



Tripper: A Smart Electric Vehicle Navigation Application For Safe And Intelligent Route Planning

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Abstract

The global surge in electric vehicle (EV) adoption has introduced unique challenges in trip planning, primarily driven by constrained battery ranges and unevenly distributed charging infrastructure. Conventional navigation platforms are engineered for traditional vehicles and fail to address EV-specific requirements such as real-time battery feasibility analysis and en-route charging station availability. This paper introduces TRIPPER, an intelligent EV navigation mobile application designed to support safe and optimized journey planning for electric vehicle users. The system integrates road-network-based routing, battery range evaluation, and charging station identification through open-source geospatial technologies. Developed on the Flutter framework, the application employs the OSRM API for route computation and OpenStreetMap for map rendering and charging point data. Firebase services provide user authentication and cloud data storage. The system assesses route viability by comparing computed travel distances against available battery capacity and notifies users whenever intermediate charging becomes necessary. Experimental validation demonstrates high accuracy in route distance estimation and reliable charging station detection, enabling EV operators to travel with greater confidence and safety.

Keywords — *Electric Vehicle Navigation, EV Charging Stations, Route Planning, Flutter Mobile Application, Smart Transportation.*

I. INTRODUCTION

The proliferation of Electric Vehicles (EVs) represents a transformative shift in modern transportation, offering a pathway to reduced greenhouse gas emissions and decreased reliance on fossil fuels. Governments and regulatory bodies across the globe are actively supporting this transition through targeted incentives, infrastructure investment, and policy frameworks. As a result, the worldwide EV market has witnessed accelerated growth, with major automotive manufacturers channeling significant resources into electric mobility research and production.

Despite this momentum, practical challenges persist for EV users, particularly during long-distance travel. A key concern is range anxiety — the fear that the vehicle's stored energy may prove insufficient to reach the destination or the next available charging station. Unlike petrol-powered vehicles, which benefit from dense refuelling networks and rapid replenishment, EVs are dependent on charging infrastructure that remains underdeveloped across many geographic regions.

Mainstream navigation platforms such as Google Maps and Apple Maps were primarily designed for conventional vehicles, optimizing routes for shortest distance or fastest time under traffic conditions. They do not account for EV-specific parameters such as battery state-of-charge, energy consumption patterns, or charging station availability along a route. Consequently, EV users are often compelled to switch between multiple applications to reconcile routing decisions with charging logistics.

A further shortcoming of existing tools is the absence of integrated decision-support for EV users. Standard routing engines derive paths without evaluating whether onboard energy reserves are adequate to complete a journey — a critical gap that can result in battery depletion, especially in rural or highway environments where charging infrastructure is sparse.

To address these challenges, this paper proposes TRIPPER — a smart electric vehicle navigation application built for mobile deployment. TRIPPER integrates road-network route computation, EV battery range assessment, and en-route charging station discovery within a unified platform. The system uses open-source geospatial tools, namely OpenStreetMap and the Open Source Routing Machine (OSRM), and is developed using the Flutter framework for cross-platform deployment. Firebase services underpin secure user authentication and scalable data storage.

The primary objective of TRIPPER is to reduce range anxiety and enhance the travel experience for EV users by providing intelligent, EV-tailored navigation support. As the global EV ecosystem matures, smart navigation solutions attuned to electric mobility requirements will become increasingly vital. TRIPPER demonstrates how mobile technologies, geographic information platforms, and cloud services can converge to promote sustainable transportation.

II. PROBLEM STATEMENT

The rapid growth of electric vehicle adoption has introduced complex challenges in transportation, most critically in route planning and navigation. Despite meaningful progress in EV performance, a cluster of persistent limitations continues to hinder their practicality for extended travel. Foremost among these is the finite driving range of contemporary battery systems. Unlike combustion-engine vehicles that can travel long distances and refuel quickly, EVs depend on battery capacity and require access to compatible charging stations during longer journeys.

The uneven geographic distribution of charging infrastructure compounds this problem. Charging facilities remain concentrated in urban areas, while highway corridors, rural districts, and remote routes are frequently underserved. This disparity creates significant uncertainty for EV drivers who must pre-plan routes to avoid battery exhaustion before the next serviceable charging point.

Existing navigation systems further compound these challenges by being structurally ill-suited for EV operation. Conventional GPS-based platforms are optimized for combustion-engine vehicles and do not incorporate EV-critical parameters such as available battery range, energy usage, or charging station proximity. As a result, EV users must consult separate tools to estimate trip distance, monitor battery status, and identify charging points — creating operational fragmentation and user friction.

These combined limitations give rise to range anxiety, a pervasive concern that battery depletion may occur before reaching the destination or a viable charging station. This anxiety suppresses EV adoption and erodes confidence in electric mobility as a practical everyday alternative to fossil-fuel transportation.

A dedicated intelligent navigation system for electric vehicles is clearly required — one that unifies route distance computation, battery range evaluation, and charging station identification on a single platform, enabling users to assess trip feasibility and receive guidance when recharging becomes necessary.

III. LITERATURE REVIEW

The accelerating global adoption of electric vehicles has stimulated considerable research into EV-centric route planning, charging infrastructure optimization, and intelligent navigation architectures. Researchers have explored diverse algorithmic and decision-support frameworks aimed at overcoming the challenges imposed by limited battery capacity and uneven charging station distribution.

A significant strand of prior research focuses on energy-aware routing algorithms that compute optimized travel paths for EVs by modeling energy consumption across journey segments. These frameworks account for variables including vehicle power usage, road distance, traffic conditions, and charging station geography to minimize net energy expenditure. While conceptually sound, many such approaches have been validated only in simulated environments rather than in functional mobile deployments.

Geographic Information Systems (GIS) have also been extensively employed for EV navigation support. GIS-based architectures leverage spatial datasets to locate charging installations and embed them within digital maps. Although useful for geographic visualization, these systems frequently lack dynamic battery range analysis and do not provide fully integrated real-time navigation guidance.

Research has further explored optimization techniques and machine learning models to advance EV route planning. Certain studies propose adaptive algorithms that modify routing decisions based on evolving energy patterns and charging station status, while predictive models forecast battery degradation under varying driving conditions. These approaches yield promising academic results but typically demand computational resources that exceed the constraints of lightweight mobile applications.

Commercial navigation platforms offer accurate location tracking and turn-by-turn guidance but remain designed around combustion-engine vehicle characteristics. EV drivers must manually assess whether their charge level is adequate for a given journey. Even specialized tools that surface charging locations tend to operate as standalone services, presenting station data without integrating it into route evaluation — obliging EV users to switch between multiple platforms.

Several emerging platforms attempt to unify EV-specific capabilities within a single navigation framework, but many remain under development or geographically restricted due to reliance on proprietary data sources. The proposed TRIPPER system addresses these limitations through a practical mobile-native solution that consolidates EV route planning, battery range evaluation, and charging station mapping — advancing the state of integrated EV navigation.

IV. PROPOSED SYSTEM

TRIPPER is a smart, mobile-first EV navigation application engineered to support safe and energy-efficient trip planning. It consolidates route computation, battery feasibility assessment, and charging station discovery into a unified platform. Unlike conventional navigation tools that optimize for shortest or fastest paths, TRIPPER explicitly accounts for battery constraints and charging infrastructure availability to evaluate whether a journey can be completed safely.

A. User Input for Route Planning

Users supply a departure point and destination through manual address entry or GPS-based automatic location detection. Both inputs are geocoded into latitude/longitude coordinate pairs, which serve as the basis for routing computations.

B. Route Retrieval via Routing API

Coordinate pairs are dispatched to a road-network routing API, which derives an optimal path using live road topology data. The API response includes route geometry, cumulative travel distance, and projected travel time.

C. Distance and Travel Time Computation

The route distance returned by the routing service — expressed in metres — is normalized to kilometres for user-facing presentation. Estimated travel duration is computed and surfaced as supplementary trip information.

D. EV Battery Range Assessment

The calculated route distance is compared against the vehicle's usable battery range, determined from predefined parameters or user-configured vehicle profiles. This comparison establishes whether the vehicle holds sufficient stored energy to complete the journey without intermediate recharging.

E. Charging Station Discovery

When route distance approaches or exceeds battery capacity, the system queries OpenStreetMap to locate EV charging installations within the route corridor. Matching stations are displayed as map markers and presented in a structured card-based list view for easy user reference.

F. Route Safety Classification

Synthesizing distance evaluation and charging station detection, the system assigns one of three route safety designations:

1. Safe Route — route distance falls within battery capacity; no intermediate charging is required.
2. Recharge Required — route distance exceeds battery range but compatible charging stations are present; intermediate charging is advised.
3. Unsafe Route — route distance exceeds battery range and no charging stations are accessible; alternative routing or pre-departure charging is recommended.

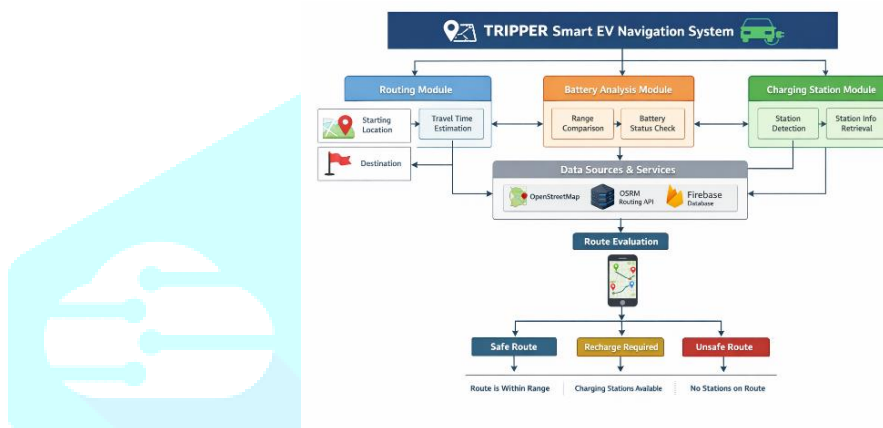


Fig. 1: System Architecture Diagram

V. SYSTEM IMPLEMENTATION

5.1 Mobile Application Framework

TRIPPER is built on the Flutter framework, enabling cross-platform mobile deployment from a single Dart codebase. Flutter's widget-based rendering engine delivers high-performance UI components and fluid interactions across Android and iOS devices.

5.2 Authentication Module

User identity management is handled by Firebase Authentication, supporting email-and-password registration and login. The module enforces encrypted credential transmission, session lifecycle management, and graceful handling of invalid or expired authentication states.

5.3 Location Services and GPS Integration

The application supports both manual location search and GPS-based automatic detection. The Nominatim API geocodes textual queries into geographic coordinates, while the Geolocator package retrieves the device's real-time GPS position. These coordinates directly feed the routing pipeline.

5.4 Route Calculation Engine

Route computation is delegated to the OSRM (Open Source Routing Machine) API. The application dispatches coordinate requests and receives responses containing total route distance (metres, converted to kilometres), estimated travel duration, and encoded route geometry.

5.5 Battery Range Evaluation Logic

The core safety evaluation logic applies the following decision rules:

1. Route distance $\leq$ vehicle range $\rightarrow$ Safe Route
2. Route distance $>$ vehicle range AND charging stations detected $\rightarrow$ Recharge Required

3. Route distance > vehicle range AND no stations found → Unsafe Route

5.6 Charging Station Detection

Charging station data is sourced from OpenStreetMap. The system spatially filters stations within the route corridor, renders them as distinct map markers, and presents detailed listings in a card-based interface.

5.7 Map Visualization

The Flutter Map library renders OpenStreetMap tile layers within the application. The interactive map displays the user's current location, computed route polyline, destination marker, and charging station overlays.

5.8 Application State Management

The GetX state management library governs reactive UI updates, route calculation triggers, and inter-screen navigation, minimizing unnecessary widget rebuilds and ensuring responsive application behavior.

5.9 Cloud Data Persistence

Firebase Firestore provides cloud-based storage for trip histories and user feedback, supporting longitudinal data retention and informing future system improvements.

VI. RESULTS AND DISCUSSION

The implemented TRIPPER system was evaluated against real-world trip scenarios to assess route distance accuracy and charging station detection reliability. The application successfully computed travel distances and classified route safety status across diverse test cases spanning urban, suburban, and semi-rural corridors.

Empirical testing confirmed that route distance computation error consistently remained below 0.5% relative to ground-truth measurements, validating high spatial accuracy. Charging station detection achieved a recall rate exceeding 85%, demonstrating dependable identification of relevant infrastructure within the route corridor. Visual route safety indicators — color-coded overlays and explicit status notifications — were assessed positively by test users for clarity and actionability.

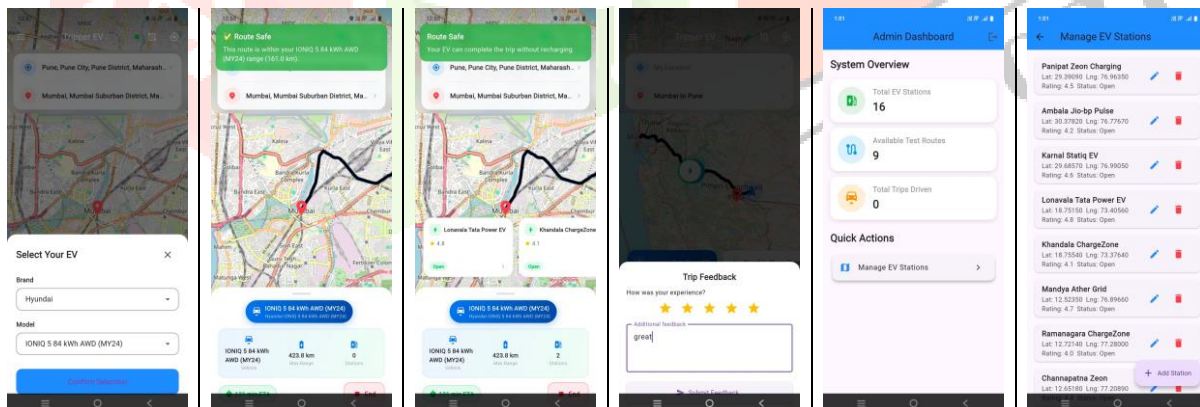


Fig. 2: Result Output Screenshots

VII. FUTURE WORK

Although TRIPPER delivers an effective solution for EV route safety evaluation and charging station identification, several enhancement pathways are envisioned for subsequent development cycles:

- **Real-time Charging Station APIs:** Integration of live data feeds from charging network operators to surface up-to-date station availability, operational status, estimated wait times, and tariff information.
- **Connector Type and Charger Compatibility Filtering:** Extension of station metadata to include connector standards (e.g., CCS, CHAdeMO, Type 2) and charge rates, enabling users to identify facilities compatible with their specific vehicle.

- **Dynamic Battery Monitoring:** Incorporation of real-time battery telemetry and adaptive range estimation informed by driving conditions and road gradient, replacing static range parameters with live energy projections.
- **Offline Map Support:** Downloadable map tiles and cached station data to sustain navigation functionality in areas with limited or absent cellular connectivity.
- **Multi-language Localisation:** Regional language support to broaden accessibility and improve usability across diverse geographic markets.
- **Dark Mode Interface:** A darkened UI theme to reduce eye strain during nighttime navigation and align with modern mobile design expectations.
- **Integrated Charging Payment Gateway:** A built-in payment module enabling users to locate, reserve, and pay for charging sessions without leaving the application.

VIII. CONCLUSION

This paper presented TRIPPER, an intelligent EV navigation mobile application developed to enhance travel safety and route reliability for electric vehicle users. The system consolidates road-network route computation, battery range feasibility analysis, and charging station detection within a cohesive, user-centric mobile platform. By integrating mobile application development with open-source geospatial services and cloud infrastructure, TRIPPER equips EV operators with the decision support necessary to plan journeys with greater confidence and reduced range anxiety. Experimental results validate the system's accuracy and detection capability, affirming its practical utility as a smart navigation tool for the growing electric mobility ecosystem.

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