EV Charging Demand Forecasting & Optimization Using Weather, Traffic & Usage Data

1. Introduction

With the exponential rise in electric vehicle (EV) adoption, optimizing EV charging infrastructure has become critical for sustainable urban mobility. This project focuses on forecasting EV energy demand and recommending an efficient charging strategy by leveraging real-time weather, traffic, and historical usage data.

Our solution integrates data engineering, machine learning (`Prophet`), and business intelligence tools (`Tableau`) to provide actionable insights for stakeholders such as urban planners, utility companies, and EV infrastructure providers.

2. Dataset Overview

The project combines data from multiple sources to form a unified time-series dataset:

Dataset	Description
EV Usage	Timestamped energy consumption per station
Weather	Temperature, rainfall, and other metrics per location
Traffic	Traffic volume categorized by timestamp and station

These datasets were merged and transformed into a clean and enriched dataset: `full_merged_data_feature`

3. Methodology

3.1 Data Preprocessing & Feature Engineering (Python)

- Merged EV, traffic, and weather datasets using timestamp and location.
- Extracted time-based features: `hour`, `day_of_week`, `season`, `part_of_day`, `is_weekend`.
- Generated weather flags (e.g., `rain_flag`) and traffic levels (`Low`, `Medium`, `High`).
- Created rolling averages and lag features to capture trends and temporal dependencies.
- Saved the final dataset after preprocessing for `Tableau` and model input.

3.2 Forecasting Model (Prophet)

- Applied **Facebook Prophet**, a robust time-series forecasting model.
- Regressors included: `traffic_volume`, `temperature`, `rain_flag`, `hour`, `day_of_week`.
- Data was grouped hourly for demand forecasting.
- Forecast generated for both past and future periods with evaluation.

Model Evaluation Metrics:

Metric	Value (example)
MAE (kWh)	12.45
RMSE (kWh)	18.32

4. Data Visualization in Tableau

Created a series of Tableau dashboards using the enriched dataset to explore demand behavior and patterns.

Charts and Dashboards Created

Sheet Title	Description
Energy Demand by Traffic Level	Shows how demand varies across different traffic levels
Station-Level Analysis	Compares demand patterns across various charging stations
Energy Usage by Part of Day	Highlights usage peaks in Morning, Afternoon, etc.
Demand by Traffic	Correlates traffic volume with energy usage
Hour vs Day Heatmap	Heatmap to visualize temporal usage patterns
Demand by Season	Explores seasonal impact on charging demand
Demand Curve by Hour of Day	A typical daily demand curve for planning optimization

Design Features

- Professional dark/light background with clear legends.
- Clean font (e.g., Segoe UI, Helvetica, or Arial).
- Consistent color palette and filters for interaction.
- KPI cards showing average energy usage, peak demand, etc.

5. Charging Optimization Strategy

Based on insights from forecasting and visualization:

- **Dynamic Scheduling:** Increase charger availability during morning and evening peak hours.
- **Location Expansion:** Deploy more charging stations at high-demand locations identified through station-level analysis.
- **Smart Grid Alignment:** Use demand forecasts to align EV charging with low-cost energy periods or surplus grid availability.
- **Rainy Season Prep:** Ensure infrastructure readiness for higher usage spikes during rainy/monsoon periods.
- **Traffic-Linked Pricing:** Consider adaptive pricing models based on traffic intensity to manage load.

6. Deliverables

- `full_merged_data_featured.csv`: Final processed dataset.
- `feature_extractions.py`: Python script for feature engineering.
- `forecasting_ev.py`: Forecasting model using Prophet.
- Tableau Workbook (`.twb` or `.twbx`) with all dashboards and charts.
- Project Report (this document) in PDF format.
- GitHub repository: Smart EV Charging Demand Forecasting & Optimization Using Weather and Traffic Data

7. Conclusion

This project successfully demonstrates the integration of time-series forecasting and business intelligence for EV infrastructure planning. The insights derived enable energy-efficient charging schedules, proactive grid management, and data-driven policy-making.