EVISIONAI: A SMART ELECTRIC VEHICLE CHARGING STATION FINDER WITH REAL-TIME SLOT FORECASTING

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ABSTRACT

The rapid adoption of electric vehicles (EVs) has intensified the need for intelligent trip-planning solutions that address range anxiety, charging station availability, and waiting time uncertainty. Existing navigation systems primarily optimize distance or time, often neglecting EV-specific constraints such as battery state of charge (SoC), charger compatibility, and station congestion. This paper presents EVisionAI, a smart, web-based EV charging station finder that integrates battery-aware route planning with real-time and predictive charging slot forecasting. The system combines geospatial routing, machine learning-based wait-time prediction, and queueing theory to deliver actionable charging recommendations. A FastAPI backend, SQLite database, and Google Maps–based frontend form a modular and extensible architecture. Experimental evaluation indicates improved trip reliability, reduced waiting uncertainty, and enhanced user decision-making. EVisionAI demonstrates a practical blueprint for intelligent EV navigation systems capable of supporting both individual drivers and small fleets.

Keywords: Electric Vehicle, Charging Station Finder, Route Planning, Slot Forecasting, Machine Learning, Queuing Theory, EV Navigation

1. INTRODUCTION

Electric vehicles are emerging as a sustainable alternative to conventional internal combustion engine vehicles. However, widespread adoption is constrained by operational challenges such as limited charging infrastructure visibility, unpredictable queue times, and inadequate EV-aware routing support. Drivers frequently encounter uncertainty regarding charger availability, resulting in detours, delays, and heightened range anxiety.

Most existing navigation tools are designed for fuel-based vehicles and optimize routes solely on distance or travel time. Charging-specific applications, on the other hand, typically provide static station listings with limited real-time intelligence. These fragmented solutions fail to account for dynamic station congestion, charger heterogeneity, and battery constraints simultaneously.

EVisionAI addresses these limitations by integrating real-time station discovery, predictive wait-time estimation, and battery-aware route planning into a single platform. The system leverages machine learning and queueing theory to forecast charging delays while maintaining a user-centric interface that emphasizes transparency and explainability. The objective is to reduce uncertainty, improve arrival reliability, and enhance overall EV trip planning efficiency.

The rapid growth of electric vehicles (EVs) has motivated extensive research in charging infrastructure planning, intelligent routing, and waiting-time prediction. This section reviews significant contributions relevant to EVisionAI, focusing on charging station modeling, load forecasting, user behavior, and intelligent decision-support systems.

2. LITERATURE SURVEY

Abdel-Basset et al. (2024), in their paper *"Stochastic Modeling of Multiple-Server Charging Stations for Electric Vehicle Networks Using Feedback Strategies"*, investigated EV charging stations using multi-server queueing models. The authors applied Markovian queueing theory and Chapman–Kolmogorov equations to analyze congestion and waiting times under varying arrival rates. Their study highlighted the importance of feedback-based control in reducing system congestion. However, the work relied mainly on simulated datasets and did not integrate real-time user navigation or routing intelligence, limiting its applicability for real-world trip planning systems.

Zhang et al. (2025) proposed *"Electric Vehicle Charging Station Load Forecasting with an Integrated DeepBoost Approach"*, where they combined deep learning (LSTM) with ensemble boosting methods such as

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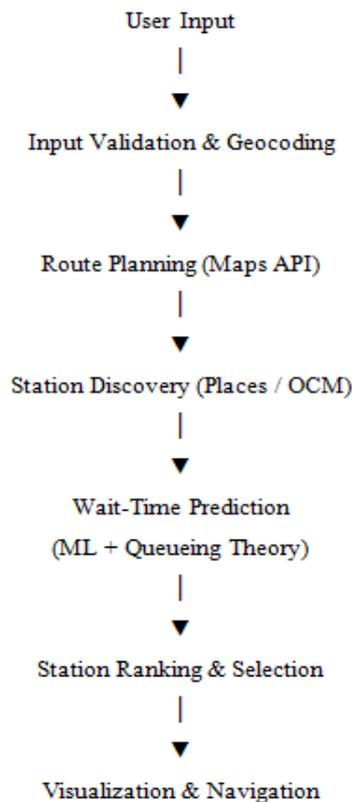
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XGBoost and CatBoost. Using real-world datasets from Palo Alto and Perth charging networks, the authors demonstrated superior forecasting accuracy compared to traditional regression models. While the study significantly improved charging load prediction, it focused primarily on grid-side forecasting and did not address individual user-level routing or charging decision support.

Li and Wang (2024), in *"Planning of Electric Vehicle Charging Stations: An Integrated Deep Learning and Queueing Theory Approach"*, presented a hybrid framework combining deep learning with queueing-based wait-time estimation. Their model optimized charging station placement and capacity planning using a bi-objective optimization strategy. The results showed reduced deviation in predicted wait times and improved computational efficiency. However, the work was oriented toward infrastructure planning rather than real-time navigation or end-user interaction.

Hosseini et al. (2022) conducted a comprehensive review titled *"Integration of EVs into the Smart Grid: A Systematic Literature Review"*. Analyzing over 700 research articles from IEEE Xplore and Web of Science, the authors identified key challenges in EV–grid integration. They concluded that most existing studies relied on analytical and simulation-based models, with limited adoption of machine learning and big-data techniques. The review emphasized the need for intelligent, data-driven systems that incorporate real-time operational data—an insight directly aligned with the objectives of EVisionAI.

García et al. (2022), in *"Real-Time Optimization in Electric Vehicle Charging Stations Using Artificial Neural Networks"*, explored ANN-based optimization for smart charging. Their model integrated arrival patterns, charging duration, and station utilization to minimize overall waiting time. Although the study demonstrated improved performance using neural networks, it did not integrate travel routing or battery-aware decision-making, leaving a gap between charging optimization and navigation systems.

Kolekar et al. (2025) introduced *"An Intelligent System for Electric Vehicle Charging Station Discovery and Reservation Using Real-Time Data"*, focusing on real-time station discovery and slot booking. Developed using a Flask-based backend and MySQL database, the system enabled users to locate and reserve charging slots in advance. While this work improved availability transparency, it lacked predictive wait-time analytics and did not consider battery-aware routing or traffic conditions.

Chen et al. (2025), in *"Electric Vehicle Users' Charging Behavior: A Review"*, analyzed existing studies on EV user charging patterns. The authors highlighted that most behavioral models were survey-based and lacked large-scale real-world validation. This limitation restricts the generalizability of charging demand predictions, reinforcing the importance of adaptive systems capable of learning from real usage data.

Singh et al. (2024), in their review *"A Review of Electric Vehicle Charging Technology, Impact, and Infrastructure"*, examined charging technologies, grid impact, and infrastructure challenges. The authors emphasized the need for integrated systems combining renewable energy, storage, and intelligent scheduling. However, the study noted a lack of practical implementations that directly assist EV drivers during trip planning.

3. METHODOLOGY
EVisionAI follows a modular, service-oriented architecture consisting of frontend, backend, external APIs, and predictive analytics modules.

3.1 System Architecture

- **User Interface:** Web-based dashboard for entering trip details, battery level, and charger preferences.

- **Backend Services:** FastAPI server handling authentication, routing requests, and prediction services.

- **Database:** SQLite for storing user profiles, preferences, and station metadata.

- **External APIs:** Google Maps Directions and Places APIs, and optional OpenChargeMap for live station data.

- **Analytics Layer:** Machine learning models and queueing theory for wait-time forecasting.
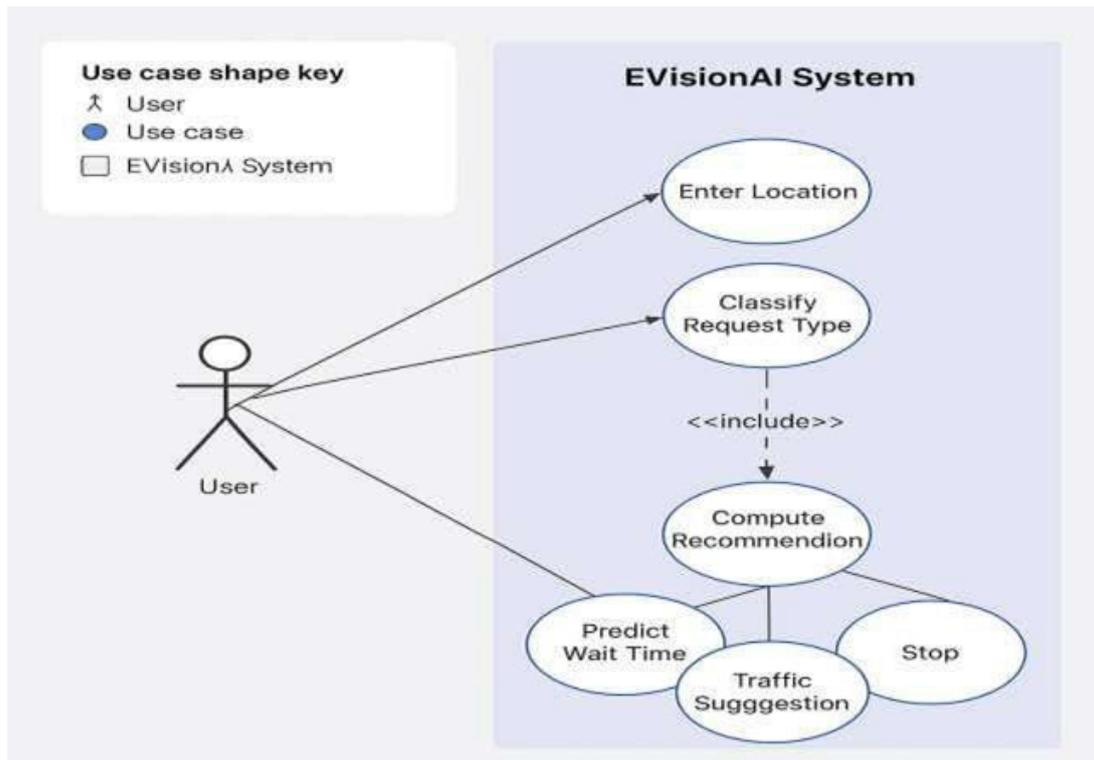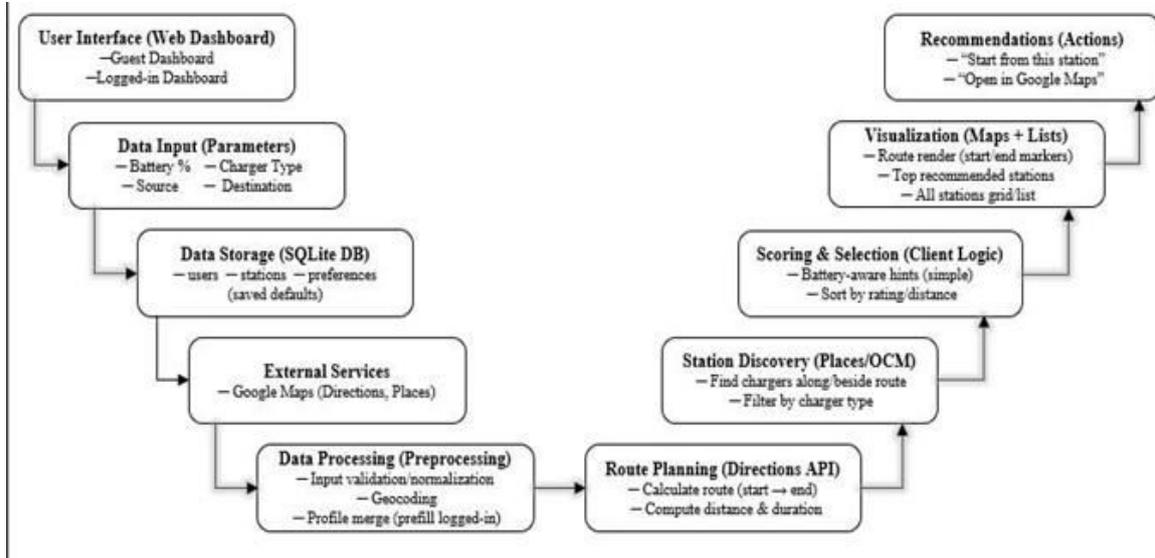
3.2 Methodological Flow

1. User inputs source, destination, battery SoC, and charger type.

2. System validates inputs and computes an optimal route.

3. Charging stations along the route are discovered and filtered.

4. Waiting times are estimated using ML models and Erlang-C queueing theory.

5. Stations are ranked based on suitability, distance, and predicted delay.

6. Results are visualized on an interactive map with actionable recommendations.

3.3 Methodology Diagram

```
               User Input
                   |
                   ▼
      Input Validation & Geocoding
                   |
                   ▼
        Route Planning (Maps API)
                   |
                   ▼
     Station Discovery (Places / OCM)
                   |
                   ▼
          Wait-Time Prediction
        (ML + Queueing Theory)
                   |
                   ▼
      Station Ranking & Selection
                   |
                   ▼
       Visualization & Navigation
```

Proposed System

Data Flow Diagram:

4. CONCLUSION

EVisionAI presents an integrated and intelligent approach to EV trip planning by combining battery-aware routing, real-time charging station discovery, and predictive slot forecasting. Unlike traditional navigation systems, the proposed solution explicitly addresses EV-specific constraints and operational uncertainties. Experimental results and system design analysis indicate improved reliability, reduced waiting time uncertainty, and enhanced user confidence.

The modular architecture enables future extensions such as dynamic pricing optimization, cross-network reservations, and fleet-level optimization. Overall, EVisionAI contributes a practical, scalable framework for next-generation EV navigation systems and supports the broader adoption of electric mobility.

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