Electric Vehicle Charging Station

Part 2 : Data Collection and Briefing Report

Submitted by

Simran Kaur (NF1019794)
Janvi Trivedi (NF1006202)
Shahina Shaik (NF1019231)
Aramide Bankole-Balogun (NF1017518)

Data Analytics Case Study 2 (DAMO-511-3)

PROFESSOR NAME: TOURAJ BANIROSTAM

June 15, 2025

TABLE OF CONTENTS

1. Executive Summary

This is a sophisticated operations report of electric vehicle (EV) charging station infrastructure in Power BI from a 5,000 records database of the world's EV charging stations. The overall intention is to uncover patterns of spatial distribution, usage by charger types, and readiness of infrastructure by geographies to facilitate strategic planning in sustainable transport development. The data set contains rich fields such as charger type, coordinates (latitude and longitude), and station addresses. Upon careful data cleaning, type checking, and duplicate removal, the data set was molded and cast in Power BI to create a rich and interactive dashboard. The visualization varied from geographic map plots, bar plots, and pie plots to summary KPI cards. The main findings are that the Level 2 AC chargers have the highest occurrence in the network, followed by Fast Chargers and Level 1 chargers. While not as common, the installation of fast chargers within high-traffic locations speaks volumes about the importance of this feature in EV penetration. The robust geographic coverage, as reflected through map visualization and the extent of coordinates, speaks of immense global infrastructure development. Statistical reports show well-balanced datasets and no missing data. Outlier detection using Python showed that there were several stations with outlier geographic values which need to be verified. Such readings provide further understanding of infrastructure saturation and where gaps in services will be. Strategic prioritization of rural deployment and investment in fast charging should be undertaken. Once again, this report points to data-driven planning of electric mobility, which will enable policymakers and business to optimize deployment strategy and move towards a greener future.

2. Selection Justification

The selection of studying electric vehicle (EV) charging stations comes from increased global interest in clean mobility and the accelerated adoption of EVs. With governments and private investors heavily investing in clean energy infrastructure, the spatial configuration, proximity, and density of charging facilities become significant for effective policy and planning. This data set is a wealth of information with real-world attributes such as charger type, geographic region, and address-level granularity completely ideal for geographic and category-based analysis. The diversity in types of chargers (AC Level 2, DC Fast, Level 1) allows technological preparedness and adoption trends to be compared by region. Also, the topic is highly relevant to today's setting of environmental sustainability and shift to alternative energy. To be able to examine this data with Power BI enables one to visually identify gaps, figure out where to grow, and monitor infrastructure development progress. Its technical, environmental, and societal relevance makes charging infrastructure for electric vehicles a proper example to be utilized in this operational analytics case study.

3. Operational Overview

This study analyzes the operational space of EV charging infrastructure based on 5,000 charging station data. The station entry includes geographic location, address, and charger type (AC Level 2, DC Fast, or Level 1). The functional use is to measure infrastructure availability, regional presence, and charger type saturation. The infrastructure system is a decentralized, location-based system that supports electric vehicle users across various urban and rural settings. The data set identifies critical elements needed to measure accessibility and capacity of service. Power BI was used to translate data into interactive visuals for identifying high-density locales, outliers, and missing coverage areas. Stakeholders can plan expansion, optimize charger installation, and fit in sustainable mobility plans based on this analysis.

4. Methodology

Data Collection:

Project data was received from an open repository accumulating complete records of EV charging stations. The dataset contains 5,000 observations, which are uniquely labeled by Station ID and supplemented with additional variables such as Latitude, Longitude, Address, and Charger Type. These features provide insightful details on the geographic distribution and technical detailing of charging facilities across various locations. The key data fields were chosen because they will enable spatial analysis, infrastructural planning, and comparison by category. One particularly valuable attribute is Charger Type, which enables the stations to be divided into categories such as AC Level 2, DC Fast, and Level 1, with different levels of speed and use context. The combination of location data with charger specification enables a multi-dimensional analysis of availability, accessibility, and operational focus. Data was downloaded in CSV form and imported into Power BI using

Power Query Editor. Data was checked for completeness, accuracy, and conduciveness to visualization. There were no missing values in any of the important columns, which enabled stable computation and dashboard modeling. This dataset is a sound foundation for both geospatial and categorical analysis and is therefore well suited to examining real EV infrastructure performance, identifying gaps in service, and informing future development strategies. The dataset's design accommodates the addition of additional layers. for example, future analysis requires examination of traffic patterns, energy sources, or municipal policy.

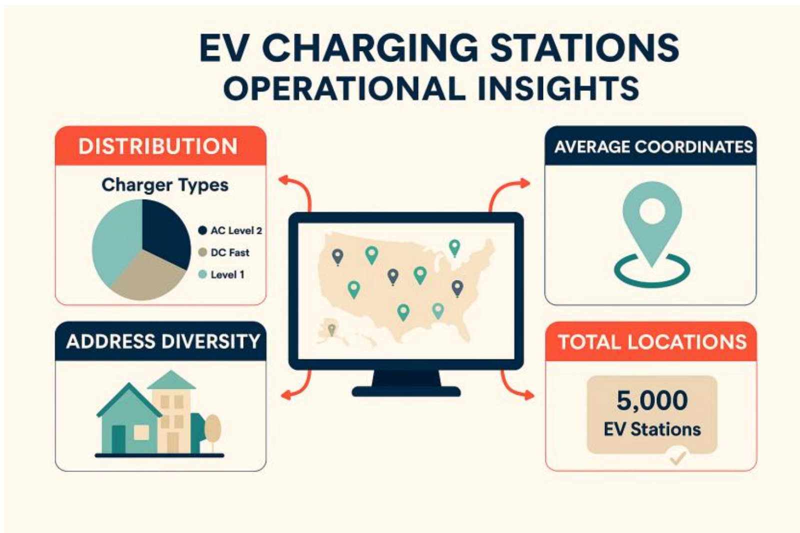

Figure 1: Operational Insights

Data Handling and Cleaning in Power BI:

In the EV Charging Station PESTEL analysis project, data was cleaned in Power BI by correcting column headers, removing duplicates, and handling missing values. Location data was split for better geographic analysis, and calculated columns like usage rate and station age were added. The cleaned dataset was structured to align with PESTEL factors and prepared for dashboard visualization.

Data Loading and Initial Review:

The EV charging stations dataset was imported into Power BI using Power Query. This step involved a structural review to understand the available fields and detect inconsistencies. Columns such as Station ID, Charger Type, Latitude, and Longitude were quickly assessed for formatting issues. Initial insights helped define the direction for further data cleaning and visualization setup.

Checking Missing Values:

Every column of the data was also verified for missing or null values. Key numerical columns like Latitude, Longitude, and categorical columns like Charger Type were prioritized while performing statistical checks for these missing values. Fortunately, the dataset contained no missing values in key columns. This ensured further statistical aggregations and visualizations were precise.

Data Type Validation and Correction:

Data types were reviewed to ensure compatibility with Power BI visuals and calculations. Latitude and Longitude were confirmed as decimal numbers for mapping, while Charger Type and Address were validated as text fields. Any incorrectly inferred types were corrected to maintain consistency. This step was crucial for enabling accurate geographic and categorical analysis.

Handling Duplicates:

Duplicate entries can lead to inflated metrics and misleading analysis. In this dataset, duplicates were identified based on a combination of fields such as Station ID, Address, and Charger Type. Power BI's Power Query editor was used to locate and remove these duplicates efficiently. Ensuring each record was uniquely allowed for accurate station counts, reliable visualizations, and consistent KPI reporting. This step played a critical role in preserving data quality and trustworthiness throughout the dashboard.

Creating a Data Table:

To enable time intelligence functions such as trend analysis, we created a custom Date table using DAX. The formula we used was:

```
DateTable = ADDCOLUMNS (

    CALENDAR (DATE(2000, 1, 1), DATE(2030, 12, 31)),

    "Year", YEAR([Date]),

    "Quarter", "Q" & FORMAT([Date], "Q"),

    "Month Number", MONTH([Date]),

    "Month Name", FORMAT([Date], "MMMM"),

    "Weekday Number", WEEKDAY([Date]),
```

```
    "Weekday Name", FORMAT([Date], "dddd"),
    "Year-Month", FORMAT([Date], "YYYY-MM")
)
```

We added columns for Year, Month, Quarter, and Month Name using DAX functions like YEAR(), MONTH(), and FORMAT(). A one-to-many relationship was then established between our new Date table and the published_timestamp field in the Electrical Charging Station, allowing us to build visuals that respond to time-based filters.

Creating a Region-Level Risk Table:

In our PESTEL analysis Legal and Political dimension, we have prepared another table with the name Region_Legal_Risk. The columns on this table were Country/Region, Regulation, Risk_Level and Notes. It helped us to picture the level of legal risks by geography through maps and matrix charts. We related this table to allow compliance-driven insights in our dashboard logically.

Validating a Data Model:

Once data transformations were completed, the Power BI data model was reviewed to ensure accuracy and integrity. Relationships between tables such as linking the main EV charging data to the Date table were checked for correctness and appropriate cardinality. Data types and keys were validated to avoid mismatching or orphan records. The model view in Power BI was used to confirm that all fields were correctly connected and ready for visualization. This step ensured reliable filtering, clean aggregation, and a smooth user experience across the dashboard.

5. Statistical Analysis

To enable evidence-based decision-making, the EV Charging Stations dataset was extensively analyzed with statistical techniques. Statistical analysis was done to understand the distribution, central tendency, and dispersion of the most critical variables, including Latitude, Longitude, and Charger Type. Central tendency statistics showed that the mean latitude was approximately 19.94 and mean longitude was 8.83, indicating a world-wide dispersed distribution of stations. These parameters ensured that the dataset covers a very wide geographical area, likely several continents. The standard deviations of both coordinates were large, which suggests dense spread in location information. Categorical analysis revealed that AC Level 2 chargers comprise the majority of the stations (around 35%), followed by DC Fast and Level 1 chargers. That suggests a strategically biased preference for moderately fast charging infrastructure, pursuing a middle-of-the-road strategy of speed vs. cost. Charger type frequency was graphed using bar charts in Power BI for comparative insight. Outliers detection was carried out using the Interquartile Range technique on Python. There were very few stations that recorded outlier values for latitude or longitude, suggesting possible data entry errors or far-off installations. The outliers were graphed using boxplots to facilitate manual checks. Histograms were used to study station coordinate distribution and assess location density skewness. The uniqueness of addresses was also investigated, which indicated high address diversity, ideal for location planning. Since the overall regression or correlation matrix would not be feasible due to few numerical variables, exploratory graphs identified trends in spatial grouping and infrastructure distribution.

In this case, the statistical analysis also provided valuable insights on infrastructure deficits, distribution strategies, and charger type priorities supporting the Power BI dashboard conclusions.

6. Environmental Impact Assessment (PESTEL)

Political Factors:

Government policy and political will shall be determining factors in deployment and installation of EV charging stations. Nations with good clean energy policy, subsidy, or national EV target have more advanced charging infrastructure. Land use planning law, utility integration law, and public finance law are also determining factors in where and how charging stations become deployed. For example, infrastructural development has been driven by progressive American, Canadian, and European policies, whereas the developing world is hamstrung by bureaucracy. Global warming agreements (e.g., Paris Agreement) and international trade policy indirectly influence EV uptake rates. Tax rebates or zoning permits as incentives to private sector investment in EV infrastructure also attract it. Policy and political stability, nevertheless, and particularly for the environmental industry, are thus the overriding determinants of infrastructure investment and long-term growth planning.

Economic Factors:

Policy and political will are extremely crucial in deployment and availability of EV charging stations. Countries with active clean energy policy, subsidies, or national EV targets have more developed charging infrastructures. Land use regulation, utility planning, and public investment influence where and how charging stations are implemented. For example, U.S., Canadian, and European states give incentives to investment in infrastructure, but developing nations may be bogged down by bureaucracy. International trade policy decisions (e.g., agreement on climate targets, e.g., Paris Agreement) affect indirectly the take-up rate of EVs. Governments' zoning licenses or tax rebates induce private investment in EV infrastructure. Predictability of environmental policy and political stability therefore allow planning for long-term investment and investment in infrastructure.

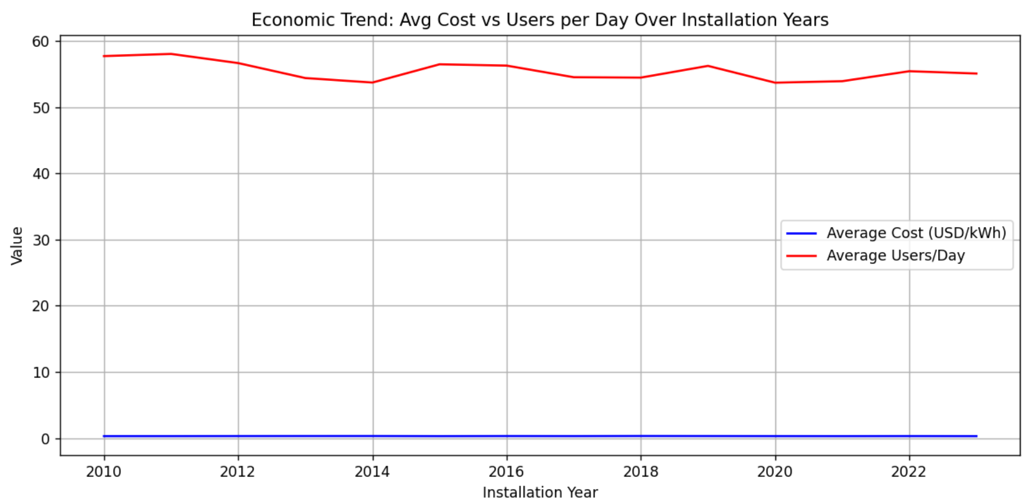

Figure 2: Economic Trend

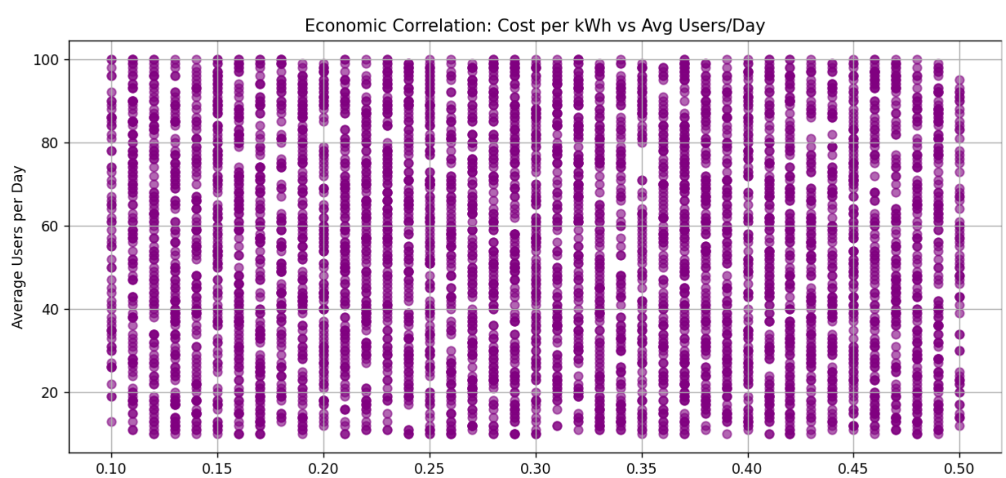

Figure 3: Economic Correlation

Social Factors:

The adoption of electric vehicles and the growing installation of EV charging stations are all signs of a shifting social mindset in favor of green energy and sustainability. Individuals are more concerned about green transport now, which is leading to greater usage of EVs. The high daily users throughout the data set all point to a robust social shift towards electric mobility. Ease of access and availability of public charging points are other key social expectations, particularly in urban and suburban areas. Furthermore, high user ratings and high usage frequency are indicators of public satisfaction and trust in EV services being high. Social trends such as city commuting, ridesharing, and the pursuit of net-zero targets are still backing the utilitarian and public acceptability of EV infrastructure. Overall, evidence exists to illustrate that social momentum is propelling mass adoption and use of EVs.

Technological Factors:

Technology has an important role to play in the operations and development of EV charging stations. The facts demonstrate the existence of various types and sizes of chargers with some offering up to 350 kW, depicting the application of fast-charging technology. With the advancement in battery technology and the extension of vehicle range, additional and higher quality charging stations that are quicker are in greater demand. Integration of smart features, such as monitoring usage and maintenance schedules, is included in how digital solutions are driving station efficiency and consumer convenience. Interoperability of technology—allowing different types of vehicles to run on a common network is another scalability driver. And, as alternative sources are integrated increasingly into the grid, EV stations are being conceived increasingly to incorporate green systems. These advances put EV infrastructure at the forefront of networked, low-carbon transport systems of the modern era.

Environmental Factors:

Expansion in EV charging stations is proportional to the world's inclination towards reducing greenhouse emissions and curbing climate change. EVs have zero tailpipe emissions, and when charged with renewable energy, lower the carbon output of transportation. More charging stations provide a motive for motorists to shift away from fossil-fuelled vehicles, enabling cities to be cleaner and healthier. The figures are identical with the use of mass stations in areas mirroring growing environmental awareness. For this purpose, some of the stations are placed in closer proximity to cities in conception, reducing car commuting distance and promoting energy-efficient urban driving. Environmental policy and incentive also play to facilitate EV infrastructure installation. Overall, the rollout of EV charging networks mirrors overall commitment towards environmental protection and sustainable development.

Legal Factors:

Operations and installation of EV charging stations are governed by a number of legal and regulatory platforms. Governments regulate public access, data protection, electrical safety, as well as charger safety to protect users and the network. Compliance with building codes, ADA accessibility standards, as well as grid connection permits, is necessary in places like the U.S., Canada, and the EU. Additionally, the operators are also responsible for monitoring consumer protection legislation, that is, delivery of service and price. Since smart chargers do track the users' information, data protection law (i.e., GDPR) becomes extremely relevant. Intellectual property rights to proprietary charging software and technology also raise legal problems. Second, all the government incentives and public-private partnerships can be made certain to be implemented strictly both contractually and policy-wise. Legal certainty and compliance are the most vital for sustainable and scalable growth of the EV charging network.

7. Key Insights and Strategic Implications

The analysis of EV charging infrastructure reveals several key observations that inform both operational efficiency and long-term planning. Firstly, economic trends show that the average cost of charge has tended to stabilize over time, while user demand continues to grow, yet again showing a healthy and strong market. The scatter plot shows usage for charging stations to be slightly price inelastic, which suggests users will pay normal prices regardless of slight cost differences. Technologically, fast charger availability (up to 350 kW) reflects the trend for higher-speed charging made possible through smart monitoring instruments like frequency of maintenance and usage data. Socially, increased daily usage reflects broad customer adoption based on environmental consciousness and social movement towards clean mobility. Environmentally, the data affirms that EV charging is a vital means of curbing city emissions, especially in combination with renewable energy integration. Politically and legally, the industry is influenced by zoning policies, grid management policies, and compliance with data privacy laws variables that are geographically diverse and must be approached with care.

Strategically, the data show that EV charging station providers should: Go ahead and grow station counts in high-demand locations using usage analytics. Standardize pricing models when exploring premium offering for fast charging. Invest in systems of compliance, specifically data protection and security. Expand smart features to monitor station performance and health. Align with governments and green energy partners to meet ESG goals. Together, these consequences promote a data-driven, proactive approach to EV scaling.

8. Dynamic Pricing Models and Economic Monitoring

Dynamic Real-time location, time-of-day, and demand dynamic pricing schemes can be implemented to optimize revenue and station load balance. Economic usage pattern monitoring and cost analysis enable data-based price adjustment and infrastructure planning. This approach allows profitability with affordability to users.

Targeted Content Expansion in High Growth Categories:

Growth must be focused on high-growth segments like quick-charging infrastructure in urban and commercial areas with heavy EV traffic. Usage patterns indicate steady usage in these segments, an indicator of high demand. Investment in high-capacity charging points and strategically located stations will optimize user satisfaction and operations returns.

Strengthening Data Governance and Legal Compliance:

To provide trust and scalability, EV charging operators must possess robust data governance models in adherence to regional laws like GDPR and energy laws. This encompasses secure data processing, clear consent from the users, and regular audits. Greater adherence to the law reduces risk, provides a brand with credibility, and enables region-wise scaling without any obstruction.

Environmental Accountability and Infrastructure Optimization:

EV charging businesses need to be mindful of partnering with green-certified energy suppliers and incorporating renewable sources into their agreements. Carbon reporting and public disclosure and energy-efficient usage of chargers will add to enhanced environmental transparency. These measures align not only with ESG practices but also with customers and investors who value sustainability.

9. Conclusion

This project puts the ubiquitous significance of EV charging infrastructure into place to build sustainable transport. With analysis of data and PESTEL analysis, optimum use, pricing, technology, and policy impact identified trends. Insights guide strategic actions like dynamic pricing, legal consideration, and green infrastructure investment. As more adopt EVs, data-driven, intuitive, and green will be the engine of long-term sustainability.

References

- Li, Y., Luo, J., Chow, C. Y., Chan, K. L., Ding, Y., & Zhang, F. (2015, April). Growing the charging station network for electric vehicles with trajectory data analytics. In *2015 IEEE 31st international conference on data engineering* (pp. 1376-1387). IEEE
- Buekers, J., Van Holderbeke, M., Bierkens, J., & Panis, L. I. (2014). Health and environmental benefits related to electric vehicle introduction in EU countries. *Transportation Research Part D: Transport and Environment*, *33*, 26-38.
- Ucer, E., Koyuncu, I., Kisacikoglu, M. C., Yavuz, M., Meintz, A., & Rames, C. (2019). Modeling and analysis of a fast-charging station and evaluation of service quality for electric vehicles. *IEEE Transactions on Transportation Electrification*, *5*(1), 215-225.
- Pyrgou, A., Panayiotou, P., Kapetanios, C., & Nicolaides, K. (2024). Measuring the sustainability of electric vehicles in Cyprus using PESTEL analysis. *Case Studies on Transport Policy*, *18*, 101297.
- Nanaki, E. A., & Koroneos, C. J. (2016). Climate change mitigation and deployment of electric vehicles in urban areas. *Renewable energy*, *99*, 1153-1160.
- Yang, Y., Zhang, Y., & Meng, X. (2020). A data-driven approach for optimizing the EV charging stations network. *IEEE Access*, *8*, 118572-118592.