Optimal Placement of EV Charging Stations

Introduction

The rapid expansion of the electric vehicle (EV) market presents a transformative opportunity in the transportation sector, offering a sustainable alternative to traditional combustion engine vehicles. As governments worldwide intensify efforts to combat climate change and reduce carbon emissions, the adoption of EVs has emerged as a key strategy to achieve these goals. However, the widespread adoption of EVs necessitates a comprehensive infrastructure network capable of supporting their charging needs.

The background of this project is rooted in the recognition of the crucial role played by charging infrastructure in facilitating the transition to electric mobility. The successful integration of EVs into the transportation ecosystem relies heavily on the availability of reliable and accessible charging stations. Effective planning and deployment of charging infrastructure require an understanding of various factors, including anticipated charging demand, geographical distribution, charging behavior patterns, and technological advancements in charging technology.

The optimal placement of charging stations is essential for addressing range anxiety—a significant barrier to EV adoption—and ensuring seamless access to charging facilities for EV owners. By strategically locating charging stations in high-demand areas and along major transportation routes, we can mitigate range anxiety, enhance the user experience, and promote the widespread adoption of EVs.

Motivation and Objective:

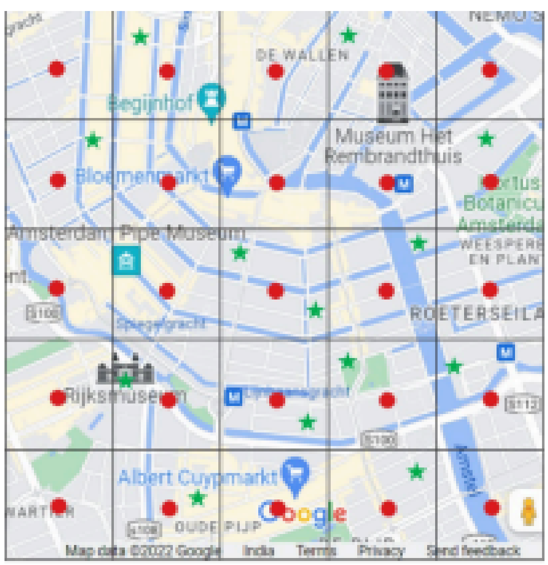
The motivation behind this project stems from the urgent need to address the challenges associated with forecasting upcoming EV charging demand and optimally placing charging stations to meet the evolving needs of electric vehicle (EV) users. As the adoption of EVs continues to rise globally, there is a pressing demand for reliable and accessible charging infrastructure to support this transition.

The objective of this project is twofold: Firstly, to develop accurate forecasting models that anticipate future EV charging demand based on factors such as EV adoption rates, demographic trends, and charging behavior patterns. Secondly, to strategically place charging stations in optimal locations to ensure seamless access for EV owners, mitigate range anxiety, and promote the widespread adoption of EVs.

By leveraging data-driven forecasting techniques and optimization algorithms, we aim to provide actionable insights and recommendations to inform decision-makers and stakeholders involved in EV charging infrastructure planning and deployment. Ultimately, our goal is to contribute to the development of sustainable transportation solutions by facilitating the transition to electric vehicles and addressing the challenges of EV charging infrastructure deployment in a rapidly evolving mobility landscape.

Problem Statement

Given a geographic location which can be assumed as a grid containing 64 x 64 cells where the the demand of each cell from the year 2010 to 2018. The geographic location contains 100 public locations which are available to install charging stations so as to meet the power demand of EVs. The objective is to predict the EV power demand for 2019 and 2020 and place the charging stations in the public locations accordingly to meet the forecasted power demand.



Total EV charging demand of each block is represented at the centre of the block. Let's call these centre points as **demand points**, which are represented as red circles in the Figure . All demand points of a geographic region collectively create a demand map over the region of interest. For each demand point, forecasting can be done using the historical demand maps.

EV charging stations are typically installed at public parking locations so that EVs can be charged during the idle parking time. These parking locations are predefined based on how real estate has been developed in the region. These are called **supply points** and are represented as green stars in Fig. 1. Each parking location has a fixed number of parking slots i.e. potential places to install EV charging stations. Typically, two types of charging stations are installed based on their supply capacity: **i) slow charging**

station (SCS) and ii) fast charging station (FCS). Based on how many SCS and FCS are installed at a parking location and their respective charging capacities, we can calculate the maximum supply that can be given by each supply point. All supply points of a geographic region collectively create a supply map over a region

Data Available:

1. Demand_History.csv: A time-series of EV charging demand over a region. We have considered the demand map of 64x64 equi-spaced points. For ease of use, we have flattened the demand map and provided the index, x-coordinate and y-coordinate of each demand point. Demand history is provided from the year 2010 to 2018.

2. Existing_EV_infrastructure_2018.csv: Details of the existing EV infrastructure of the year 2018. This dataset comprises index, x-coordinate and y-coordinate of each of the 100 parking locations (supply points). It also provides the maximum number of parking slots available at each parking location along with the number of SCS and FCS already in place as of 2018.

The demand for a cell in the grid represents the average of maximum power demand observed in a day for the entire year.

i.e., Demand = $(D_1+D_2+D_3+......D_{365})/365$
where $D_i$is the maximum power demand on the i^{th} day.

Using the above data, forecasting the demand and optimization of EV infrastructure for the year 2019 and 2020 under certain practical constraints.

List of symbolic Representations:

i = Index of the demand point. i varies from 0 to 4095

j = Index of the supply point (parking location). j varies from 0 to 99

D_i = EV charging demand at the i^{th} demand point.

SCS_j= Number of slow charging stations at j^{th}supply point

FCS_j = Number of fast charging stations at j^{th}supply point

PS_j= Total parking slots available at j^{th}supply point

Cap_{SCS}= Charging capacity of a slow charging station = 200

Cap_{FCS}= Charging capacity of a fast charging station = 400

$Smax_j$ = Maximum supply that can be given from j^{th}supply point

$= (Cap_{SCS} \times SCS_j) + (Cap_{FCS} \times FCS_j)$

$Dist_{ij}$= Distance between i^{th} demand point and j^{th}supply point (Distance matrix)

DS_{ij}= How much demand of the i^{th} demand point is satisfied by the j^{th}supply point (Demand-Supply matrix)

Practical constraints:

1. All values of the demand-supply matrix (DS_{ij}) must be non-negative. 2. All values of the number of slow (SCS_j) and fast charging stations (FCS_j) must be a non-negative integer.

3. Sum of slow (SCS_j) and fast charging stations (FCS_j) must be less than or equal to the total parking slots (PS_j) available at each j^{th}supply point.

4. You can only build incremental EV infrastructure on top of the 2018 infrastructure. That means, SCS_j and FCS_j must increase or stay constant year-on-year at each j^{th} supply point.

5. (Sum of fractional) Demand satisfied by each j^{th}supply point must be less than or equal to the maximum supply available.

$$\Sigma_i DS_{ij} \leq Smax_j$$

6. (Sum of fractional) Forecasted demand at each ���� ����ℎ demand point must exactly be satisfied.

$$\Sigma_i \, DS_{\mathbf{ij}} = ��_{forecast,i}$$

Cost Function :

customer dissatisfaction cost (c1) = Σ $Dist_{\mathbf{ij}} * DS_{\mathbf{ij}}$

Infrastructure cost (c2) = Σ $(SCS_{\mathbf{j}} + r * FCS_{\mathbf{j}})$

Overall cost = a * c1 + b * c2

where a=1 , b=25 , r=1.5