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Visualization Tool for Electrical Vehicle Charge and Range Analysis

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ABSTRACT: With the global transition toward sustainable mobility, Electric Vehicles (EVs) have seen a significant rise in adoption. However, a major deterrent for potential users remains "range anxiety"—the uncertainty regarding a vehicle's ability to cover specific distances based on real-time battery status and driving conditions. Current monitoring systems often provide static data that is difficult for non-technical users to interpret, leading to inefficient trip planning.

This paper presents the development of a Smart Visualization Tool designed to monitor battery charge and predict driving range through interactive data analytics. Utilizing the EVIndia, Electric Car Specifications, and Charging Station datasets, the project employs Python (Pandas) for data preprocessing and Tableau for high-fidelity visualization. The system transforms raw, complex data into intuitive dashboards that illustrate critical correlations such as Speed vs. Range and Charge vs. Distance.

The results provide a comprehensive 360-degree overview of the EV landscape in India, identifying high-density charging regions like NDMC, analyzing power capacities (predominantly 15 kW and 142 kW), and categorizing service types. By converting raw data into meaningful visual "Stories," this tool empowers users to make data-driven decisions, optimize trip planning, and significantly reduce range anxiety, thereby improving the overall EV user experience and supporting the infrastructure for smarter green transportation.

I. INTRODUCTION

The global automotive landscape is currently undergoing a transformative shift from internal combustion engines (ICE) to sustainable electric mobility. This transition is primarily driven by the urgent need to reduce carbon emissions and mitigate the effects of climate change. Electric Vehicles (EVs) have emerged as the leading solution for green transportation, offering zero-tailpipe emissions and higher energy efficiency. Despite the rapid growth in the EV market in India and globally, significant challenges persist that hinder widespread consumer adoption.

One of the most critical barriers is "Range Anxiety"—the persistent fear among drivers that their vehicle will run out of power before reaching a destination or a charging station. Unlike traditional petrol or diesel vehicles, where refueling stations are ubiquitous and refueling takes minutes, EV charging infrastructure is still in a developmental phase. Furthermore, battery performance is highly dynamic; factors such as vehicle speed, driving behavior, and ambient conditions significantly influence the remaining range.

Current EV monitoring systems often provide users with basic, static information regarding battery percentage. However, raw data in the form of percentages or spreadsheets is difficult for the average user to translate into actionable trip planning. There is a clear gap in the market for a system that can process complex datasets—such as vehicle specifications, charging station locations, and real-time battery behavior—and present them in an intuitive, visual format.

This project addresses these challenges by developing a Smart Visualization Tool for EV charge and range analysis. By leveraging Tableau for advanced data visualization and Python for robust data preprocessing, the system transforms raw datasets into interactive dashboards. The primary objective is to provide a "360-degree" view of the EV ecosystem,

allowing users to visualize correlations between speed and range, locate the nearest high-capacity charging stations, and understand their vehicle's energy consumption patterns through storytelling.

The proposed system serves as a bridge between complex electrical data and the end-user, empowering EV owners with the confidence to plan long-distance travel. By identifying high-density charging corridors—such as those in the NDMC and Noida regions—and analyzing power capacities like 15 kW and 142 kW, this tool supports the broader goal of making electric mobility transparent, reliable, and user-friendly.

II. PROBLEM STATEMENT

The global transition to Electric Vehicles (EVs) is frequently hindered by a psychological and technical barrier known as "Range Anxiety." Despite the technological advancements in battery density, several core issues prevent users from fully trusting electric mobility for long-distance travel. The problem can be categorized into the following four dimensions:

A. Static and Non-Interactive Data

Traditional vehicle monitoring systems provide basic, static information—typically just a battery percentage or a fixed kilometer estimate. These systems do not allow users to interact with the data or see how different variables (like terrain or speed) change the outcome. This lack of interactivity makes it difficult for a driver to gain a deeper understanding of their vehicle's true potential.

B. Complexity of Raw Data

Raw EV datasets (such as energy consumption rates, battery discharge curves, and charging station specifications) are often stored in complex formats like CSV or Excel. For an average consumer or researcher, interpreting rows of numerical data is time-consuming and prone to error. There is a lack of simplified, visual representations that translate this "Big Data" into "Actionable Insights."

C. Lack of Variable Correlation

The relationship between Vehicle Speed vs. Driving Range and Battery Charge vs. Distance is non-linear. Many drivers do not understand that increasing speed significantly decreases the available range due to aerodynamic drag and energy discharge rates. Existing systems fail to visually correlate these variables, leaving users guessing about their energy consumption.

III. METHODOLOGY

The methodology follows a structured data pipeline to convert raw information into actionable insights.

A. Data Sets Used

EVIndia Dataset: Contains local market trends.

Electric Car Specifications Dataset: Provides technical battery and performance details.

Charging Station Dataset: Lists geographic locations and technical capacities of chargers.

Data Sets Links:

<https://drive.google.com/drive/folders/1Rkzdks6Us1Uq2SRB4nxMAb83jN5bpHll>

B. Implementation Steps

Data Cleaning: Utilizing Python (Pandas) to handle missing values and inconsistencies.

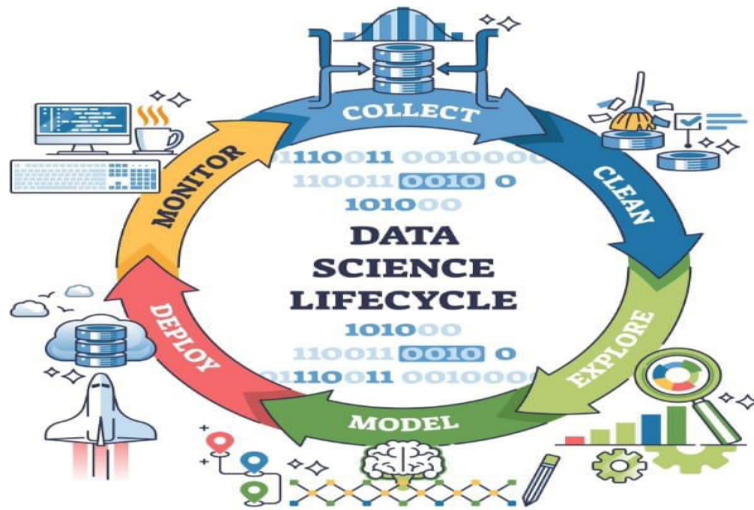
Data Transformation: Formatting and filtering data for specific features such as range, speed, and charge.

Visualization: Using Tableau to create interactive dashboards and "Stories" that map energy consumption.

System Architecture

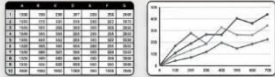

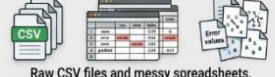


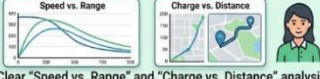

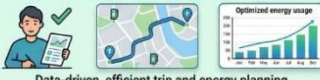
The project flow follows a linear progression:

Raw Data → Collection & Cleaning → Processing → Visualization → Insights → Decision Making.



- Data Source Layer:** Consists of CSV files containing EV specs and infrastructure data.
- Processing Layer:** Involves the use of Python for cleaning and Tableau Prep for structuring the data relationships (joining the EV specs with charging locations).
- Visualization Layer:** The core engine where Tableau transforms numerical data into visual elements like bar charts, maps, and trend lines.
- Insight Layer:** The final output where "Stories" are generated to help a user decide, for example, if their current 80% charge is sufficient to reach a 142 kW fast-charger in a neighboring city.

Comparison: Existing vs. Proposed System

| Feature Comparison: Existing Systems vs. Proposed Visualization Tool | | |
|--|---|---|
| Feature | Existing Systems | Proposed Visualization Tool |
| User Interface |  <p>Static tables and non-interactive range predictions.</p> |  <p>Interactive "Smart Dashboards" and Tableau "Stories".</p> |
| Data Format |  <p>Raw CSV files and messy spreadsheets.</p> |  <p>Clean, processed visual insights and color-coded graphs.</p> |
| Range Clarity |  <p>Users are uncertain about exact travel distances.</p> |  <p>Clear "Speed vs. Range" and "Charge vs. Distance" analysis.</p> |
| Planning Type |  <p>Manual, stressful trip planning (Range Anxiety).</p> |  <p>Data-driven, efficient trip and energy planning.</p> |

IV. RESULTS AND DISCUSSION

The implementation resulted in a comprehensive dashboard providing a 360-degree view of the EV landscape. Regional Distribution: High-density charging areas were identified in regions like NDMC and Noida. Power Capacity: Most stations support 15 kW charging, with a growing number of 142 kW fast-charging options. Service Types: The data confirms that Self Service is the primary charging model currently available.

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V. CONCLUSION

The development of the "Visualization Tool for Electrical Vehicle Charge and Range Analysis" successfully addresses the critical challenge of "range anxiety" in the burgeoning EV market. By transitioning from static, spreadsheet-based data to dynamic, interactive Tableau dashboards, this project has bridged the gap between complex electrical metrics and user-centric decision-making.

The core findings of this research emphasize:

Data Transparency: The integration of the EVIndia and Charging Station datasets allows users to visualize infrastructure gaps and high-density charging zones, specifically identifying regions like NDMC as leaders in EV support.

Operational Clarity: Through "Speed vs. Range" and "Charge vs. Distance" analysis, the tool provides a clear correlation between driving behavior and battery depletion, which is often misunderstood by new EV adopters.

Informed Planning: The Tableau "Storytelling" module demonstrates that visual analytics can significantly improve trip efficiency by matching vehicle specifications with the appropriate power capacity (15 kW to 142 kW) of available chargers.

VI. FUTURE WORK

While the current tool provides a robust framework for EV analysis, the following areas are proposed for future enhancement:

Real-Time API Integration: Future iterations could incorporate Live API feeds from vehicle Telematics and Charging Station Management Systems (CSMS) to provide real-time occupancy and battery status.

Machine Learning Implementation: Integrating predictive models (using Python's Scikit-learn) to forecast range based on individual driving styles, real-time traffic conditions, and topographical variations (hills vs. plains).

Mobile Application Development: Transitioning the Tableau dashboards into a cross-platform mobile application (using Flutter or React Native) to assist drivers with on-the-go navigation and energy alerts.

Weather Impact Analysis: Adding datasets related to ambient temperature and humidity to visualize how seasonal changes affect lithium-ion battery discharge rates.

VII. ACKNOWLEDGEMENT

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