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Research Paper

From Policy to Practice: Analysing India's EV Growth and Infrastructure Evolution

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ABSTRACT: *This paper tracks Indian EV growth from 2013 to 2024. It covers important trends, government actions, infrastructure upgrades, and stakeholder impacts. The statistics show strong increase, especially in two and three-wheelers. This is due to rising petrol prices, urban mobility demand, and cost effectiveness. Four-wheeled electric automobiles are still in development, but they have made progress. This growth shows consumer confidence and technology advancement. The National Electric Mobility Plan (NEMMP), FAME I and FAME II, and Production Linked Incentive (PLI) programs have helped India buy and make electric vehicles. The uneven distribution of Public Charging Stations among states raises equality problems. Urban areas like Delhi and Maharashtra have the most infrastructure, while northeastern and remote areas lack it. The analysis shows that India is moving towards electric vehicles, but a collaborative, inclusive, and fair strategy is needed to ensure stakeholder acceptance and sustainability.*

KEYWORDS: *Policy, Electric Vehicle, Charging Infrastructure, Sustainability, Mobility*

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I. INTRODUCTION

Globally, the transportation sector emit approximately 24% of carbon from fuel combustion, in which roadways accounting about 70% of this share (*Global EV Outlook 2023 – Analysis*, 2023). Growing urbanisation, economic growth, and the need for mobility have led to a large increase in the usage of motor vehicles, which has increased the environmental burden. To counter this, one of the primary objectives is to reduce local air pollution, slow down global warming, and increase energy economy by electrification of transportation. Plug-in hybrid electric vehicle (PHEVs), Fuel cell electric vehicle (FCEVs), battery electric vehicles (BEVs) are among the electric vehicles that are significantly reduce carbon emissions. Their lifetime emissions are also less than those of traditional combustion fuel vehicles, especially when they are powered by low carbon electrical sources (*Hawkins et al.,2013*). Moreover, EVs play essential role in achieving national decarbonisation goals. Combining EVs with smart grids, urban design projects, and renewable energy sources opens opportunities for more strong and sustainable mobility choices. With third largest automobile market worldwide by volume, India offers unique blend of opportunities and challenges for electric vehicles. Major cities like Delhi, Mumbai, and Bangalore, underscores the need for cleaner substitutes to tackle faster urbanisation, increased fuel costs, and worsen air quality. Simultaneously, India's large domestic market, growing industrial base, and dynamic political environment help to create favourable conditions for the EV adoption. Driven by the urgent need for greener and more sustainable mobility solutions, India, a key and fast growing automotive market is undergoing a significant change in its transportation sector. Given the worsening air quality in big cities and the great reliance on imported crude oil, the Indian government has realised that switching to electric mobility is very necessary. Under accords like the Paris Agreement, this shift not only addresses environmental issues but also acts strategically to strengthen energy security, increase local manufacturing, and meet international climate commitments (RMI,2017).

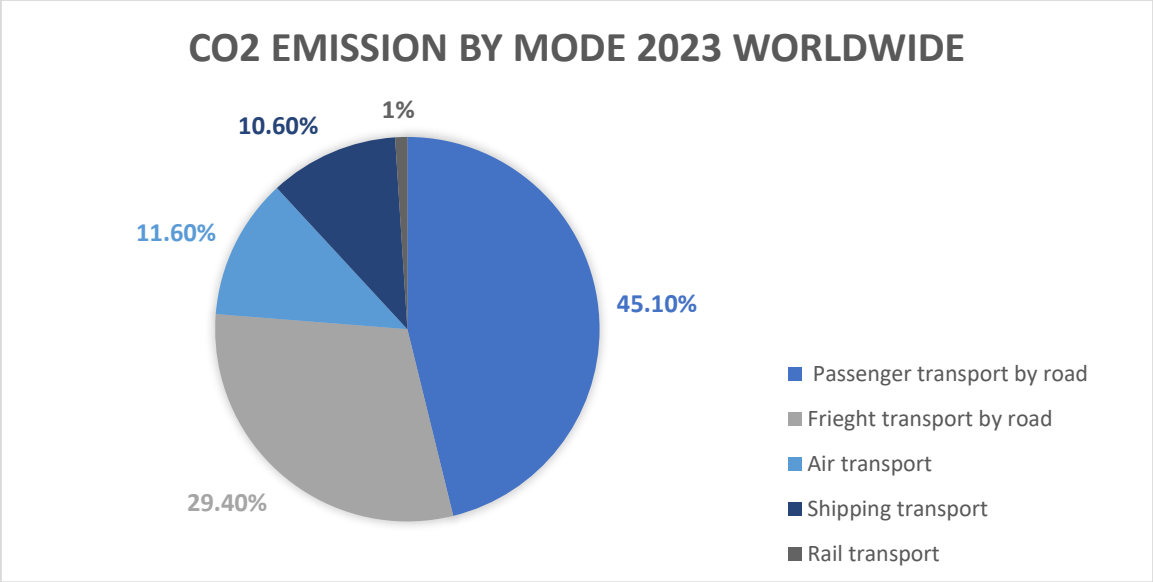

Figure 1 CO2 emission

Source: IEA,2023

Beginning with the National Electric Mobility Mission Plan (NEMMP), which set the basic vision for electric vehicle adoption in the country, the Faster Adoption and Manufacturing of (Hybrid) Electric Vehicles (FAME I) plan was developed by Ministry of Heavy Industries,2015. Initiated in 2019 with a significantly higher budget commitment of 10,000 crores, the FAME II initiatives aim at electrification of public and shared transport. While working to enhance public charging infrastructure, the program provided direct subsidies for electric 2-wheelers,4-wheelers, and buses (*Ministry of Heavy Industries*). Targeting both the automotive sector and battery manufacture, the governments production linked incentive (PLI) plans in 2021 help to improve the electric vehicle ecosystem. The PLI for Advanced Chemistry Cell (ACC) battery storage is meant to be used into boost domestic manufacturing capacity, reduce reliance on imports, and create a strong EV supply chain. The governments ongoing dedication to encourage the acceptance of electric vehicles is shown by the most recent FAME II extension until 2024 (*FAME PHASE-II SCHEME*). Sales of electric vehicles have climbed significantly thanks to these legislative initiatives. Significantly increasing adoption, data from VAHAN and the Society of Manufacturers of Electric Vehicles (SMEV) show that electric 2-wheeler sales jumped from over 19,000 units in 2019 to over 7,20,000 units in 2023 (*VAHAN SEWA| DASHBOARD*). Categories for electric 3-wheeler and 4-wheeler have seen notable increase. After 2021, a good amount of this acceleration has occurred in line with positive legislative actions and the spread of charging infrastructure. Public charging station are absolutely essential for the ecosystem of electric vehicles. Reducing range anxiety and increasing consumer confidence in electric vehicles depend on a consistently distributed and dependable charging network. The ministry of Power and the bee estimate that over 12,000 operational PCSs are now spread around India. Still, there are geographical inequalities Maharashtra3079, Delhi 1886, and Karnataka 1041 are leading PCS deployment while other Northeastern states and Union Territories are less served.

This paper aims to provide a comprehensive analysis of India's electric vehicle development and infrastructure construction from 2013 to 2024. It delineates the evolution of significant legislative measures, integrates statistics on electric car sales across various categories, and evaluates the deployment of public charging stations at the state level. The objective is to identify the deficiencies and opportunities within India's future mobility landscape, as well as to assess the impact of policy and infrastructure on electric vehicle adoption. The objectives of this paper are to analyse the growth trend of EV sales in India from 2019 to 2023 by vehicle segment, to study the impact of policy intervention on EV adoption, and to assess the distribution and adequacy of PCS across Indian states.

II. CURRENT TRENDS IN ELECTRIC VEHICLE TECHNOLOGY

2.1 Innovation and Cost reduction of batteries

Core of EV technology are batteries. The main technology of lithium-ion batteries has undergone rapid evolution in terms of energy density, thermal stability, and performance. According to (*BNEF Electric Vehicle Outlook,2023*), typical battery pack prices dropped from $1200/kWh in 2010 to around $153/kWh in 2022, with forecasts showing $82/kWh pricing by 2026, a critical criterion for price parity with internal combustion engine (ICE) vehicles refer figure 2. Emerging advancements encompasses are solid state batteries that provide enhanced

energy density and safety, with prospects for faster charging and longer range, battery chemistry diversification Nickel -Manganese – Cobalt and Lithium- Iron- Phosphate are refined for energy efficiency and cost effectiveness, respectively and second life applications by decommissioned EV batteries are progressively repurposed for stationary energy storage, prolonging their functionality and minimising waste.

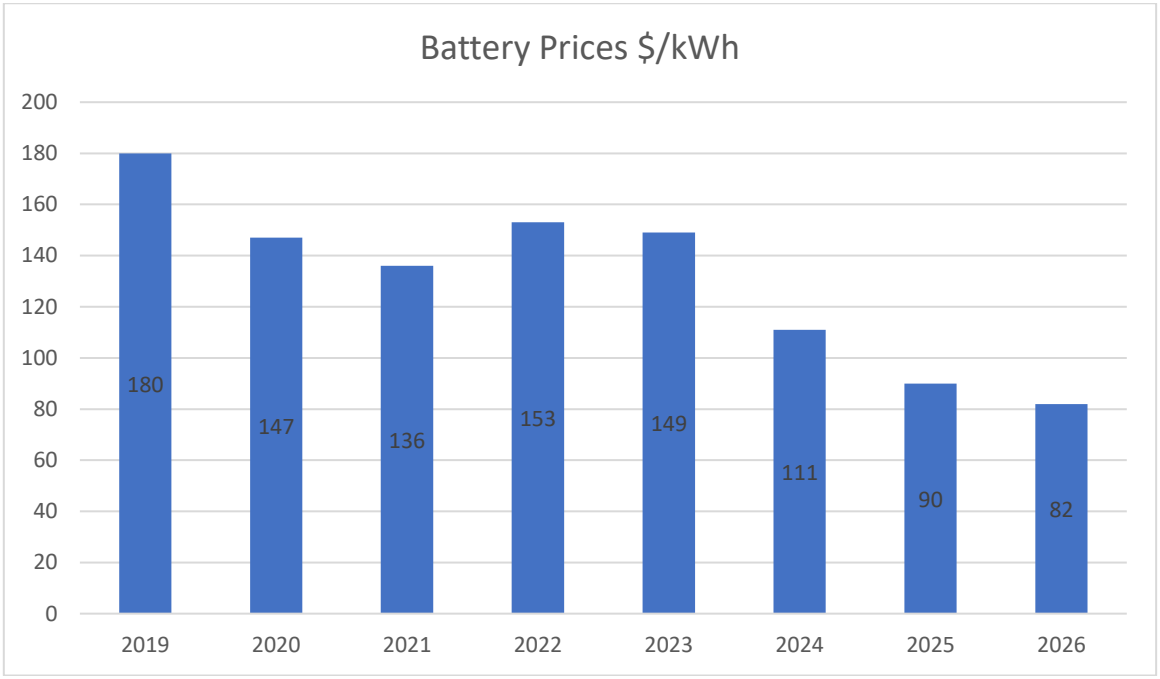

Figure 2 Battery Prices
Source: Goldman Sachs Research 2025-2026 are forecasts

2.2 Technological advancements in India

Indias dependence on imported battery cells causes problems with pricing and supply stability. However, local capacity is growing, driven by the Production Linked Incentive (PLI) program for Advanced Chemistry Cell (ACC) manufacturing. Gigafactory construction by companies such as Reliance New Energy and Ola Electric marks a conscious move towards local value creation. Starting with two and three wheelers, startups are pioneering in battery swapping by using standardised, modular batteries. For urban transportation, this method is perfect since it reduces charging downtime, lowers vehicle expenses, and permits fast battery replacements. Smart systems also support fleet efficiency, real time tracking, flawless digital integration.

III. ADOPTION OF ELECTRIC VEHICLES: INDIAN AND GLOBAL POSITIONS

3.1 Trends in the Global Market

The global market for electric vehicles has grown in large number. In 2019, EVs made up of less than 3% of all new cars sold. By 2022, they made up 14% of all new cars sold, with over 10 million units. This trend continued into 2024, producing a notable 25% annual rise that raised yearly sales to 17.1 million units refer figure 3 (*IEA*, 2023). This rise is the result of many things working together, such as better technology, changing customer preferences, and most importantly, active government policies. By having a broad and well-coordinated industrial policy, investing a lot in battery technology, and having control over large parts of the electric vehicles supply chain, such as making lithium-ion batteries and rare earth materials, China has become the world leader in both making and using electric vehicles (EVO Report 2024, BloombergNEF). The Chinese government has kept up strong internal benefits and pushed for EVs rules, which have made it even more dominant in the global EV market (Tian et al., 2024). Europe and the US, on the other hand, are moving faster to encourage people to buy electric cars by putting in place supply side rules and demand side incentives. The (*Climate Action - European Commission*, 2025) has had strict rules about CO2 pollution for all cars since 2023, and by that year, they want to make it illegal for all vehicles with internal combustion engines. According to the U.S. (*Department of Energy*, 2023), the inflation reduction act of 2022 has made it easier to buy electric cars by increasing tax breaks and encouraging local content requirements for production in the U.S.

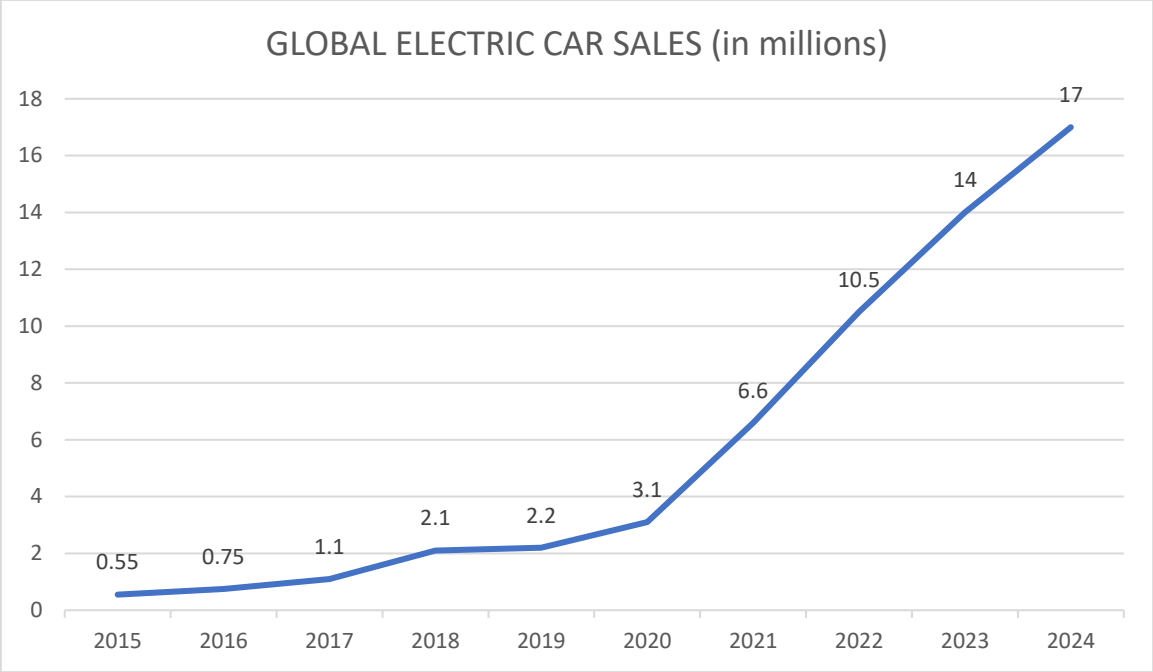

Figure 3 Global Electric Car Sales

Source: IEA (2025)

Supported by industry competitiveness, climate pledges, and consumer acceptance, these regional policies taken together reveal a rising global convergence towards sustainable mobility. The move to electric mobility seems not only natural but also irreversible as infrastructure spending scale up and battery prices keep declining.

3.2 Trends in the Indian EV Market

Electric vehicle development in India is impressive and has the potential to revolutionise the country, even if it is still in its early stage. Compared to previous years, EV sales in the nation fiscal year 2022-23 were over 5% (*VAHAN SEWA*,2023). More than 60% of all electric vehicle registered were electric 2 wheelers. Their affordability, user-friendliness, and suitability for urban mobility, particularly in densely populated areas, contribute to their dominance (*RMI-EVreport-VF_28_1_21.Pdf*, 2022.).

The following factors are increasing this growing trend;

- Availability of models improved- Customers across a variety of vehicle segments, such as two-wheelers, three-wheelers, passenger cars, and commercial vehicles, are increasingly being provided electric models. Both domestic and international manufacturers are broadening their offering to accommodate a range of pricing ranges and use cases, companies like Hero Electric, Ola Electric, MG, BYD, and Ather Energy (*IBEF,2023*).
- Lower Operating Expenses- In contrast to internal combustion engines (ICE), electric vehicles (EVs) exhibit much lower operating expenses. Electricity is considerably more economical per kilometre than petrol or other diesel, and electric vehicles possess fewer moving components, hence diminishing maintenance expenses (CEA, 2023). A study by the Council on Energy, Environment, and Water indicates that electric vehicle owners can reduce petrol expenses by 70 to 80 percent during the lifespan of their car (*Mapping India's Energy Policy, 2022*).
- Enhancing leasing framework and financing alternatives: financial innovations such as electric vehicle specific loans with reduced interest rates, leasing contracts, and battery subscription models are alleviating the obstacle of substantial of substantial initial expenses. Financial institutions are progressively engaging in the electric car market due to government supported incentives and the industry's long term prospects (NITI Aayog).

Notwithstanding these achievements, there are still significant obstacles to overcome:

- High Initial Costs: Despite the fact that EVs typically have lower total costs of ownership, the initial acquisition cost is still high compared to internal combustion engine (ICE) cars, which deters many price-conscious buyers (*ICRA Limited*, 2023)
- Limited Awareness and Consumer Perceptions: The advantages of the technologies, government incentives, and electric vehicle remain unfamiliar to numerous prospective purchasers. Specifically, misconceptions about car reliability, battery longevity, and charging duration persist in semi urban and rural areas (EY India,2022).

- Inadequate charging infrastructure: Tier-2 and Tier-3 cities receive inadequate service since public charging stations are primarily located in large urban regions. In early 2023, India had just over 8,700 public charging stations, which was insufficient to keep up with the anticipated rise in the number of electric vehicles (*Electric Mobility BEE,2023*). In less urbanised areas, adoption is challenging due to "charging anxiety".

Addressing these challenges through coordinated government support, infrastructure investment, and public private partnerships will help India meet its ambitious electric vehicle penetration targets, which state that 30% of new vehicle sales be electric by 2030 (*NITI Aayog,2021*).

IV. POLICY FRAMEWORK AND INSTITUTIONAL SUPPORT

4.1 The global policy framework

A range of actions meant to hasten the transition from internal combustion engine vehicles to more environmentally friendly solutions shape the international regulatory framework for electric vehicles. These projects reflect the main goals of the climate: lower greenhouse gas emissions, improve urban air quality, and support energy security. To encourage the acceptance of electric vehicles, nations and regions all over have combined infrastructure, regulatory and financial strategies.

- Direct subsidies and tax rebates:

Financial incentives remain one of the most often employed policy instruments to enhance the competitiveness and affordability of electric vehicles compared to conventional automobiles. To mitigate the typically elevated initial expenses of electric vehicles, government offers income tax credits, upfront purchase subsidies, and reduction in registration fees. The United States provides a federal tax credit of up to $7,500 for new electric vehicle acquisitions, contingent upon battery capacity and manufacturer (*Alternative Fuels Data Center*, 2023). Similarly, Germany's "Umweltbonus" program provides grants of up to €9,000 for each electric vehicle, jointly funded by the federal government and automobile sponsorship (*European Alternative Fuels Observatory*, 2023).

- Regulations regarding fuel efficiency standards and emissions:

Stricter tailpipe emissions regulations and fuel efficiency criteria compel manufacturers innovate and promote environmentally friendly vehicles. The European Union's CO2 emissions regulations for new passenger vehicles have profoundly influenced automobile manufacturers portfolios, necessitating a transition to electric and hybrid models (*Light-Duty Vehicles - European Commission*,2021). The Corporate Average Fuel Economy (CAFE) standards in the United States have similarly influenced expenditures on electric vehicle technologies.

- Investment in charging infrastructure:

Mitigating range anxiety and enhancing the operational feasibility of electric vehicle rely on investments in charging infrastructure. Countries such as China, Norway, and the Netherlands have allocated substantial resources to develop extensive, high-speed charging infrastructure. As of 2023, China has constructed the largest number of public charging stations over 1.2 million (*Global EV Outlook,2024*). The European Union's Alternative Fuels Infrastructure Regulation (AFIR) aims to establish a fundamental distribution of charging stations along important transportation corridors.

- Urban mobility plans prioritizing electrification:

Numerous cities and metropolitan regions have established low emission zones, implemented congestion pricing, and prohibited diesel vehicles to promote the transition to electric vehicles under urban mobility strategies emphasising electrification. Urban mobility plans emphasise e mobility inside public transit networks and increasingly incorporate infrastructure for electric automobiles. The Ultra Low Emission Zone in London has enhanced air quality and increased the use of electric vehicles within the city (*Greater London Authority*,2022).

California's Zero Emission Vehicle (ZEV) mandate requires automakers to sell a certain percentage of zero-emission vehicles, including battery electric and hydrogen fuel cell vehicles. This market driven strategy has facilitated the expansion of the variety and availability of electric car models (*California Air Resources Board*,2022). The credit based quota system for New Energy Vehicles (NEVs) in China requires manufacturers to meet minimum NEV credit obligation based on their sales volume. This plan has recognised China as the preeminent market for electric vehicles globally (*MIIT China,2023*). These policy incentives, sometimes integrated, constitute a complete strategy for advancing electric vehicles that includes financial incentives, regulatory mandates, infrastructure enhancement, and sustainable urban design.

4.2 India's Policy Framework

A diverse policy structure that combines federal government mandates with state level initiatives defines India's approach to electric mobility. These programs seek to develop strong ecosystem for the production of electric vehicles, incentivize consumers, address supply side constraints, and build charging infrastructure. As a signatory to Paris agreement and committed actor in global climate initiatives, India views electric mobility as a crucial tool for attaining energy security, decreasing urban air pollution, and lowering greenhouse gas emission.

National Policies

- FAME I (2015-2019): The Faster Adoption and Manufacturing of Hybrid and Electric Vehicles in India (FAME I) scheme was launched by the Department of Heavy Industry in 2015 to catalyse early stage EV adoption. Commencing with a foundational investment of ₹795 crore, it offered demand-side incentives for electric automobiles, buses, three-wheelers and two-wheelers. Program funding encompassed research and development and the establishment of charging infrastructure. It led to sale of over 2.8 lakh EVs during its tenure (*Department of Heavy Industry,2019*).
- FAME II (2019-2024): Building on its predecessor, FAME II was introduced with a significantly larger budget of ₹10,000 crore. With a goal of deploying 7,000 electric buses, 5lakh electric 3 wheelers, 55,000electric 4-wheeler passenger cars, and 10 lakhs electric 2wheelers, this phase focuses on facilitating electrification in the public and shared transportation sectors (*Press Information Bureau*, 2019). FAME II has been extended until 2024 to allow for broader adoption and includes investments in charging infrastructure, notably along city corridors.
- Production-Linked Incentive plans: to promote domestic production of electric vehicles and related components, India has put PLI plans into place. To encourage investments in contemporary automotive technology, including electric vehicles, the PLI for Automobile and Auto Components offers incentives worth ₹25,938 crore (*Ministry of Heavy Industries*, 2021). ₹18,100 crore is allocated by the Production- Linked Incentive (PLI) for Advanced Chemistry Cell Battery Storage to support high-efficiency battery production in an effort to reduce reliance on imports and promote self-sufficiency (*Ministry of Heavy Industries*,2021).

These national level initiatives represent an integrated approach to tackling both demand and supply side bottlenecks in India's EV transition.

V. RESEARCH METHODOLOGY

This paper uses a descriptive research design to examine the trends and patterns in the spread of electric vehicle (EVs) and the development of related infrastructure more especially public charging stations (PCS) in India between 2013 and 2024. The approach stresses the presenting of conclusions using basic statistical and visual tools as well as the gathering, arrangement, and analysis of secondary data from reliable sources. The data used in this paper was collected from various official and publicly available secondary sources. Electric vehicle sale data is collected for the time period of 2019 to 2023 for three segments two-wheelers, three-wheelers, and four-wheelers from the VAHAN portal and reports by the SMEV. The timeline for the government policy is 2013 to 2024 in which information on major government policies and schemes related to electric mobility was collected. The policies and schemes examined are National Electric Mobility Mission Plan, FAME I, FAME II, Production Linked Incentive, and FAME II Extension. Next the state wise data of public charging stations were gathered in which no. of operational PCS across India was obtained from the Bureau of ee and recent government reports on EV infrastructure. So majorly the sources of data are government reports, VAHAN database, SMEV annual reports and IEA. This paper applies simple descriptive methods to analyse the data. For the trend analysis EV sales figures from 2019-2023 were presented to observe annual growth in different segments and sales pattern were compared before and after the introduction of major policies. Then for policy correlation qualitative observation by aligning the timeline of policy introduction with EV sales trends, we observed how each policy appears to have influenced market growth and although no statistical testing was done, visual inspection helped identify periods of significant change. For the analysis of PCS distribution state wise data on operational PCS was compiled into a table and bar chart. This helped in identifying which states have developed strong charging infrastructure and which are lagging. EV sales and PCS distribution were compared across high performing states and low performing regions to highlight infrastructure gaps. Microsoft excel was used to organise the data, create bar charts, trend lines, and summary tables. Simple calculations such as year over year growth, cumulative totals, and rankings by state were performed to interpret the data meaningfully. Visual representations were used to make the results more understandable and clearer. This descriptive methodology provides a clear and straightforward approach to understanding how government policies and infrastructure development have influenced EV adoption in India over the past decade. The goal is to give a visual and factual representation of progress while identifying areas for further improvement.

VI. RESULT AND ANALYSIS

The EV sales figures showing in reveal three distinct phases first was early adoption phase till 2020, in which two wheelers increased from 19,333 units in 2019 to 1,52,000 units in 2020, rise of 685% refer figure 4. Three wheelers segment grew modestly from 1,26,000 to 1,40,000 with a rise of 11% and four wheelers remained flat at 3600 units. Notwithstanding the onset of the COVID-19 pandemic, the dramatic surge in two-wheeler sales in 2020 indicates significant latent demand for affordable last mile electric mobility solutions. Typically requiring lower initial investments and facilitating simpler deployment for daily commutes, two wheeler electric vehicles predominately cater to commercial sectors, such as last mile delivery and shared rides. Three wheelers have also had a minor increase, but constrained by initial driver reluctance and regulatory limitations. Four wheelers were

limited, likely due to inadequate charging infrastructure and higher price in 2020. Next the 2nd phase was pandemic impact and consolidation 2020-2021, in which two wheeler segments slightly declined to 1,43,000, 6% decrease compare to 2020 and three wheelers fell to 88,000 declines of 37% whereas, four wheeler segments have small uptick to 5,905. Overall sale decreased during this phase 20% decline compare to 2020. The overall dip in 2021 reflects pandemic related disruptions manufacturing shutdowns, supply chain bottlenecks for lithium ion cells, and consumer hesitancy. The two wheeler and three wheeler segments were disproportionately impacted as numerous users faced economic instability. The slight increase in four wheeler electric vehicles indicates that early adopters in higher income levels have remained relatively unaffected. Consequently, 2021 functioned as a year of consolidation, during which fundamental demand was moderated by external disruptions. 3rd phase was accelerated growth phase 2021-2023, during those sales of two-wheelers skyrocketed to 2,52,539 in 2022 and then to 7,20,733 in 2023 the rise of 185%. In the segment of three-wheelers rebounded to 1,88,447 in 2022 and then to 3,99,549 in 2023 with increase of 112% and in four wheeler segment sales jumped to 21,000 in 2022 and then increased to 53,843 in 2023. Overall sale during that phase accelerated from 2,365,905 in 2021 to 4,61,986 in 2022 and further to 11,74,116 in 2023. The period from 2022 to 2023 exhibits a typical "hockey-stick" development pattern across all sectors.

Two-wheelers led the way due to the rapid introduction of new models by OEMs, the reduction of battery costs, and the expansion of financing options like EMI scheme. The economic recovery that followed the lockdown was advantageous for three-wheelers, which are used for intra-city last-mile logistics and shared mobility. They found electric vehicles to be commercially enticing due to their lower operating costs. Despite their lower absolute count, four-wheelers experienced a 15 fold increase from 2019 to 2023, suggesting that customers confidence in personal electric automobiles was at an early stage when the charging infrastructure began to develop.

EV sales experienced a roughly eightfold growth from 2019 (1,48,933) to 2023 (11,74,116). This exponential increase highlights how policy incentives, along with macroeconomic recovery, simulated swift adoption particularly after industry-wide supply chain limitations were alleviated post 2021.

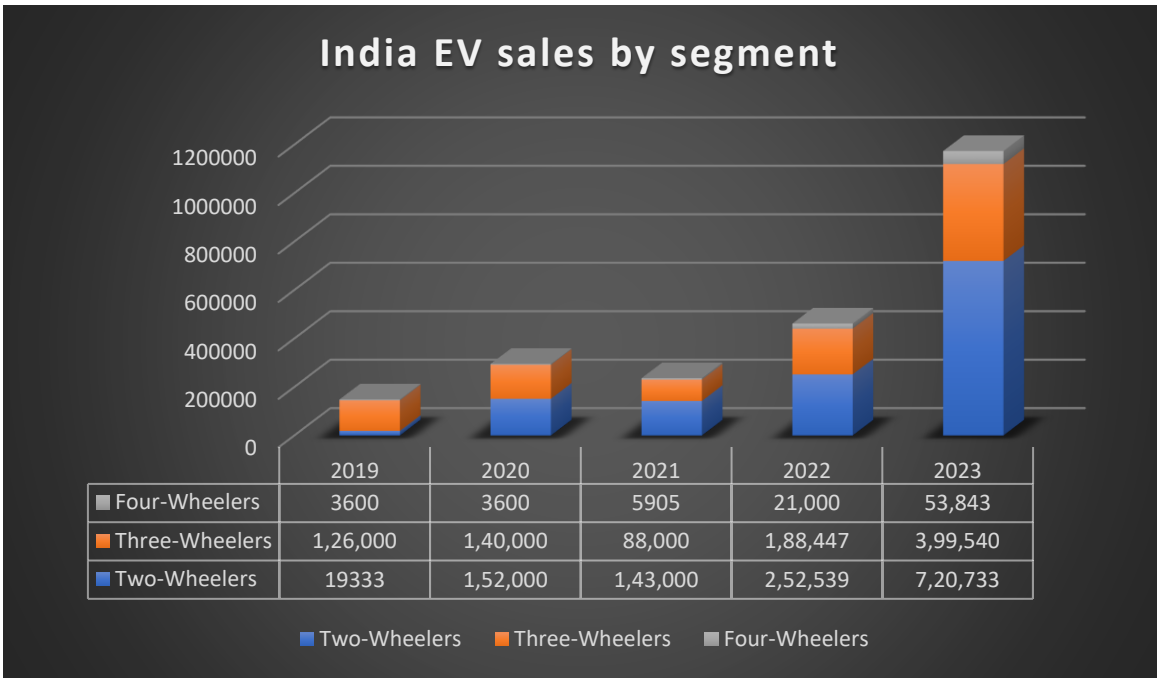

Figure 4 Indian EV sales

Source: VAHAN Portal

Aligning the policy timeline with sales data, NEMMP era 2013-15 launched with the objective to create a policy framework and stimulate research and development. FAME I 2015-19 offer purchase incentives for electric two-wheelers and three-wheelers, and subsidies for pilot projects. The market impact of it was that by 2019, two-wheeler sales reached 19,333 still modest. These early incentives largely benefited pilot fleets but did not translate into mass-market adoption due to limited charging stations and higher unit costs. FAME II 2019-24 objective was to substantially scale up purchase subsidies, incentivize electric buses and allocate funds for public charging infrastructure. The launch of FAME II in April 2019 corresponds with the initial acceleration seen in 2020. Although 2021 saw a pandemic induced dip, FAME II subsidies particularly for two and three wheelers catalysed OEM investments in EV models priced below 1.5 lakh, resulting in the massive 1,52,000 two wheeler

registrations recorded in 2020. The programs infrastructure component laid the groundwork for the PCS expansion that followed, further boosting consumer confidence in 2022-23. PLI scheme launched in 2021 with the objective to encourage domestic manufacturing of batteries and EV components via production linked incentives. Although PLI does not directly subsidize vehicle purchases, it begins to bear fruit in 2022-23 through lower battery pack prices, enabling OEMs to offer more competitively priced EVs. This indirectly stimulated sales most notably in the four wheeler segment, which saw 15 times increase from 2019 to 2023. Additionally, PLI supported cell manufacturing alleviated supply constraints that had hampered growth during 2020-21. Extension of FAME II to maintain continuity of incentives as adoption scales, ensuring no policy gap, it signal strong government commitment, reducing investment risk for OEMs and reassuring early adopters concerned about shrinking subsidies.

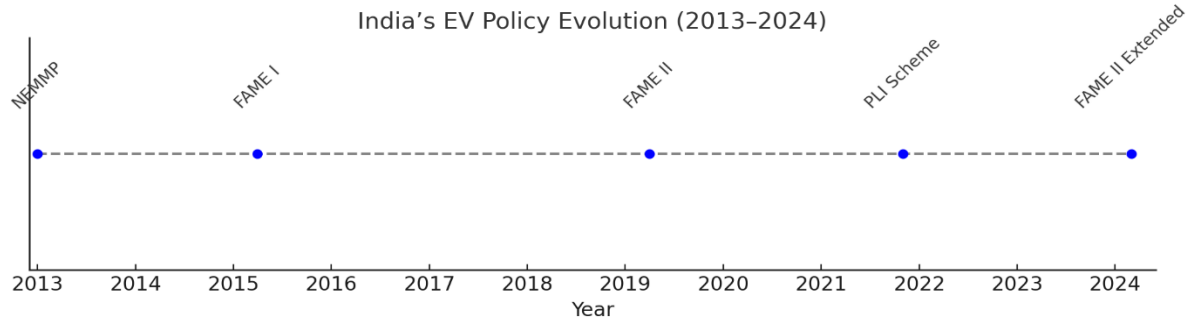

Figure 5 EV Policy evolution

Source: Author owns work

The policy timeline clearly aligns with the major inflection points in the data. FAME II launch precipitated the initial acceleration. The PLI scheme's indirect impact became evident in 2022-23, manifesting in lower retail prices and broader model availability. In essence, policy support has been both demand side and supply side, working in tandem to drive the EV ecosystem forward.

The state wise PCS counts reveal significant geographic disparities top performers are high PCS density states like Maharashtra, Delhi, and Karnataka. Maharashtra has 3079 PCS, Mumbai air pollution concern and strong buying power in Pune and Mumbai corridors led both public and private players to proliferate chargers refer figure 6. Delhi has 1886 PCS as the national capital, aggressively deployed charging points under city transport initiatives and Delhi metro's parking structures. Karnataka has 1041 PCS, Bangalore startup ecosystem and IT driven adoption spurred early charger rollouts. These high density states also correlate with strong EV sales growth Maharashtra, Delhi, and Karnataka collectively accounted for over 35% of total two and three wheeler registrations in 2023. A robust charging network reduces "range anxiety" and legitimizes EV ownership for both personal and commercial use. Mid-Tier performers states have moderate PCS deployment, states like Kerala, Tamil Nadu, and Uttar Pradesh. Kerala has 852 PCS, there proactive green energy policies and community charging initiatives explain its relative strength despite a smaller vehicular base. Tamil Nadu has 643 PCS their industrial corridors and Chennai port driven logistics have attracted OEMs to set up charging stations. In Uttar Pradesh, 582 PCS denser urban centres like Lucknow and Noida have begun installing chargers, but rural penetration remains low. These mid-tier states display an emerging but uneven infrastructure picture urban hotspots have decent charger coverage, but peripheral regions lag. Consequently, EV sales in these states while growing remain disproportionately concentrated in a few metros. Under served regions have low PCS density northeastern states and union territories like Nagaland, Sikkim, Lakshadweep, and Daman & Diu fall in this category. Their challenging geography, lower per capita incomes, and limited electricity infrastructure have delayed charger deployment. The dearth of PCS in these regions translates to negligible EV sales local transport continues to rely on traditional ICE vehicles, exacerbating air quality issues and denying these states the opportunity to leapfrog to cleaner mobility.

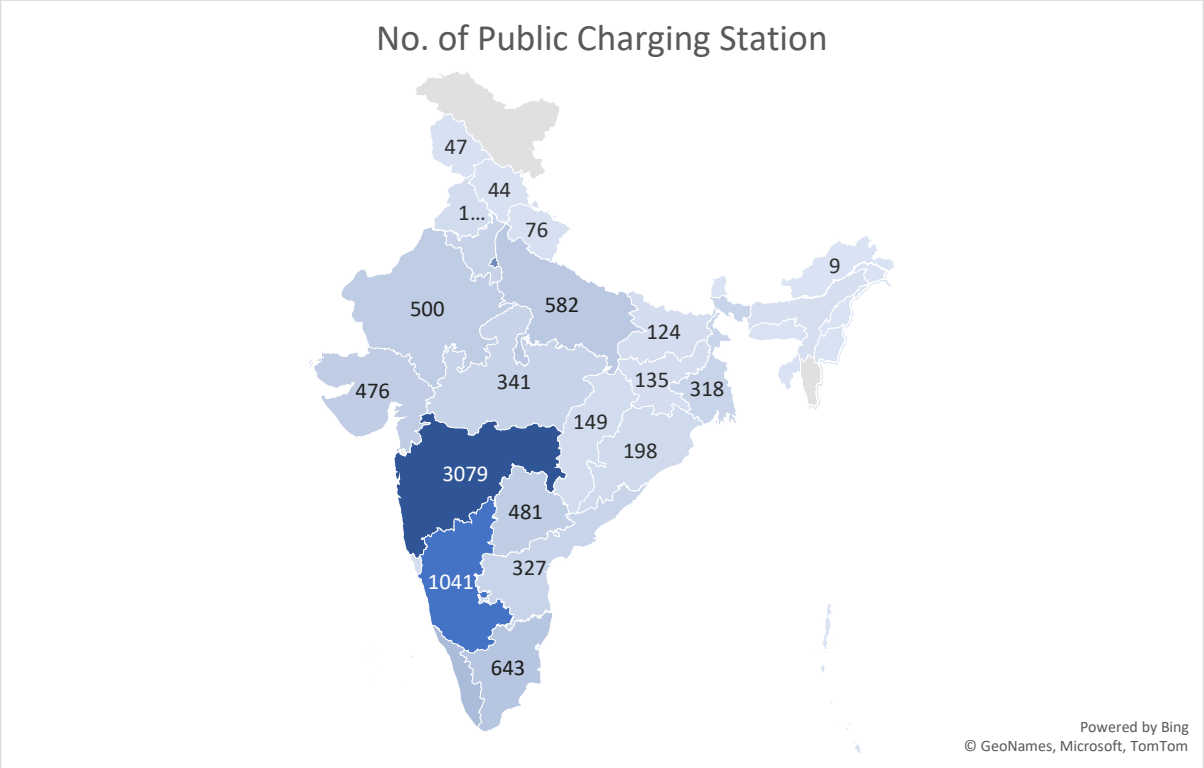

Figure 6 Public charging station mapping

The synchronized growth of EV sales alongside the acceleration in PCS deployment indicates a mutually reinforcing dynamic. For instance, FAME II infrastructure budget empowered state governments and private aggregators to expand charger networks, which in turn encouraged OEMs to introduce new models tailored for state specific markets. States such as Maharashtra, which prioritised the early establishment of public charging infrastructure, shown significantly greater levels of electric vehicle adoption. This pattern highlights the interdependent relationship between infrastructure and demands the absence of public chargers dissuades consumers from acquiring EVs, while inadequate EV adoption hinders private investment in charging networks. Also, the segment's cost sensitivity in two-wheelers and reliance on daily commuters means that even a modest PCS network often provided through home charger subsidies and it was sufficient to drive explosive growth. Public chargers primarily served as "confidence boosters". Three wheelers commercial viability hinged on operating costs. States with higher electricity tariffs or erratic power supply saw slower three-wheeler uptake despite subsidies. This suggests that beyond sheer PCS numbers, charger availability and electricity pricing are crucial. Although four wheeler EV numbers remain a small fraction of total EVs, their 15x growth from 2019 to 2023 reflects increasing model diversity and improved high DC fast charging availability in major metropolitan cities.

Numerous issues about equity arise due to the uneven distribution of Public Charging Stations throughout Indian states. Regions characterised by inadequate charging infrastructure, challenging topography, or low socioeconomic conditions are susceptible to becoming "EV deserts." This implies they will forfeit the enduring advantages of electric vehicles, including reduced operational expenses, improved air quality, and energy autonomy. To prevent the exacerbation of this mismatch, supply-side initiatives must supplement the existing demand-side subsidies. Potential solutions include utilising mobile charging vans in rural or elevated regions, establishing micro-grid-powered charging stations in locations with inconsistent energy access, and fostering public-private partnerships to expedite the deployment of chargers in underserved areas. India may develop a bifurcated electric vehicle ecosystem if it fails to implement specific regulations. Affluent urban regions would benefit from electrification, while rural and semi-urban areas would be excluded, exacerbating the disparity in the transition to clean transport regarding geography and income.

VII. DISCUSSION

The trajectory of India's electric vehicle (EV) market from 2013 to 2024 demonstrates significant transformation driven by astute governmental policies, increased public awareness of EVs, and enhanced infrastructure. The prevalence of electric car usage has significantly increased, particularly from 2019 to 2023. This indicates a greater faith in electric transportation among individuals. The substantial increase in electric two-

wheeler sales-from 250,000 in 2022 to over 720,000 in 2023 - indicates that electric two-wheelers have become a viable option due to their affordability, rising petrol prices, and the necessity for urban mobility. Electric three-wheelers, primarily utilised for commercial activities such as last-mile delivery and ride-hailing, have experienced consistent growth. This indicates that the transition to electric vehicles is expanding beyond personal use to encompass shared and commercial transportation. Despite comprising a minor segment of the industry, sales of four-wheeled electric vehicles surged fifteenfold from 2019 to 2023. This indicates that individuals are increasingly assured regarding the efficacy of electric vehicles, their range, and their accessibility.

Policy modifications have proven to be quite beneficial. The National Electric Mobility Mission Plan (2013) established the foundation, while FAME (2015) and FAME II (2019) offer direct incentives and emphasise the development of charging stations and the electrification of public transit. The Production Linked Incentive (PLI) scheme established in 2021 aimed to enhance the manufacturing of electric vehicles and batteries in the United States. The latest extension of FAME Il in 2024 demonstrates the government's ongoing commitment to long-term mobility. he advancement of Public Charging Stations (PCS) remains inconsistent. Maharashtra, Delhi, Karnataka, and Kerala exhibit the highest prevalence of public charging stations and electric car adoption, while Nagaland, Sikkim, Lakshadweep, and Daman & Diu lag well behind. This presents equity concerns, as inadequate infrastructure may establish a disparity between electric vehicles in urban locales and those in rural or remote regions.

Significant challenges persist, including range anxiety, inadequate infrastructure in rural areas, elevated beginning prices, and insufficient client education. To address these issues, a multifaceted strategy is required, encompassing the enhancement of charging infrastructure via collaborations between public and private sectors, increasing awareness of subsidies and the advantages of electric vehicles, and implementing localised solutions such as micro-grids or mobile chargers in underserved areas. In the absence of inclusive policies, India risks developing a skewed electric vehicle ecosystem that offers advantages solely in select areas.

VIII. CONCLUSION

The period from 2013 to 2024 signifies a significant transformation in India's electric transportation sector. The data indicates a significant increase in the adoption of electric vehicles, with this trend accelerating markedly over the past five years. Two-wheeled electric cars have emerged as the most prevalent vehicle type in the market because to their affordability, low maintenance requirements, and suitability for urban transportation. Simultaneously, electric three-wheelers have gained popularity in sectors such as logistics and public transportation. Currently, four-wheeled electric vehicles constitute a little segment of the industry; nevertheless, their recent expansion indicates an increasing consumer willingness to purchase them and advancements in technology.

An effective policy framework has mostly facilitated this advancement. The National Electric Mobility Mission Plan (NEMMP), FAME 1 & I1, and the Production Linked Incentive (PLI) scheme are governmental initiatives that have facilitated significant financial incentives, enhanced charging infrastructure, and promoted domestic manufacture. The proliferation of Public Charging Stations (PCS) in pivotal states has alleviated a significant consumer apprehension— range anxiety— resulting in increased adoption. Nonetheless, numerous issues persist. The disparate allocation of charging stations across states reveals significant regional disparities. Numerous northeastern and remote regions remain significantly underdeveloped, despite the rapid advancement of metropolitan and industrialised states such as Maharashtra, Delhi, and Karnataka. This underscores the significance of formulating inclusive policies that ensure the accessibility of electric vehicles beyond urban areas.

India's electric vehicle initiative has the capacity to enhance the nation by diminishing reliance on oil imports, decreasing greenhouse gas emissions, and ameliorating air quality in its heavily populated urban areas. To ensure the permanence of this shift, governmental support is essential, business engagement is necessary, and emphasis must be placed on equitable infrastructure implementation. India has the potential to spearhead a comprehensive national transition to sustainable mobility, which will enhance its economy, environment, and populace by resolving existing deficiencies and ensuring continuous advancement through extensive, region-specific initiatives.

IX. IMPLICATIONS

A multitude of stakeholders within India's electric vehicle (EV) ecosystem are profoundly impacted by the results of this study. Policymakers must ensure the equitable distribution of electric car infrastructure in urban and rural areas at the earliest opportunity. Public Charging Stations (PCS) ought to be established in regions with limited services and sparse population density by means of financial incentives and regulatory assistance. Moreover, it is essential that the planning of electric vehicle infrastructure be incorporated into broader urban development strategies, especially within smart city frameworks, to guarantee coherence and sustainability. Insufficient understanding about it persists among individuals, constituting a considerable problem. Policymakers must execute focused initiatives to educate the public of the long-term savings, environmental advantages, and

rebates linked to electric automobiles. To cultivate consumer trust and enhance product utilisation, effective and consistent communication is essential.

Manufacturers and industry experts ought to prioritise product diversity for rural and semi-urban consumers. Creating electric vehicle models that are resilient and cost-effective, featuring prolonged battery longevity and reliable post-purchase assistance, will facilitate your entry into new markets. The progress in battery technology, especially solid-state batteries, battery swapping systems, and improved battery management systems, could improve vehicle performance and lower maintenance costs. The creation of a comprehensive and integrated electric car infrastructure requires a cooperative ecosystem involving energy suppliers, technological firms, and automotive manufacturers.

Infrastructure planners must prioritise the creation of intelligent, adaptive, and resilient charging alternatives. Innovative solutions that cater to diverse user needs and streamline tasks encompass solar-powered, portable, and rapid-charging stations. Planning must also account for the potential effects of electric vehicle charging on local electrical networks. Integrating energy-efficient equipment with technology that guarantees the stability of the power network is essential for its reliability. To prevent the waste of infrastructure and guarantee a favourable user experience, it is essential to implement standardised charging methods and assure compatibility across diverse vehicle kinds and brands.

Ultimately, there exist several prospects for further investigation in the future. Crucial insights for improving policy initiatives can be derived from extensive study on the social, economic, and environmental impacts of electric car utilisation. A behavioural study analysing individuals' feelings towards electric automobiles, their range anxiety, and post-purchase contentment can enhance our understanding of the subtle factors that deter consumers from acquiring an electric vehicle. To determine the overall sustainability of the shift to electric transportation, it is essential to perform lifetime assessments of electric vehicles, encompassing battery manufacture, use, recycling, and disposal.

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