off any changes they made while driving.
- Street-View - clients are able to view actual street location of stations. The map interface on the website will be updated to include the street-view function so users will be able to identify and evaluate the actual location specified to each assigned station.
- Real-time Charger Availability - In the fast paced world we live in today, NIH wants to provide their customers the option to select the next best charger in case the chosen charger is busy. We are planning on implementing live feeds on availability of EV chargers to help drivers plan out their trips!

5 Conclusion

At NIH Solutions, each one of the members is passionate about helping change the way society approaches electrical vehicles. The main aim is to provide the clients and users with the most pivotal information regarding electric charger vehicles throughout the country. The immense increase in popularity amongst electrical vehicles is ever growing. NIH's website using its algorithms will provide users with the optimal locations of charging stations and the type of chargers at each station. NIH Solutions' work will have a major impact on the economy and the environment both. Using important data and including receptive motion maps in our website, NIH aims to be at the forefront of the advancement of electric vehicles across the globe.

6 References

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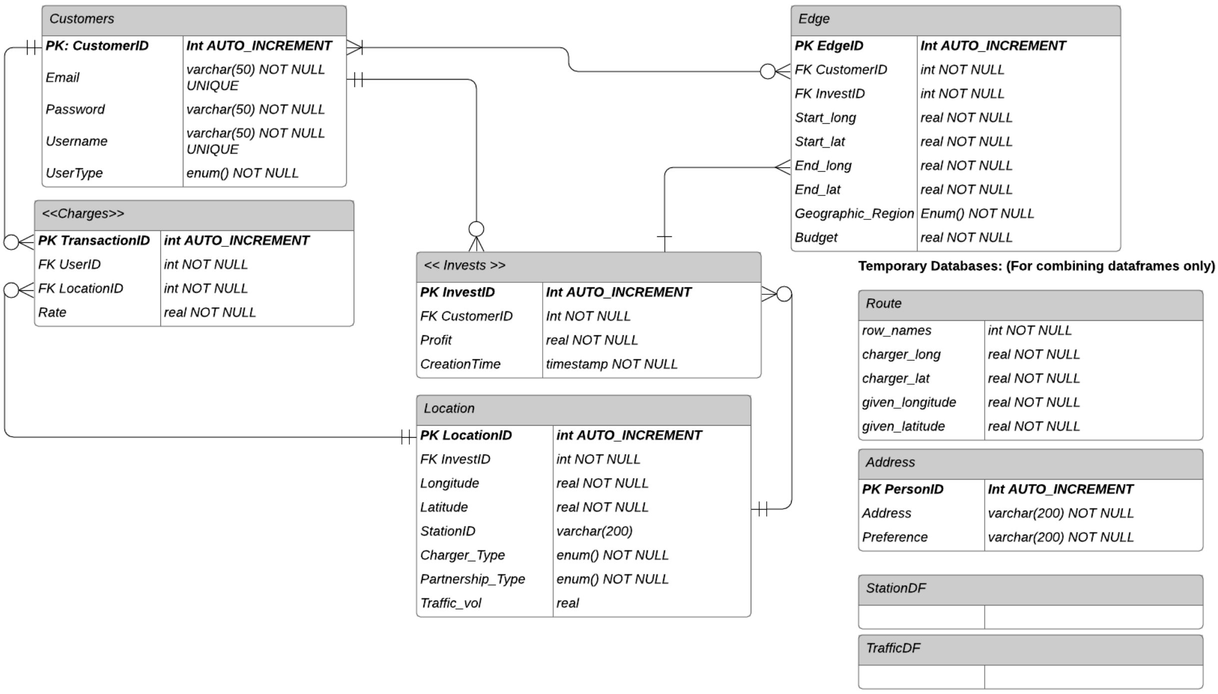
7 Appendix

7.1 Database Design ERD

Figure 1. ERD of Database for webpage in Crows foot notation



7.2 Simulation Model

Description

The group was tasked with creating an algorithm that will simulate projected traffic in all of the United States, based on the traffic data spreadsheet provided and other sources. The goal of this is to create a better estimation of traffic based on the traffic pattern acquired from past data. The further goal is to rely less on the data spreadsheet and more on the projected estimation and to continually improve this algorithm, adding more sources for better accuracy.

To simulate the data we first found which distribution fit the traffic the best, using the graph seen in Figure 1., we noticed that beta was the best fit but beta is a distribution form 0 to 1, thus we used gamma which was the next closest and used gamma distribution parameters found from the traffic data given to us to generate the traffic for the next 5 years. The fit of gamma to the distribution can be seen visually through Figure 2.

Figure 2. Distribution check using Cullen and Frey Graph

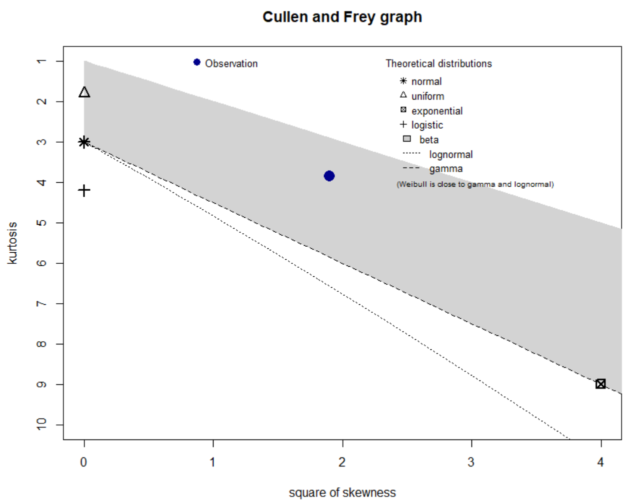
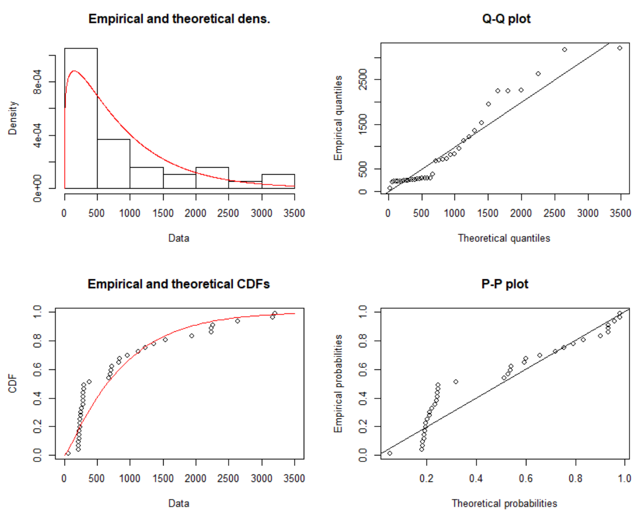


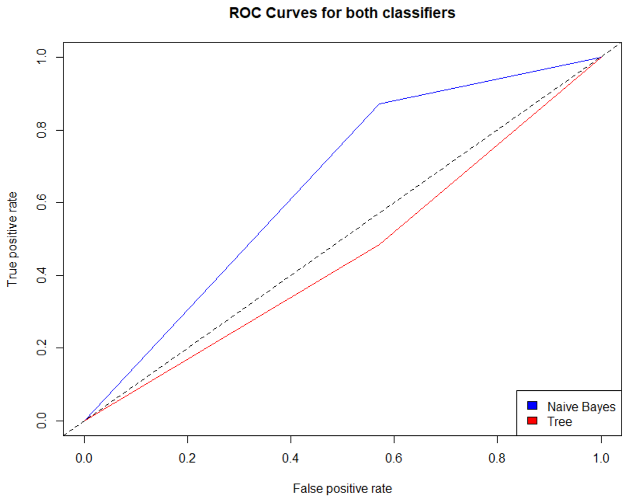
Figure 3. The four plots to check fit of a particular distribution



We used machine learning to classify if the demand was worthy of a hotel or a store, our assumption was that any demand higher than the median of the demand would be for a hotel. Thus, using the classification of the data given (2015), we trained two different classification models, Naive Bayes and Decision Tree. After testing them with the 2016 data, we found that the Naive Bayes classifier was a better model (greater AUC) as seen in the ROC plot in Figure 3. After using NB to test on the other data sets, Years 2016-2019, we noticed that the confusion matrix showed an average accuracy of 85%

which is comparable to the 88% accuracy shown by the confusion matrix of the 2015 test data and 2016 predicted data.

Figure 4. ROC plot



Top Challenges

- The challenge with the ML part was: how to predict/classify daily data. There were a lot of difficulties predicting or classifying daily traffic, because of the way the data was structured. Thus we used prediction and classification on stationIDs again with aggregated data which worked well. Code Lines 422 - 480
- The challenge with the simulation part was: to trust the simulated data or not. Since the data was varying in size each time we ran and tested the algorithm, the distribution varied a lot in terms of the fit of QQ plot and PP Plot. We overcame it by using law of averages, each time with the data set increasing in size, we noticed that gamma was still the closest distribution, Figure 3 is for one of the bigger data sets so you can see it deviated from the central line, but if the traffic trends are noticed in the Client PDF submitted, those are from a different sized solution set and the trends are all similar to each other, thus gamma was a suitable distribution. Code Lines 364 - 370

7.3 Optimization model

Description The group's optimization model made use of the Simulated Annealing algorithm to determine the optimal locations and the number of charging stations and the number of hotels and convenience store partnerships. Both longitude and latitude and the budget is given by the client in the website interface and are passed down into R. The geographical region merges the traffic and station data sets to help create the initial optimal solution. All the coordinates that exist between two given nodes are extracted from the data set and passed through a function as an initial solution. The solution is then aggregated by stationID to get the average daily traffic for each station thus improving the initial solution before its run in the SA. An objective function was created to calculate partner profits and the company's profit based on a number of factors like demand, cost-profit analysis, and occupancy rates to make a realistic solution. Based on the objective function, the SA chose the solution based on the max profit returned. A neighbor function was created to swap out a charger that didn't meet the needs and instead sampled from the remaining data to void duplication.

Top Challenges

There were many challenges that the group encountered when creating the algorithm to determine the optimal locations for the charging stations. The top two challenges that we had found most difficult to troubleshoot were the discarding duplicate values in the merged data sets and reducing the run time of the algorithm.

- When merging the traffic and station data sets, there existed many duplicate entries because of the different fips code being applied to the same coordinates pair or because of the same station being picked due to its high demand over several days. This would become an inconvenience since it introduced error and inaccuracy into our computed output. To tackle this problem, we aggregated the data set by stationID and took an average of the daily traffic to result in one daily average for each station. Also, for every iteration that the algorithm had to compute a new neighboring solution, a data set was created that removed any instance of duplicates that existed in the merged traffic and traffic stations data sets. Code Lines: 139-142
- The initial algorithm we had created had a run time of over thirty-five minutes to complete! Our goal was to create the most efficient algorithm that would be able to generate a correct solution in the most reasonable amount of time. To tackle this, there were many considerations that the group has taken, for instance, we had placed several constraints (like aggregation and only working with certain interval of coordinated) that would drastically reduce the size of the data set that would be passed down the simulated annealing algorithm. One major fix was the removal of most of the while and for loops in the algorithm, which drastically decreased run times. Our efforts have reduced the run time of the algorithm to around 10 minutes!

Psuedo Code

```
Initialize( Temperature T, Random Initial_Solution)
WHILE Cool <= MaxIteration
        Cool = Cool + 1
        Temp_iteration = 0
        WHILE Temp_iteration <= reps
        Temp_iteration = Temp_iteration + 1
        SELECT a neighborhood_sequence from the neighborhood function
        COMPUTE Objective_value(neighborhood_sequence), SET AS neighbor_Sol
        IF neighbor_Sol > Compute Objective_value(Initial_Solution), ACCEPT Neighbor
        Else, Repeat and Store
        END
        END
END
```

7.4 Path-finding algorithm

Description The group was tasked with creating a viable algorithm to test the viability of the service we created. This algorithm is supposed to create paths between two points going through our charging station network. This is useful because we can directly test how good our assignment of charging stations was, by simulation what an average electric car trip would be using this path finding algorithm. Therefore, if the path were to be outputted successfully, then the charger placement network is viable and can be functional in realistic scenarios. This algorithm is supposed to show our investors and potential customers that our service is realistic and could be applied in reality.

To create this tool, we have made use of both Geo-Coding and a Routing API by Google. In the web platform, the driver inputs their location's address (not in the format of coordinates), and their desired location for their charger (a hotel or a strip mall/convenience store). With the use of PHP, the stores the user's input into a database created with MYSQL, and executes a R script to find the closest charger location based on the preference of the user. The algorithm takes in the consideration of the traffic density and the distance between the charger and the driver.

Top Challenges

The biggest challenge our group faced when tackling the routing problem was integrating the routing algorithm with the web page and database. A lot of work had to be done to have the web page and database work alongside with the routing algorithm since errors arose after implementing a working Simulated Annealing algorithm. Since path finding algorithms are relatively simple concepts and there are many such examples available online, another challenge was getting the routing algorithm to work correctly with the simulated annealing algorithm used in our simulation. We had to create weights for all the charging locations which were based on the traffic density and the distances between the user and the charging locations.

Psuedo Code

```
GET Address
GEOCODE Address, SET to Geo_Address
EXTRACT Longitude AND Latitude FROM  Geo_Address, SET AS Start_Cords
GET Preference FROM User
SEARCH SQL Locations WHERE PartnershipType = Preference
CALCULATE DISTANCE BETWEEN Locations AND Start_Cords
SET Index = MIN(Distance)
GET Locations(Index), SET Goal
ROUTE Start_Cords TO Goal
```