**Optimizing EV Charging Station Locations: A Data-Driven Approach**

### Executive Summary

With the rise of electric vehicles (EVs), ensuring efficient and accessible charging infrastructure has become a key challenge for city planners and private enterprises. This project leverages **data-driven decision-making**, **optimization modeling**, and **multi-criteria analysis** to identify optimal EV charging station locations in Bristol. By applying **Python, SQL, machine learning, and optimization algorithms**, we developed a **scalable framework** that improves charging station coverage by **70.89%** while minimizing user travel distance.

1. **Business Problem**

**Challenges in EV Charging Infrastructure**

* **Uneven Distribution**: Many EV users struggle with **charging station availability**, especially in high-demand areas.
* **Investment Inefficiency**: Poor site selection leads to **underutilized** or **overcrowded** charging stations.
* **User Experience**: Longer travel distances to charging points **reduce convenience**, affecting EV adoption.

1. **Our Solution: Data-Driven Site Selection**

This study employs **a systematic decision-making framework** that integrates:

* **Multi-Criteria Decision Analysis (AHP, Huff Model)** for candidate site ranking.
* **Mixed Integer Programming (MIP)** to optimize charging station locations.
* **Machine Learning (XGBoost)** for sensitivity analysis to enhance model robustness.

1. **Data & Methodology**

**Data Collection**

We utilized **public and proprietary datasets** from:

* **Government Reports**: EV charging plans & regulations
* **Open Data Bristol**: Population demographics, road networks
* **GIS Mapping**: Existing and potential charging station locations

**Optimization Strategy**

**1. Candidate Site Evaluation (AHP Model)**

Using **Analytic Hierarchy Process (AHP)**, we ranked potential locations based on:

* **Proximity to Demand** (EV commuters within 1 mile)
* **Accessibility** (Distance from main roads)
* **Expansion Potential** (Young population density for future growth)
* **Distance to Nearest Station** (Avoiding redundant placements)

**2. Demand Estimation (Huff Model)**

We applied the **Huff Model** to predict the probability of users selecting a charging station based on:

* **Travel Distance** (Shorter = Higher probability)
* **Charging Station Attractiveness** (Capacity, pricing, accessibility)

**3. Optimization & Sensitivity Analysis**

* **Mixed Integer Programming (MIP)** identified the best station locations while optimizing for **total coverage and efficiency**.
* **XGBoost Model** was used to test different distance parameters, ensuring robust site selection across various user behaviors.

1. **Results & Business Impact**

**Key Findings**

* **Optimal Site: Site 57** achieved the highest balance of accessibility, coverage, and efficiency.
* **Improved Charging Access**: Coverage increased by **70.89%** with reduced user travel time.
* **Investment Optimization**: The model ensures stations are **strategically located**, reducing operational costs.

| **Metric** | **Before Optimization** | **After Optimization** | **Improvement** |
| --- | --- | --- | --- |
| Charging Coverage (%) | 41.5% | 70.89% | +70.9% |
| Avg. Travel Distance (miles) | 4.2 | 3.1 | -26.2% |
| Median Vehicles per Station | 12.3 | 10.97 | +11.3% |

**Visualization: Optimized Site Distribution**

*(Include map highlighting selected optimal sites and travel distance heatmaps)*

1. **Business Applications & Next Steps**

**Real-World Applications**

This framework can be applied to: ✅ **City Planners** - Optimize public EV infrastructure placement. ✅ **EV Charging Companies** - Improve station ROI & operational efficiency. ✅ **Retail & Commercial Hubs** - Strategically place charging points for customer attraction.

**Future Enhancements**

📌 **Real-Time Data Integration**: Use live charging station data to improve demand forecasting. 📌 **Financial Analysis**: Estimate potential **ROI per station** for private investment feasibility. 📌 **Scalability**: Adapt this model for multiple cities with different traffic and EV adoption patterns.

1. **Conclusion**

By leveraging **advanced analytics and optimization techniques**, we have created a **data-driven, scalable framework** that enhances EV charging infrastructure **efficiency and accessibility**. This approach not only benefits users by reducing charging inconvenience but also supports stakeholders in making **smarter investment decisions**.

📎 **[Full Report Available Here] (Insert link)**