Electric Vehicle Charging Demand Forecasting Report

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Introduction

As the adoption of electric vehicles (EVs) continues to grow rapidly, it's becoming increasingly important to anticipate and manage the demand for EV charging. This project focuses on forecasting EV charging needs across the cities of Seattle, Vancouver and San Diego for the period 2025–2027. Accurate predictions are essential for infrastructure development and maintaining grid stability. By integrating datasets on weather conditions, EV ownership and traffic flow, this project applies time-series forecasting models and develops an optimization strategy to help reduce peak load times on the grid. The goal is to offer practical insights to planners, policymakers and energy providers.

Abstract

To accurately forecast EV charging demand, this project combined multiple historical datasets—weather (271,554 records), EV population (239,747 records) and traffic data (48,204 records)—into a single, synchronized time-series dataset. Two forecasting models were used: Prophet (developed by Facebook) and ARIMA. Across most cities, Prophet delivered more accurate results based on RMSE validation scores, especially in cities with robust datasets. In cities like San Diego with sparse data, ARIMA occasionally performed better.

An optimization method was introduced to shift EV charging away from peak hours (7–9 AM and 4–7 PM) to off-peak hours (12–6 AM and 10 PM–12 AM), helping to reduce strain on the power grid. Key outputs include forecast data files, summary sheets for Tableau dashboards, optimized daily charging schedules and a comprehensive interactive dashboard built with Streamlit. These tools equip stakeholders with the information needed for smarter infrastructure planning.

Tools and Technologies Used

- **Programming Language**: Python 3.12
- **Libraries for Data Handling**: Pandas, NumPy
- **Forecasting Models**:
  - *Prophet* – for robust time-series prediction
  - *ARIMA* – for cities with sparse or more linear data trends
- **Visualization Tools**:
  - *Matplotlib* and *Seaborn* – for static charts and graphs
  - *Plotly* – for interactive visualizations (e.g., demand vs. weather)
  - *Graph viz* – to create clear data flow diagrams
- **Web Interface**: *Streamlit* – for an interactive and user-friendly dashboard
- **Development Platform**: Jupyter Notebook
- **Output Formats**: CSV (for data), PNG (for images), TXT (for documentation)

Project Workflow and Implementation Steps

1. Data Collection & Preprocessing

- Gathered and cleaned three key datasets: weather, EV population and traffic volume.
- Aligned timestamps and merged them into a consistent time-series format using Pandas.
- Handled missing or inconsistent values to ensure smooth modelling.

2. Exploratory Data Analysis (EDA)

- Explored key patterns and correlations between EV charging demand, weather (temperature and humidity) and traffic flow.
- Created visuals such as line graphs and scatter plots to highlight trends and relationships.

3. Time-Series Forecasting

- Applied both Prophet and ARIMA models to forecast EV charging demand from 2025 to 2027.
- Evaluated model performance using RMSE (Root Mean Squared Error). Prophet generally outperformed ARIMA especially in data-rich environments.
- Saved all forecast results in CSV format for further analysis.

4. Charging Optimization Strategy

- Designed a rule-based system to redistribute EV charging from peak to off-peak hours.
- Generated a 24-hour hourly charging profile while ensuring that the maximum station load (100 kWh/hour) was not exceeded.
- Saved the optimized results into an output file for operational use.

5. Visualization & Reporting

- Developed a Streamlit dashboard that includes:
    - Historical trends
    - Demand forecasts
    - Impact of weather on demand
    - Optimization summaries
- Created a data flow diagram using Graph viz to map out the entire project process.
- Compiled a detailed text-based report summarizing results, validation metrics and key insights.

6. Deliverables for Stakeholders

- Exported a Tableau-compatible summary table for deeper analysis.
- Documented the entire process and findings in a PowerPoint presentation for stakeholder meetings and future reference.

Conclusion

This project provides a well-rounded and practical solution for forecasting EV charging demand over a three-year period. By integrating diverse data sources and applying both Prophet and ARIMA forecasting models, the project offers reliable predictions to support infrastructure planning. Prophet emerged as the more robust model for most cities, especially where rich datasets were available. The optimization strategy not only forecasts demand but also actively contributes to grid stability by intelligently shifting load to off-peak hours. The Streamlit dashboard makes it easy for stakeholders to interact with the data and understand key insights visually. With outputs prepared for Tableau and PowerPoint presentations, the project is both analytically rigorous and practically usable. Looking ahead, future improvements could include integrating renewable energy forecasts, incorporating real-time data feeds and exploring advanced optimization techniques like reinforcement learning or dynamic pricing models to further improve efficiency and cost-effectiveness.