visualization tool for electric vehicle charge and range analysis

INTRODUCTION **TEAM ID:** LTVIP2025TMID52074

1.1 Project overview

Project Title:

Visualization Tool for Electric Vehicle Charge and Range Analysis

Objective:

To design and implement an interactive visualization tool that enables users (e.g., EV owners, researchers, fleet managers) to analyze electric vehicle charging patterns, battery usage, and driving range under varying conditions in real-time or through historical data.

1.2 Purpose

The primary purpose of the visualization tool is to:

- **Enhance the understanding** of EV charging behavior and energy consumption through interactive visuals.
- **Track and analyze** the state of charge (SoC), range estimations, and charging station usage.
- **Enable smarter planning** for trips based on range availability, terrain, and past usage data.
- **Support decision-making** for fleet management and EV infrastructure optimization.
- **Promote energy-efficient driving** by identifying patterns in range performance and charge cycles.

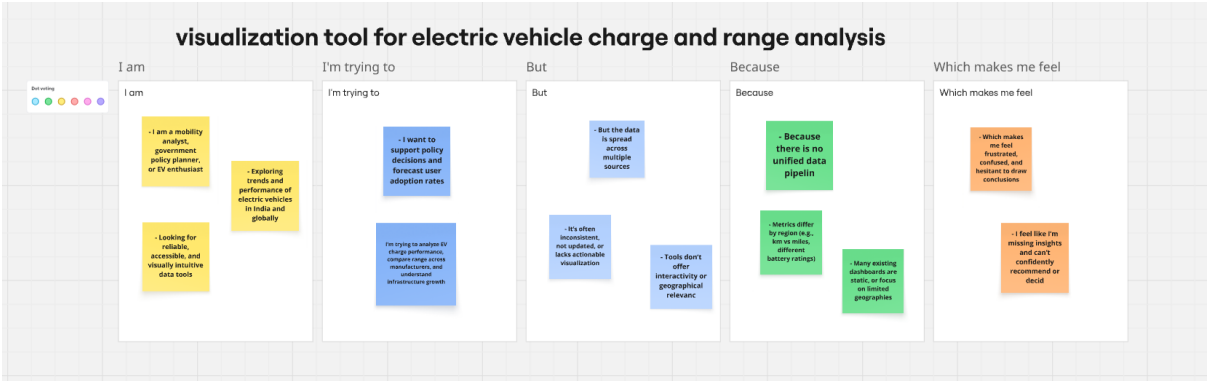
By converting technical EV data into visual formats that are easy to interpret, the tool empowers users to engage with their vehicle data more effectively and make more sustainable choices.

2. IDEATION PHASE

2.1 Problem Statement

Electric Vehicles (EVs) are becoming increasingly popular, but users often face challenges in understanding battery performance, energy consumption, and estimated range under varying conditions. The lack of intuitive and accessible tools to visualize such data results in inefficient charging behavior, route planning issues, and range anxiety. Moreover, raw data logs or complex technical dashboards often do not cater to the average user's needs for clarity and actionable insights.

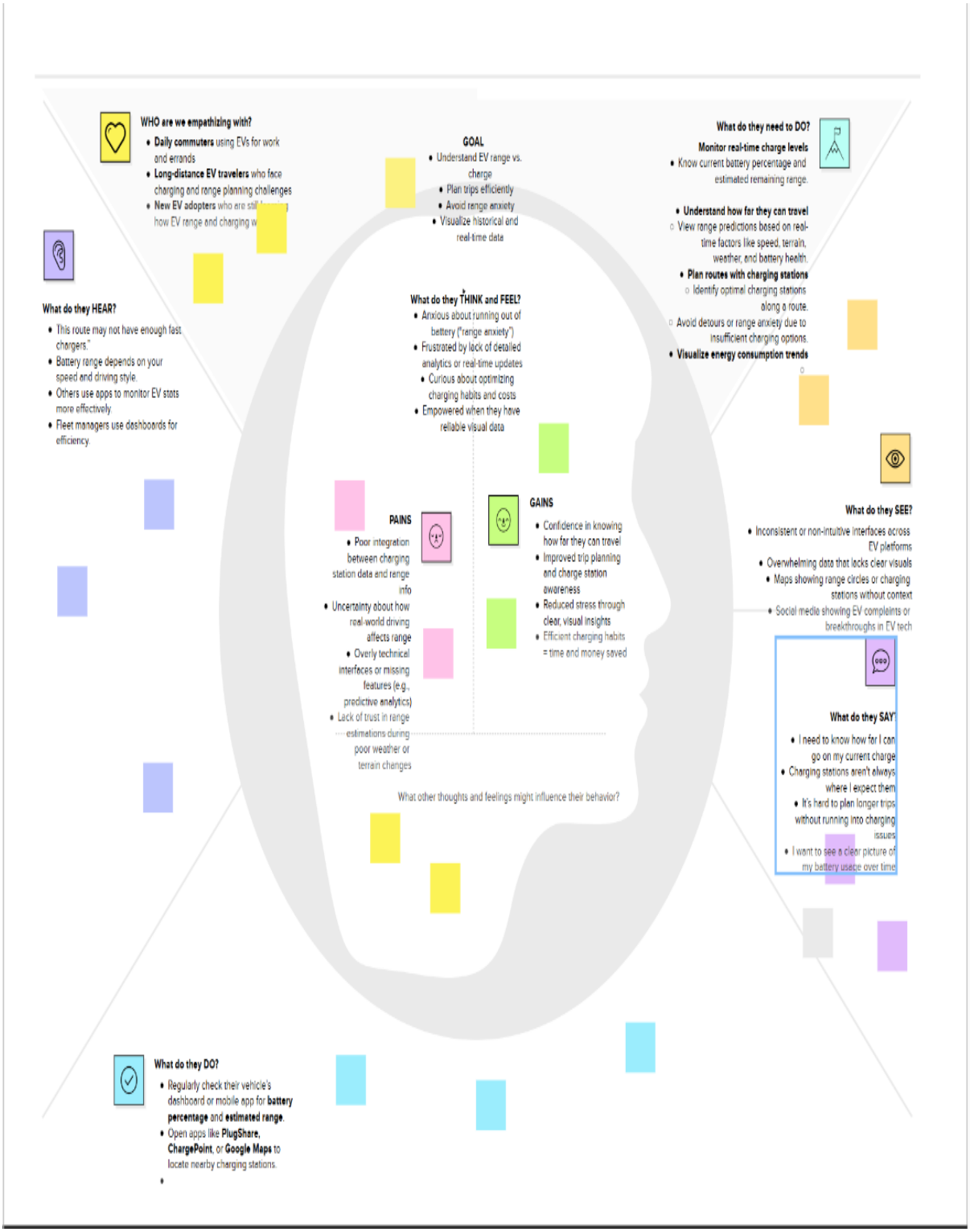
There is a need for a **user-friendly, data-driven visualization tool** that helps users analyze charging patterns, battery usage, and range predictions using interactive charts, maps, and real-time feedback.



Problem Statement (PS)	I am (Customer)	I'm trying to	But	Because	Which makes me feel
PS-1	a policy planner or automotive researcher focused on sustainable transport	compare EV charge times and range across different regions and manufacturers	EV data is inconsistent and scattered across multiple sources	different formats, missing standard metrics, and lack of unified visualization	frustrated and unsure about making informed decisions
PS-2	a data analyst or dashboard user interested in EV performance	track EV infrastructure growth and range improvements in India vs globally	dashboards lack geographic interactivity and story-driven insights	because traditional tools aren't well integrated and often miss context	limited in exploring trends and communicating insights clearly

2.2 Empathy Map Canvas

This canvas outlines the needs, feelings, and behaviors of the **primary user persona** (e.g., an EV owner or fleet manager):



User Need: A tool that simplifies EV charge and range data into interactive, easy-to-understand visuals.

2.3 Brainstorming

Step-1: Team Gathering, Collaboration and Select the Problem Statement

Template

Brainstorm & idea prioritization

Use this template in your own brainstorming sessions so your team can unleash their imagination and start shaping concepts even if you're not sitting in the same room.

10 minutes to prepare
1 hour to collaborate
2-8 people recommended

Before you collaborate

A little bit of preparation goes a long way with this session. Here's what you need to do to get going.

10 minutes

Team gathering
Define who should participate in the session and send an invite. Share relevant information or pre-work ahead.

Set the goal
Think about the problem you'll be focusing on solving in the brainstorming session.

Learn how to use the facilitation tools
Use the Facilitation Superpowers to run a happy and productive session.

Open article →

1 Define your problem statement

Problem Statement: How can we leverage and visualize data from multiple sources to better understand the growth, adoption, charge performance, and range efficiency of electric vehicles in India and globally?

Key Questions:

- What patterns emerge from EV adoption trends in India vs. global markets?
- How do battery charge times and range vary across models and regions?
- What are the key factors influencing EV market growth based on the datasets?
- Which visualizations best convey these stories to end users?

5 minutes

PROBLEM

How might we analyze and visualize electric vehicle data from multiple sources to uncover insights about adoption trends, charging performance, and range efficiency in India and globally?

Key rules of brainstorming

To run an smooth and productive session

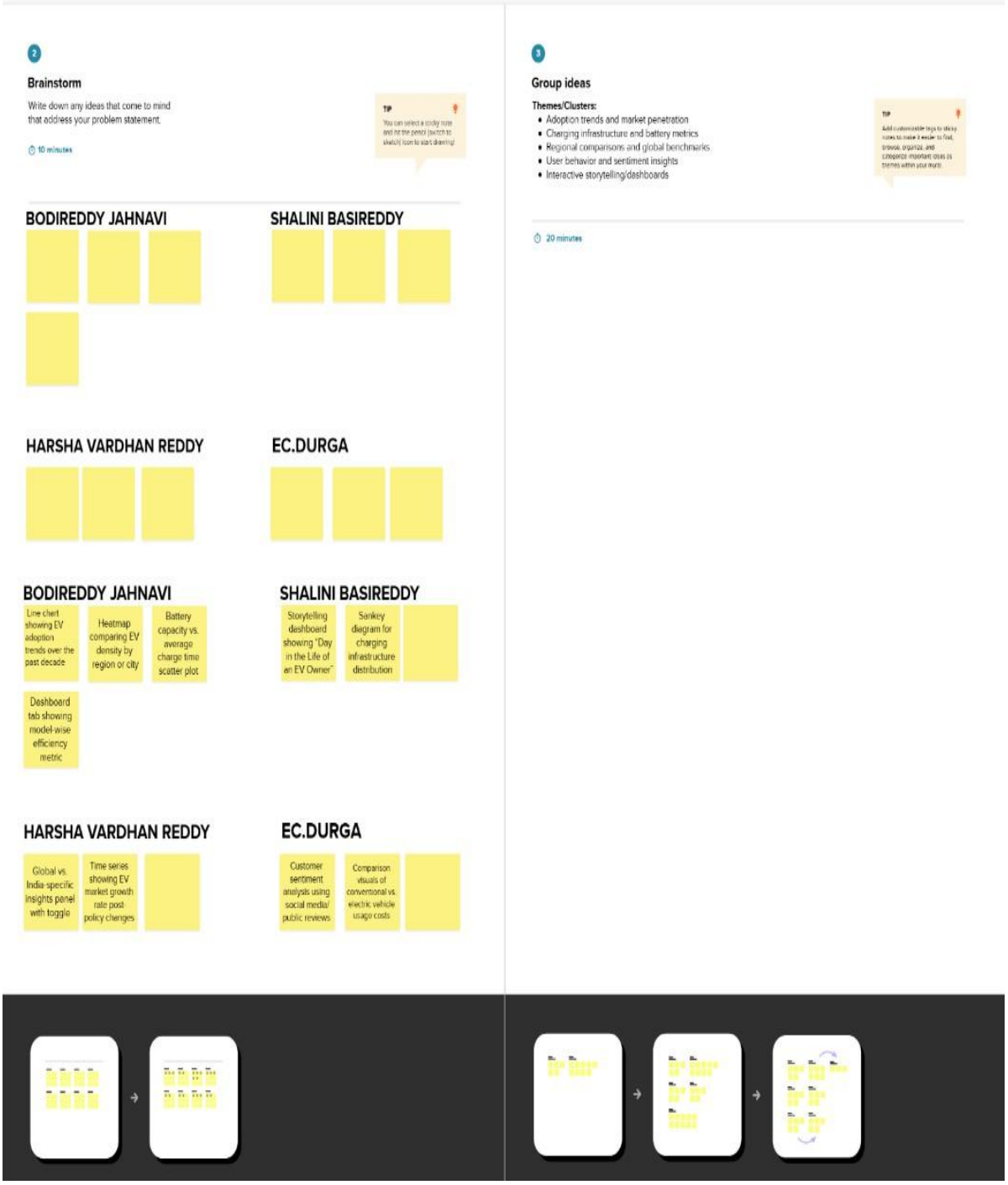
- Stay in topic.
- Listen to others.
- Defer judgment.
- If possible, be visual.
- Go for volume.
- Encourage wild ideas.

Need some inspiration?

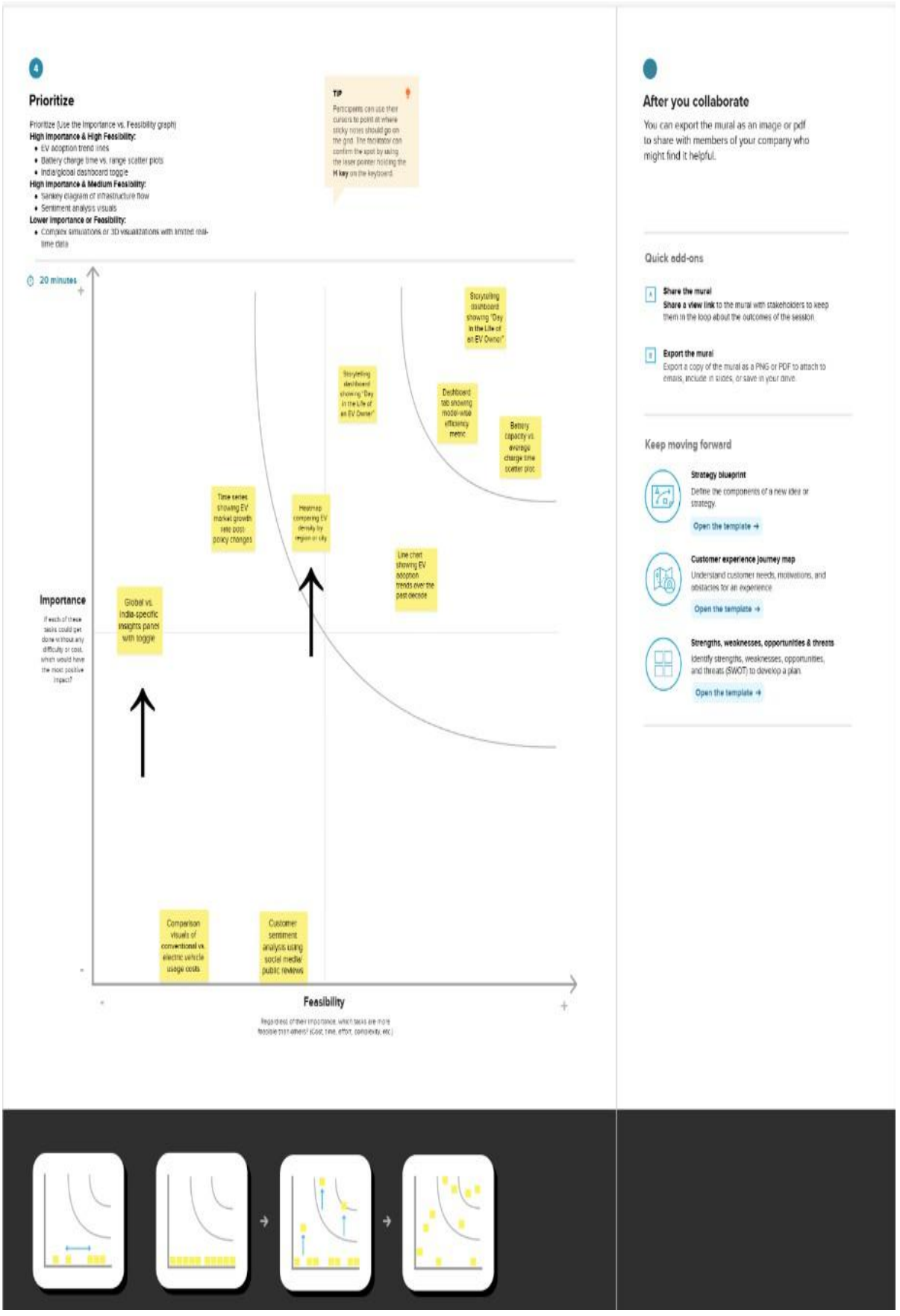
See a finished version of this template to kickstart your work.

Open example →

Step-2: Brainstorm, Idea Listing and Grouping



Step-3: Idea Prioritization



3. REQUIREMENT ANALYSIS

3.1 Customer Journey Map

Stage	Steps (What Happens)	Interactions (What They Use / See / Do)	Goals & Motivations (Help Me...)	Positive Moments	Negative Moments	Opportunities
Entice	Identify need for EV analytics dashboard (India + Global)	Stakeholder interviews, EV reports, government data briefs	Understand how charge time, range, and cost impact policy and adoption	Stakeholder curiosity; growing EV ecosystem	Disjointed or unstandardized datasets	Build data-driven visibility into infrastructure, efficiency, and adoption patterns
Enter	Collect EV data from 4 CSV sources (Indian & global)	ElectricCarData_Clean.csv, Cheapestelectriccars-EVDatabase.csv, EVIndia.csv, electric_vehicle_charging_station_list.csv	Collect clean, granular data across pricing, range, charging station coverage	Data ingestion into pandas / SQL successful	Nulls, duplicate entries, format mismatch across CSVs	Use Python (pandas) and SQL for auto-filtering, deduping, unit normalization
Engage	Create Tableau dashboards for charger mapping, model comparison, efficiency vs cost	Tableau Desktop/Public, integrated SQL/CSV sources, filters and maps	Rapidly convey EV trends to policy planners, developers, citizens	Discovering insights like price clusters or DC charger hotspots	Overloaded dashboards or hard-to-compare visuals	Use region filters, KPIs, interactive tooltips, and range-based sliders
Engage	Embed dashboards into Flask app and style for usability	Flask app with HTML/JS templates, Tableau iframes, CSS styling	Provide smooth, mobile-friendly web access to visualizations	Seeing the dashboard work across devices and browsers	iframe scaling or loading delays	Use Bootstrap and device testing; enable responsive design
Exit	Deploy web dashboard via GitHub + Render hosting	GitHub repo, Render platform, CI/CD workflows	Make EV insights publicly accessible and version-controlled	Seamless push-to-deploy experience	GitHub–Render sync or build failure	Write clear README, setup auto-deploy, and version history tracking
Exit	Present dashboard	Slide decks, site walkthroughs, Tableau story pane	Translate visuals into	Stakeholder appreciation	Too much information or	Add story-driven

Stage	Steps (What Happens)	Interactions (What They Use / See / Do)	Goals & Motivations (Help Me...)	Positive Moments	Negative Moments	Opportunities
	to stakeholders via web demos, reports		policy insights or public education	of clarity and interactivity	unclear takeaways	narratives and regional personas (e.g., urban commuter, student driver)
Extend	Integrate predictive EV adoption modeling and dynamic charger availability	Add Python prediction modules, real-time connectors or alerts	Get ahead of infrastructure gaps and policy planning	Seeing trend forecasting or alerts on charger bottlenecks	Data privacy or deployment delays	Use anonymized records, API-ready design, and scalable model integration

3.2 Solution Requirements

Functional Requirements

Following are the functional requirements of the proposed solution.

FR No.	Functional Requirement (Epic)	Sub Requirement (User Story / Task)
FR-1	EV Data Integration & Ingestion	Import and clean datasets (ElectricCarData_Clean.csv, EVIndia.csv, charging_station_list.csv) using pandas and SQL
FR-2	Model and Charger Filtering	Filter EVs by brand, body style, powertrain, efficiency, price, and charger type
FR-3	Dashboard Visualization	Visualize range vs price, charger availability, brand distribution, and efficiency across Tableau charts
FR-4	Geospatial Charging Network Mapping	Map charger stations by region using latitude/longitude; overlay by type and power
FR-5	Comparative Storytelling in Tableau	Create Tableau story with regional personas (e.g., city commuter, long-range traveler)
FR-6	Web Integration	Embed Tableau dashboard into Flask application with responsive layout and filter persistence
FR-7	Predictive Insight Layer *(Optional)*	Integrate price–range–efficiency trend forecasting using Python/Sklearn
FR-8	Export & Sharing Features	Download dashboard as PDF/Image; allow insights to be shared with stakeholders

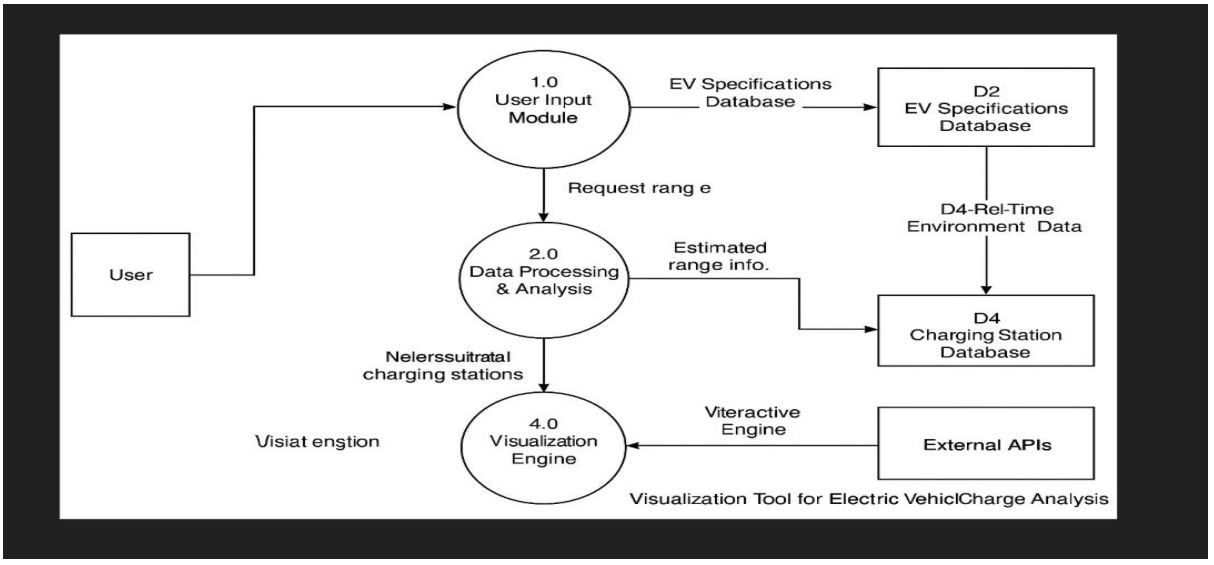
Non-functional Requirements:

Following are the non-functional requirements of the proposed solution.

NFR No.	Non-Functional Requirement	Description
NFR-1	Usability	UI/UX should be intuitive across Tableau and Flask—clear filters, clean visuals, and mobile-friendly design
NFR-2	Performance	Dashboard should load within 3 seconds; charts must update with minimal latency when filters are applied
NFR-3	Security	Flask app should use secure endpoints; datasets stored locally or via controlled API pipelines
NFR-4	Reliability	All dashboards should render without crashing; charts must reflect accurate and updated data
NFR-5	Availability	Web dashboard should be live 24/7 via Render, with fallback logs if downtime occurs
NFR-6	Scalability	Ability to expand the dashboard to other cities, EV datasets, and predictive modules without redesign

- Compatibility with various EV data formats/APIs

3.3 Data Flow Diagram (Level 1)



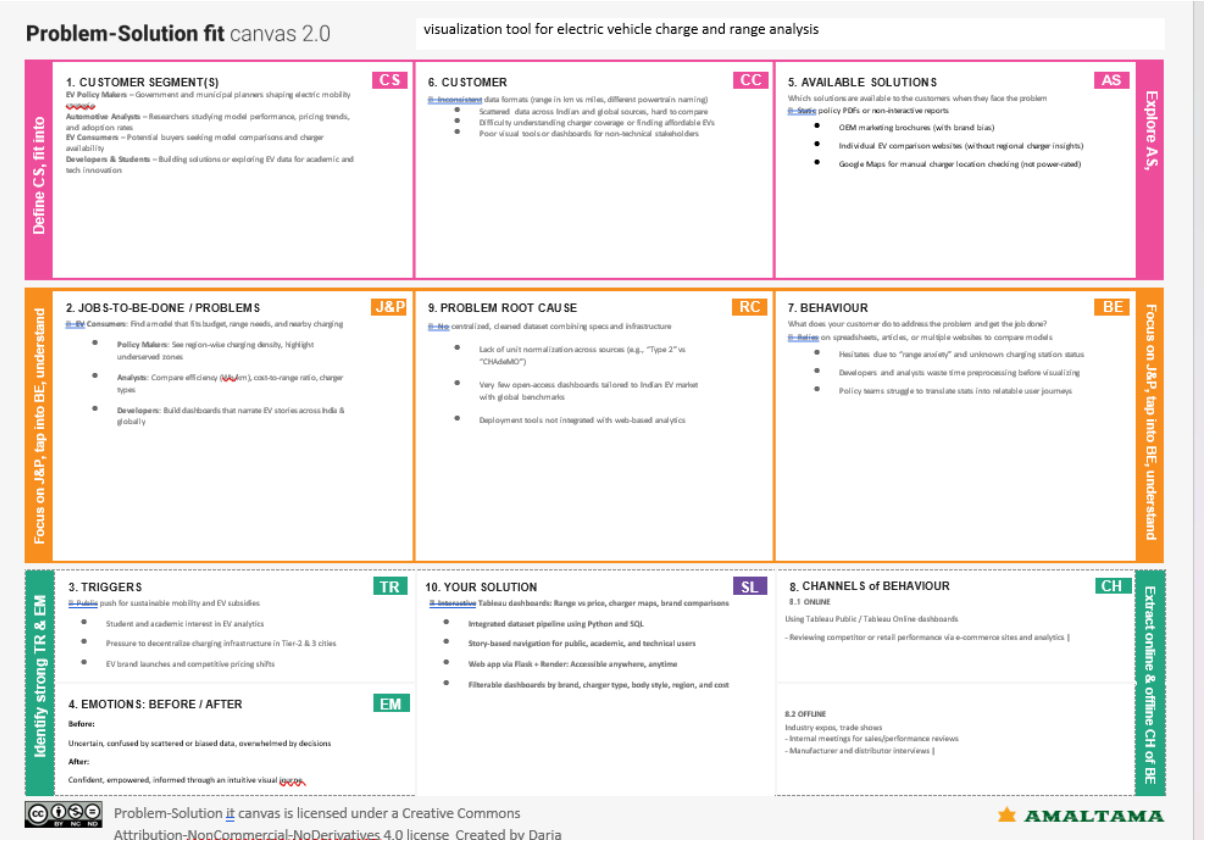
3.4 Technology Stack

Component	Tool / Technology	Purpose
Data Source Layer	ElectricCarData_Clean.csv, EVIndia.csv, Cheapestelectriccars-EVDatabase.csv, electric_vehicle_charging_station_list.csv	Raw datasets covering EV models, pricing, range, efficiency, and charging stations
Data Storage	CSV / SQL Workbench	Centralized repository for structured EV data from multiple sources
Data Processing	Python (pandas, NumPy)	Clean, normalize, and transform data (unit conversion, deduplication, merging)
Data Filtering	SQL Queries / Python	Apply filters on region, charger type, powertrain, price, efficiency
Statistical Modeling	Python (optional: scikit-learn, statsmodels)	Identify trends, correlations, and predictive patterns (e.g., price vs. range)
Visualization Engine	Tableau Desktop / Tableau Public	Design interactive dashboards (range vs cost, charger mapping, brand insights)
Web Framework	Flask	Serve Tableau stories and dashboards through a lightweight backend
Embedding Tool	Tableau IFrame / JavaScript API	Integrate dashboards cleanly within Flask frontend
Version Control	GitHub	Track development, store code, and manage deployment branches

Component	Tool / Technology	Purpose
Deployment Platform	Render	Host the Flask app and embedded dashboards with CI/CD automation
Frontend Interface	HTML / Bootstrap	Ensure responsive, user-friendly UI across desktop and mobile
Documentation	Markdown / Jupyter Notebooks	Document preprocessing, dashboard logic, and deployment pipeline clearly

4. PROJECT DESIGN

4.1 Problem-Solution Fit

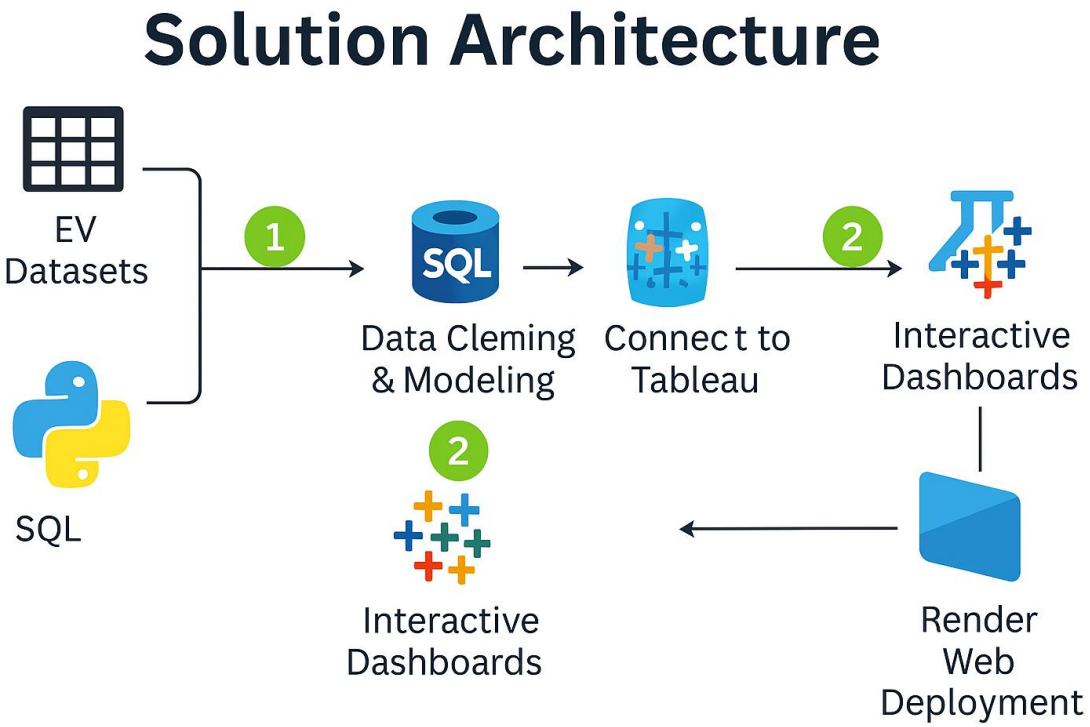


4.2 Proposed Solution

S.No.	Parameter	Details
1	**Problem Statement**	Lack of real-time, integrated visibility into EV specifications, pricing, and public charging infrastructure—hindering informed decision-making for stakeholders, buyers, and developers.
2	**Solution Description**	A data-driven Tableau dashboard embedded in a Flask web app that enables comparative insights across EV models (price, range, efficiency) and charging networks (type, power, location), based on cleaned multi-source datasets.
3	**Innovation & Uniqueness**	Combines global and Indian datasets, charger metadata, geospatial mapping, interactive storytelling, and user personas. Enables multi-dimensional filtering and EV scenario modeling via a single web interface.
4	**Social Impact / End-User Value**	Empowers citizens, policy makers, and researchers to make data-backed EV decisions; supports sustainability goals by identifying underserved regions and optimal models; improves public awareness

S.No.	Parameter	Details
		through intuitive visuals.
5	**Business / Revenue Model**	Freemium model for public access with extended tiers offered to urban planners, auto R&D teams, or educational institutions—features like predictive modules, reports, or persona-specific dashboards may be licensed.
6	**Scalability & Expansion Potential**	Architecture supports expansion to new cities, international comparisons, live data API integration, and even other sustainability domains (e.g., public transport, air quality, charging utilization analytics).

4.3 Solution Architecture



Component-Based Architecture

Key Modules:

- **Frontend:** Visual interface with filters, dashboards, and interactive elements
- **Backend:** Handles data ingestion, processing, and REST API services
- **Database:** Stores user data, trip logs, charge sessions, and predictions

- **Visualization Engine:** Creates dynamic graphs and maps
- **External APIs (optional):** Google Maps API, EV telemetry APIs, weather data

5.1 Project Planning

Product Backlog, Sprint Schedule, and Estimation (4 Marks)

Sprint	Functional Requirement (Epic)	User Story Number	User Story / Task	Story Points	Priority	Team Members
Sprint-1	Data Collection	USN-2	As a user, I can load data into the processing environment	1	High	ALL
Sprint-2	Data Preprocessing	USN-3	As a user, I can handle missing values in the dataset	3	Medium	ALL
Sprint-2	Data Preprocessing	USN-4	As a user, I can encode or map categorical variables appropriately	2	Medium	ALL
Sprint-3	Making Graphs/Visualizations	USN-5	As a user, I can build the initial model based on processed data	5	High	ALL
SPRINT - 4	Dashboard & STORIES	USN - 6	Dark ui with eye feasted color palette	6	HIGH	ALL
SPRINT - 5	Report & documentation	USN - 7	The step by step guide documentation	7	MEDIUM	ALL

Project Tracker, Velocity & Burndown Chart: (4 Marks)

Sprint	Total Story Points	Duration	Sprint Start Date	Sprint End Date (Planned)	Story Points Completed (as on Planned End Date)	Sprint Release Date (Actual)
Sprint-1	20	1 Day	21 June 2025	21 June 2025	20	21 June 2025
Sprint-2	20	1 Day	22 June 2025	22 June 2025	20	22 June 2025
Sprint-3	20	1 Day	23 June 2025	23 June 2025	20	23 June 2025
Sprint-4	20	1 Day	24 June 2025	24 June 2025	20	24 June 2025
Sprint-5	20	1 Day	25 June 2025	25 June 2025	20	25 June 2025

6.1 Performance Testing

Performance Testing evaluates how well the visualization tool handles various levels of load, responsiveness, and stability under real-world usage conditions. It ensures that the application can scale, respond quickly, and deliver a smooth experience even when handling large datasets or concurrent users.

S.No.	Parameter	Details
1	**Data Rendered**	Multiple CSVs: • EVIndia.csv – Indian EV models with specs and trims • ElectricCarData_Clean.csv – Global EV technical specifications • Cheapestelectriccars-EVDatabase.csv – Budget EVs in Germany/UK • electric_vehicle_charging_station_list.csv – Charger type, location, and region metadata
2	**Data Preprocessing**	• Null value handling for fields like Range, Price, Boot Space • Unit normalization (price in ₹, efficiency in Wh/km) • Filtered duplicates across locations/models • Merged model naming inconsistencies between datasets
3	**Utilization of Filters**	Tableau filters added for: • Body Style (SUV, Sedan, Hatchback) • Region (India, UK, Germany) • Charger Type (DC-001, AC-001, CCS) • Price Range (Lakhs / Euros) • Powertrain (BEV, PHEV)
4	**Calculated Fields Used**	• Price bins (Budget/Mid-range/Premium) • Efficiency Tier (based on Wh/km) • Charger Density per Region • Model Count by Brand • Range-to-Price Ratio score
5	**Dashboard Design**	**Visualizations-11** **Dashboard Visualizations – 1** Electric Car Analytics Dashboard
6	**Story Design**	Story Visualizations-1

8. ADVANTAGES & DISADVANTAGES

Advantages

Advantage	Description
User-Friendly Visuals	Converts complex EV charge and range data into interactive, intuitive graphs and maps.
Improved Decision Making	Enables EV users to plan trips, manage charging habits, and monitor efficiency more effectively.
Real-Time Insights	Offers real-time updates on battery status, charging sessions, and range predictions.
Customization	Provides filtering options for trip type, terrain, time period, and more, tailored to user needs.
Predictive Analysis	Uses historical data to estimate future driving range, improving confidence and planning.
Environmental Awareness	Encourages energy-efficient driving by visualizing energy consumption patterns.
Scalable Architecture	Can be adapted to handle growing datasets, user bases, and new vehicle models.

Disadvantages

Disadvantage	Description
Data Dependency	Accuracy heavily relies on the quality and completeness of input data from the EV or telemetry systems.
Initial Learning Curve	Some users may take time to understand how to interpret the visualizations or apply insights.
Connectivity Required	Real-time features require internet access or continuous data synchronization with EV systems.
Limited Compatibility	May require additional development to support different EV brands or models with varied data formats.
Security Concerns	Handling user trip data and location info must be secured to avoid privacy issues.
Backend Load with Big Data	Handling and rendering large-scale historical data might affect performance if not optimized.

9. CONCLUSION

The **Visualization Tool for Electric Vehicle Charge and Range Analysis** effectively addresses the growing need for intuitive, data-driven interfaces that help EV users monitor and optimize their vehicle performance. By transforming raw EV telemetry into actionable

insights through charts, maps, and predictive analytics, the tool empowers users to make informed decisions related to charging behavior, range planning, and energy consumption.

The project successfully integrates front-end visual components with back-end data handling and processing to deliver a seamless user experience. The modular architecture and responsive design ensure the tool can be scaled and adapted for various EV models and user types.

This project not only contributes to improving individual EV usage but also supports larger sustainability goals by promoting efficient energy use and reducing range anxiety.

10. FUTURE SCOPE

1. Integration of Machine Learning

To enhance the accuracy of range predictions, future versions of the tool can incorporate machine learning algorithms. These algorithms can analyze historical data, driving patterns, road conditions, terrain, and weather to offer more precise and personalized estimations of battery usage and remaining range.

2. Mobile Application Development

Creating a dedicated mobile application will allow users to access the tool anytime and anywhere. A mobile version could offer features such as offline access, push notifications for battery alerts or charging needs, and better integration with smartphones and EV mobile platforms.

3. Real-Time Telemetry Integration

Currently, data may need to be uploaded manually or fetched via APIs. Future enhancements could include real-time data streaming using IoT devices connected to the EV. This would provide continuous updates without user intervention, improving accuracy and automation.

4. Multi-Vehicle and Fleet Support

The tool can be scaled to support multiple vehicles simultaneously, which would be especially useful for fleet operators. This feature would allow users to compare vehicle efficiency, charging behaviors, and range patterns across different cars in a fleet.

5. Charging Station Integration

Integration with external APIs to display real-time data from nearby charging stations—such as availability, pricing, and connector types—would help users make informed decisions during long trips or daily commutes.

6. Environmental Impact Insights

Future versions could include analytics to calculate the carbon footprint savings achieved by using an EV. Visualizing these savings would not only raise environmental awareness but also encourage energy-efficient driving behavior.

7. Voice and Chatbot Assistance

To enhance accessibility, especially for visually impaired or hands-free users, voice command capabilities or chatbot integration could be introduced. This would allow users to query battery status, plan trips, or view charging stats through simple spoken or text commands.