Data-Driven Analysis of Electric Vehicle Adoption in India: A Statistical Comparison of Maharashtra and Karnataka

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***Abstract*—As the importance of sustainable transportation is increasing globally, electric vehicles (EVs) are being rapidly adopted in emerging markets like India. This study explores the growth trends of EV usage using a data-driven statistical approach, based on sales data collected over several years. In particular, it focuses on a comparative performance analysis of the states of Maharashtra and Karnataka. Yearly growth models were analyzed to understand adoption progress. State-level differences were assessed using statistical significance tests such as Welch's t-test, F-test, and two-sample z-test. Research findings indicate that EV sales in India continue to show strong growth; this has been significantly influenced by government policy initiatives like the Faster Adoption and Manufacturing of Electric Vehicles (FAME) scheme and the expansion of charging infrastructure. Although statistical results show no significant difference in average EV sales between the two states, a clear disparity is observed in sales variability. This study emphasizes that stable policy frameworks and robust infrastructure development are essential to ensure sustained EV adoption.**

***Index Terms*—Electric Vehicles, EV Adoption, India, Statistical Analysis, Sustainable Mobility, FAME Scheme, State Comparison**

I. INTRODUCTION

Due to factors such as the increase in greenhouse gas emissions and heavy dependence on fossil fuel resources, transportation electrification has taken a significant role in global climate change mitigation efforts. India, one of the world's largest vehicle markets, has introduced various policy measures to accelerate the adoption of electric vehicles. These include purchase incentives, charging infrastructure development, and industrial manufacturing programs. Specifically, government schemes like FAME-II have notably encouraged EV adoption and the expansion of charging facilities across many parts of the country.

Although EV usage has grown at the national level, variations in adoption are observed across states. These differences are influenced by factors such as economic structure, level of urbanization, industrial capacity, and the nature of policy implementation. Maharashtra and Karnataka are key contributors to India's EV landscape. Maharashtra has major vehicle manufacturing hubs, while Karnataka has developed due to the advancement of technology-driven urban markets, particularly centered around Bengaluru.

This study aims to evaluate EV adoption patterns using statistical methods like quantitative data analysis and hypothesis testing, and to provide insights into regional adoption dynamics at the state level.

II. LITERATURE REVIEW

Many studies on EV adoption emphasize that government policy incentives, availability of charging infrastructure, and technological advancements are key factors determining market growth. Incentive amounts and infrastructure investment programs provided through schemes like FAME have had a measurable impact on increasing EV usage in India. Furthermore, infrastructure readiness of charging facilities is directly related to the adoption rate. Increasing charging stations reduces range anxiety and boosts user confidence. With government support, the expansion of charging stations under the FAME scheme has accelerated EV adoption in several states. However, studies comparing EV performance across Indian states using statistical hypothesis testing methods are limited. Filling this research gap is the main contribution of this study.

III. OBJECTIVES

The main objectives of this study are as follows:
1. To analyze the year-wise growth of EV sales in India.
2. To compare EV adoption between the states of Maharashtra and Karnataka.
3. To use statistical hypothesis tests to evaluate differences in mean and variance.
4. To interpret the study findings in policy and socio-economic contexts.

IV. DATA AND METHODOLOGY

Data Source and Description

This survey is based on several years of electric vehicle (EV) sales data in India. The dataset includes key variables such as Year, State, Vehicle Type, and EV Sales Quantity. This data helps to understand the growth of EV adoption over time and to explore differences between states.
The states of Maharashtra and Karnataka have been selected for comparison. Maharashtra is a major vehicle manufacturing hub in India, while Karnataka leads in technological development and new EV initiatives. The unique economic and industrial structures of these two states make them suitable for statistical comparison. Before the study, the data were preprocessed and errors were removed. Annual EV sales volumes were aggregated, and national-level growth trends were examined.

Analytical Framework

This study employed two approaches: Descriptive Statistics and Inferential Statistics:

1. Descriptive Analysis
The year-wise EV sales growth, decline, and accelerated periods were examined through charts and summaries.

2. Inferential Statistical Analysis
Hypothesis testing was used to scientifically confirm the differences between the states of Maharashtra and Karnataka.
• Null Hypothesis (H_0): There is no significant difference in EV sales between the two states.
• Alternative Hypothesis (H_1): There is a significant difference.

Statistical Methods

Welch Two-Sample t-Test

The Welch t-test was used to compare the average EV sales between two states. This method is highly suitable for real-world data because it does not require the variances to be equal.
This test was used to assess whether the observed difference in average sales is real or due to random variation. A 0.05 significance level was used.

F-Test for Variance Analysis

To understand the stability of EV sales, variances were compared using the F-test.
• High variance → Sales fluctuate significantly.
• Low variance → Stable growth.
Using this, the adoption consistency of states was assessed.

Two-Sample Z-Test

In addition, the z-test was used to validate the T-test results. This test helps confirm the difference in averages in data with large samples.

Software Tools

All statistical calculations were performed using the R programming language. This ensures reproducible research and enhances the reliability of the study.

V. RESULTS AND DISCUSSION

Year-Wise EV Adoption Trends

Research results show that EV sales in India continue on a growing trajectory. In the initial stages, growth was slow due to factors such as high prices, lack of charging stations, and user hesitation. However, later rapid growth was observed due to the following reasons:
• Government incentive schemes (such as FAME)
• Expansion of charging infrastructure
• Battery technology improvements
• Increased environmental awareness
Although growth was somewhat slow in certain years, it is considered to be due to global economic and supply-chain challenges.

Comparative Analysis: Maharashtra vs Karnataka

Mean Comparison (T-Test Results)

T-Test Results
• t = 1.0344

• p-value = 0.301
Since p-value > 0.05, there is no significant statistical difference in average EV sales between the two states. Both states show the same level of EV adoption.
The Welch two-sample t-test produced a test statistic value of t = 1.0344 with a p-value of 0.301. Since the p-value exceeds the threshold of 0.05, the null hypothesis is not rejected.

This indicates that the average EV sales between Maharashtra and Karnataka are statistically similar. From a policy perspective, this suggests that both states are contributing equally to India's EV transition despite differing economic structures.

Variability Analysis (F-Test Results)
F-Test Results
• F = 1.7313
• p-value < 0.05
This indicates a significant difference in variance.
• EV sales in Maharashtra show higher fluctuations.
• Karnataka shows more stability in adoption.
Maharashtra exhibits higher fluctuations in EV adoption, possibly due to broader market diversity and varying regional demand patterns.
Karnataka displays relatively stable sales trends, reflecting consistent demand driven by urban technology-oriented consumers and policy stability.
This finding highlights that similar averages can mask important differences in adoption consistency.

Validation through Z-Test
• z = 1.0344
• p-value = 0.1505
This result confirms the t-test results. That is, there is no significant difference in average sales. The consistency across two independent statistical methods strengthens the reliability of the results and reduces the possibility of methodological bias.

Overall Interpretation
This study reveals three key findings:
1. The use of EVs in India is continuously growing.
2. Maharashtra and Karnataka show similar average sales.
3. There are differences between states in the sustainability of adoption.

As a result, this study emphasizes that it is important for policy design to consider not only the level of EV adoption but also its sustainability.

VI. DISCUSSION

The findings of this study indicate that, in terms of average EV sales, both Maharashtra and Karnataka contribute similarly to the national level EV adoption growth. However, the differences observed in sales variability reflect changes in the market dynamics of the states.

Due to Maharashtra's diverse industrial economy, there is a possibility of fluctuations in EV demand. On the other hand, Karnataka's technology-centric urban environment and innovation-driven economic structure support sustainable growth.

The study's findings reveal that policy frameworks like FAME-II and the expansion of charging infrastructure have reduced barriers to EV adoption across the country. Furthermore, consistent and uniform policy implementation at the state level, along with continuous infrastructure development, is highlighted by these findings as crucial for long-term EV adoption sustainability.

Policy Implications
• Stable government incentive programs improve the sustainability of EV adoption.
• Expansion of charging infrastructure significantly reduces adoption barriers.
• Tailored policy strategies for states can help improve market balance.
• Continuous government support for setting up charging stations is essential.

VII. LIMITATIONS

• The dataset used contains only a small number of states and time periods.
• Factors related to consumer behaviour are not included.
• Policy impacts are analyzed only in general, not individually.
• External factors such as fuel price changes and the global supply chain are not modeled.

VIII. FUTURE SCOPE

Future studies can be conducted in the following areas:
• Comparative analysis involving multiple states.
• Modeling the relationship between infrastructure and sales.
• Machine learning models for forecasting EV adoption.
• International comparative studies with leading EV markets.

IX. CONCLUSION

This study confirms that EV adoption is continuously growing in India. Government incentive schemes and improvements in charging infrastructure are key drivers of this growth. Statistical analysis results indicate that Maharashtra and Karnataka are at similar average adoption levels, although differences are observed in sales variation.

The study emphasizes the need for consistent policies and enhanced infrastructure to sustain long-term growth. It is expected that in the future, as policy measures continue to advance and technological development increases, EV adoption in India will grow at an even faster pace.

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