Electric Vehicle Charging Station - Optimizing Placement Tool via Infrastructure Modeling (EVCS-OPTIM)

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Abstract

The transition to electric vehicles (EVs) is critical in reducing greenhouse gas emissions and promoting sustainable transportation. However, the expansion of EV infrastructure, particularly charging stations, must be strategic to support increased EV adoption effectively. This project, EVCS-OPTIM (Electric Vehicle Charging Station - Optimizing Placement Tool via Infrastructure Modeling), utilizes data-driven methodologies, including time-series analysis, graph theory, geospatial analysis, and optimization modeling, to determine the most effective locations for new EV charging stations within the SDG&E service territory. By integrating historical EV adoption data, transit patterns, and power grid constraints, this project aims to provide an interactive tool that facilitates strategic decision-making for EV infrastructure deployment.

Code: https://github.com/ericstratford/charger-optimization

1 Introduction

The EV industry is experiencing rapid growth due to advancements in technology and a growing emphasis on clean transportation. EV sales are projected to account for over 30% of all new vehicle sales in the United States by 2030. California is one of the leaders in this shift, having made it a goal to have 100% of its newly sold consumer vehicles be zero emission by 2035. In the San Diego region alone, the number of registered electric vehicles has doubled since 2022.

To support the growing transition to EVs, it is fundamental that the relevant infrastructure be developed alongside EV adoption. The strategic placement of electric vehicle charging stations has become a significant challenge in this shift. An insufficient network of chargers leads to “charging deserts”, range anxiety, and inaccessibility. Developing a well-distributed grid of charging infrastructure is necessary to minimize reluctance towards EV adoption and support increased capacity demands.

In this study, we aim to effectively determine and identify optimal places for new EV charging stations to effectively encourage and accommodate increases in EV adoption. We will analyze variables such as cost-network data, proximity to existing infrastructure, and consumer-demand incentives. Moreover, we will examine how these factors correlate with the location of existing EV chargers. By understanding how these factors interact, we can create a model that generates the most optimal parking lots for new EV charging stations.

1.1 Literature Review

As we explored the topic of identifying optimal placements for potential EV charging station development, we encountered a few existing resources pertaining to the problem. One key resource was a research paper which examined optimization models to locate potential development sites through a combination of “Distribution Network Operator”, “Cat Swarm Optimization”, and “EV user”. This involved using electricity network capabilities, upfront installation and recurring costs, as well as demand-side costs. The proposed modeling techniques by these metrics were gray wolf optimization as well as machine learning (Ahmad et al. 2022). This paper in particular inspired much of the techniques explored in our approach to the problem, namely the data areas. However, the paper’s discussion of both optimization algorithms as well as machine learning was a large part of our approach. As we built our features and refined our understanding of the problem at hand, we came to realize that the recommendation of new chargers was better suited through optimization, as the machine learning approaches involved assumptions that were not safe to make. Machine learning was better served as a technique used during our feature selection process. Instead, we have been and are continuing to explore optimization models and scoring methods which leverage field-expertise and understanding alongside feature weighting algorithms.

Aside from literature in particular, there are also existing public-access models which attempt to provide recommendations for EV charger placement, though their capabilities are often limited to specific use cases, and do not broadly address the recommendation question. Sites such as NREL provide numerous tools relating to this. EVI-EnSite and EVI-LOCATE are examples of neighboring tools which help evaluate proposals of specific site deployments, utilizing data related to that which would flow into our model. These tools provide direction on how specific forms of data can be used to inform our recommendation process, especially when it comes to the capacity and cost data.

1.2 Data Review

To achieve project objectives, we will use datasets from:

- Alternative Fuels Data Center (AFDC): Public charging station locations and specifications.
- Data SD: Traffic volume and patterns at key intersections.
- SANDAG: Income, demographic, and census data.
- SDG&E: Energy usage data and charger development information.
- CA DMV: Vehicle registration data.

Key features include:

- High-traffic areas (OSMnx).
- Proximity to commercial hubs and transit destinations.
- Demographics and income by zip code.
- Development and operational costs.
- Electric vehicle distributions and adoption rates.

The key to the success of our project is having access to high-quality, relevant data that will enable us to conduct meaningful analysis and achieve the desired outcomes. In addition to the data used for our Quarter 1 project, we will be incorporating several new datasets from the Alternative Fuels Data Center, Data SD, SANDAG, and San Diego Gas & Electric. These datasets will provide the comprehensive information necessary to carry out our project's goals.

The data provided by the Alternative Fuels Data Center (AFDC) has information on all public alternative fuel stations across the United States and Canada. This dataset includes key details such as station locations, descriptions, and specifications of each charging facility. For our analysis, we will filter the data to focus exclusively on chargers within the San Diego area. Managed by the U.S. Department of Energy, the AFDC is a reputable and reliable data source, which we also leveraged extensively in our Quarter 1 project. Given our prior experience with this dataset, we are confident in its accuracy and suitability for supporting the objectives of our current project.

In addition to charger data, our project incorporates transit and traffic data, which we can access from Data SD. The data is publicly available and is distributed by the City of San Diego, so it is of sufficient quality for our use. The transit dataset has information on the name and location of every transit stop managed by the San Diego County Metropolitan Transit System (SDMTS) and the North County Transit District (NCTD). The traffic dataset contains the vehicle counts at specific San Diego street intersections over 12 years. Both transit and traffic data are important factors to consider for our project because identifying high-traffic areas can help us place chargers in high-demand locations, ensuring accessibility and convenience for drivers. Several other key factors also influence traffic patterns and road network design, including road capacity, travel time reliability, proximity to key destinations, and the overall connectivity of the network. To evaluate these factors, we will use data from OpenStreetMap, SANDAG, and other datasets from Data SD, all reputable geospatial data analysis resources. By evaluating these additional factors, we can ensure that charger placement meets demand and integrates seamlessly with existing infrastructure, optimizing accessibility for users.

We will utilize income data from the SANDAG Open Data Portal to ensure our project effectively addresses demographic factors. This dataset provides detailed information on the number of households within each income bracket for every zip code in San Diego. In addition, we will incorporate data from SANDAG's Census Datasets to gather further insights into San Diego's population, including ethnicity, age, and educational attainment. SANDAG is a well-regarded organization specializing in urban planning and transportation in San Diego, making its data a reliable source for our analysis. Using this census data is essential for our project, as it will help us identify underserved communities where EV chargers can be strategically placed to promote greater access to electric vehicle infrastructure and encourage adoption in disadvantaged areas.

Additionally, we will incorporate energy usage data from San Diego Gas & Electric (SDG&E). This dataset provides monthly data on the energy usage for each zip code within SDG&E's service area, broken down by customer type—residential, commercial, or industrial. Since SDG&E is a well-known electrical utility company, the dataset is accurate and suitable for our project. Access to detailed energy usage information is crucial for our project, as it allows us to assess electrical grid demand to ensure that new chargers won't overwhelm the existing electrical demand.

Since our project will be outputting the most optimal parking lots to place new EV chargers at, we will use parking lot data from Overpass Turbo and OSMnx. The dataset contains the location of every public parking lot in San Diego County. The dataset is generally reliable and accurate, but there may be a few limitations. The data from Overpass Turbo and OSMnx are based on user contributions, which may cause potential gaps in coverage, especially in less populous areas. As a result, our dataset may not include all parking lots in San Diego.

2 Methods

This study evaluates public parking lots within San Diego County as potential locations for new EV chargers. The objective is to develop a metric that scores how optimal each parking lot is for EV charger installation based on several key factors, such as proximity to key infrastructure, traffic density, population density, and city planning zones. Proximity to infrastructure measures the distance between the parking lot and important facilities like transit stops, commercial districts, and retail centers. Traffic and population density are other important factors to consider because areas with higher vehicle flow and populations are expected to have greater demand for EV charging stations. Finally, city planning zones are used to understand the land use surrounding each parking lot, as residential or business zoning areas may experience different charging demand levels.

Each feature is then standardized through normalization and percentile ranking to ensure that every factor is measured on a common scale. Normalization scales the data for each feature to be between 0 and 1, while percentile ranking is used to position each parking lot relative to others in the dataset.

Once the features are standardized, they are assigned a weight to reflect their overall impact on EV charger locations. Each feature's weight is determined based on our correlation analysis of the data. The weighted, standardized features are combined to calculate a total score for each parking lot. This score, which ranges from 0 to 1, provides a metric of the parking lot's suitability for EV charger placement.

Based on the scores, parking lots are either recommended for installation or ranked according to their suitability. Parking lots with scores exceeding a certain threshold may be directly recommended for EV charger installation, while others are ranked based on their total score.

3 Results

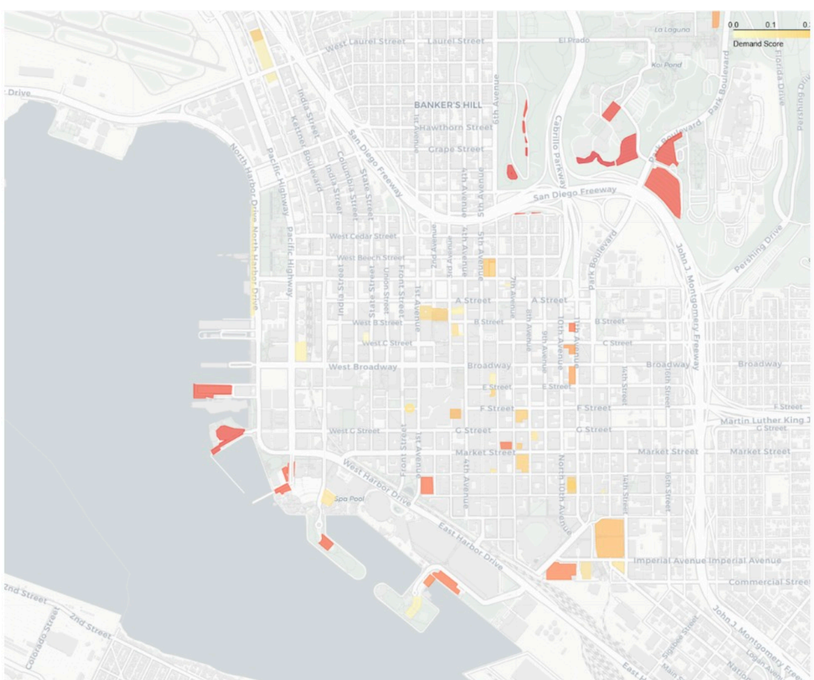

Figure 1: Preliminary map of public parking lots colored by demand score. This image only shows demand score based on a percentile optimization scoring method from proximity to existing chargers.

4 Conclusion

5 Appendix

5.1 Original Project Proposal:

https://drive.google.com/file/d/13v77ZbZaUOx34HUbx6grOSFk-v7XmN2N/view?usp=sharing

5.2 Other Images

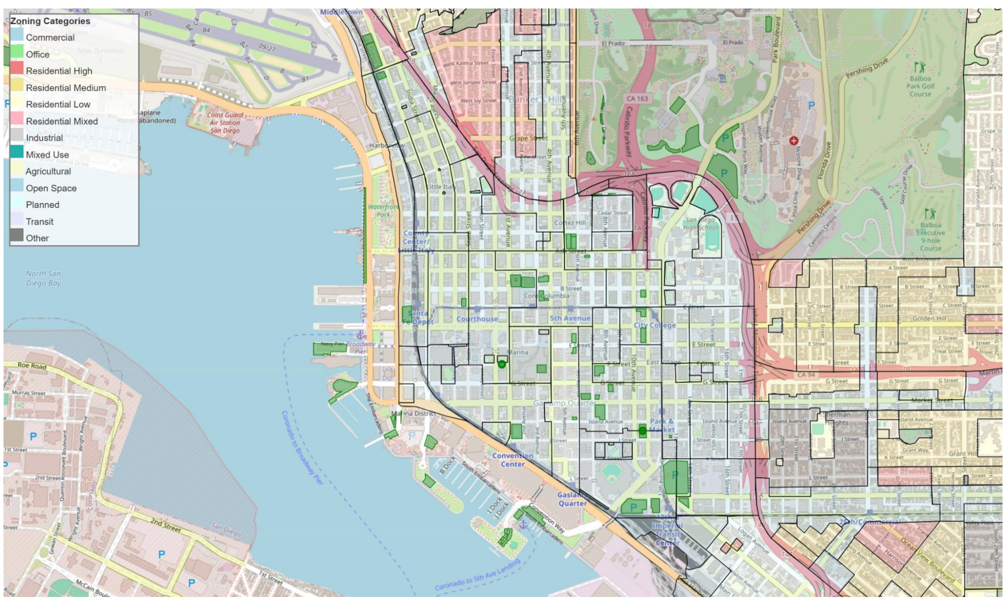

Figure 2: Public Parking Lots and Zones

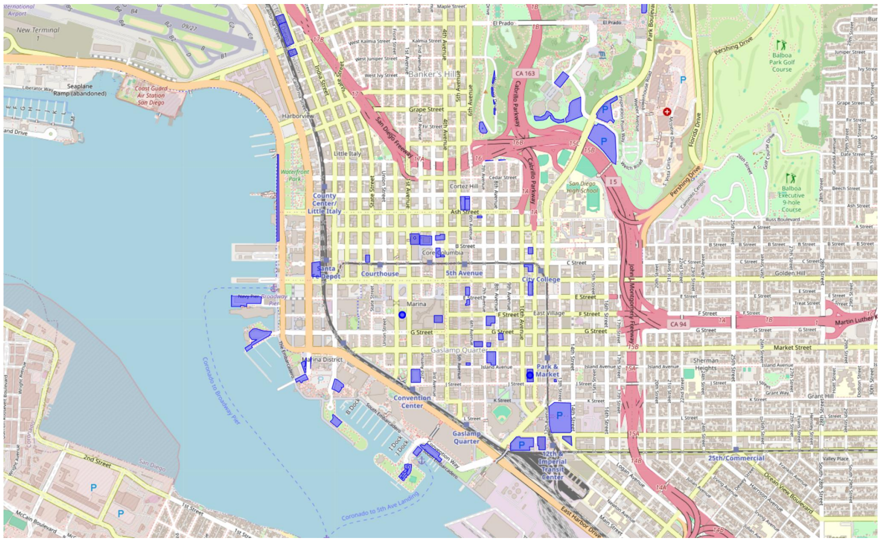

Figure 3: Public Parking Lots

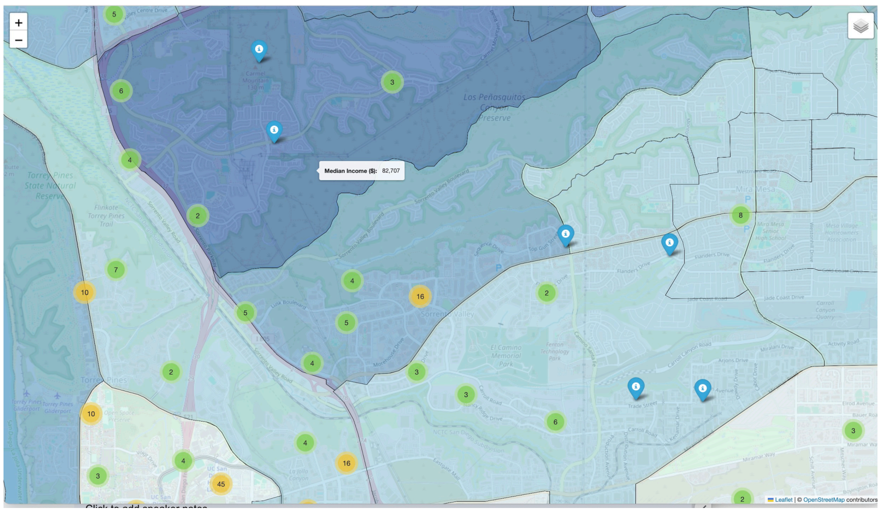

Figure 4: Public Parking Lots

6 Contributions

Here are the contributions that each group member did for the project:

- **Vanessa**: Explored traffic and transit data. Worked on model development.
- **Eric**: Explored cost-based data. Worked on model development.
- **Mianchen**: Explored demographic and EV adoption data by zipcode. Worked on model development.
- **Xianzhe**: Explored zoning data. Worked on website.

References

Ahmad, Fareed, Atif Iqbal, Imtiaz Ashraf, Mousa Marzband, and Irfan khan. 2022. “Optimal location of electric vehicle charging station and its impact on distribution network: A review.” *Energy Reports* 8: 2314–2333. [Link]