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DISSERTATION I

**Electric Vehicle Adoption in India: A Multi-Criteria Comparative Study
of Consumer Preferences in Gujarat and Uttar Pradesh**

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1. Introduction

Transportation keeps modern economies running, but the environmental cost of relying on traditional gas-powered vehicles is becoming harder to ignore. In countries like India, where cities are expanding fast and the economy is booming, the pressure on the transportation system is growing too. In fact, road transport in major global economies accounts for more than 70% of domestic transport emissions (Anastasiadou & Gavanas, 2022). In India's bustling urban centers, nearly 40% of total emissions come from vehicles alone (Khandar et al., 2014). This growing problem has pushed the government to focus on greener alternatives, with electric vehicles (EVs) at the heart of their plans.

India has set an ambitious goal to cut its GDP emission intensity by 45% by 2030 (Nationally Determined Contribution, 2022), and EVs seem like a promising solution. EVs don't produce any exhaust emissions and are much more energy efficient—turning around 60% of electrical energy into power for the wheels compared to just 17-21% in traditional gas-powered cars (Alanazi, 2023). We can already see the shift happening globally. Norway and China are leading the way, showing how good policies can drive EV adoption by combining incentives, better infrastructure, and technology upgrades (Ziegler & Abdelkafi, 2021). Norway, for instance, made EVs cheaper than gas-powered cars by offering tax breaks (Greene et al., 2014), while China has poured money into EV factories and charging networks, making it the world's biggest EV market.

The step ahead for India is, however, more complicated. While the NEMMP and FAME scheme aimed to spur development in hybrid as well as electric vehicles, the transition to the use of EVs has not been uniform across states. Other states, including Maharashtra and Karnataka, lead the pace of adoption because the government is very supportive, and the infrastructure is much better, while in Bihar and Odisha, they are behind owing to weak policies and even scarcity of charging stations (Nair et al., 2017). This indicates a deeper issue; there seems to be a lack of uniform growth due to how fast local factors, like infrastructure and consumer attitude, work on the intake of EVs differently in areas.

What the past studies have concentrated on so far relate to barriers like high upfront cost for EVs and the inadequacy of charging stations (Habib et al., 2015). Most studies are not exhaustive in accounting for both socio-economic and policy-related determinants of electric vehicles coverage

in states which have economic, infrastructural, and social variations. This research addresses the need to explain these regional differences in more detail in particular through the lens for Gujarat and Uttar Pradesh. Utilizing the extensive EV Adoption Index provided by Patil and Majumdar (2021) for Hyderabad, this research will seek to test the applicability of the factors drawn in a primary urban center to other states or if the factors are of a different nature and thus need different policies.

1.1 Motivation

Considering the present scenario with respect to the developed and developing economies, the twenty-first century has witnessed calls for a drastic change from the conventional modes of transport, and this change – to a large extent – can be driven by the electric vehicles (EVs) in relation to the sustainability challenges facing India. Today, discussions about the adoption of electric vehicles for transportation systems have become a subject of particular interest as they provide a glimpse into the future where a mantra for greening transportation is sought.

Such popularity is the demand of much research in this area because it has become very clear that transportation using internal combustion engines running on fossil fuels is causing pollution – which is offset using electric vehicles, however, the expansion of such technology is not uniform across the regions which creates problems with the strategy.

While some Indian states like Gujarat and Uttar Pradesh are moving ‘leaps and bounds’ towards electric vehicle adoption, it becomes even more important to assess the understanding of the regional inhibiting or enabling factors of this drive. In addressing these intra-state variations, it is expected that the study would be able to recommend more specific policies that would promote a balanced and widespread shift to electric vehicles in the country.

2. Literature Review

India's updated Nationally Determined Contribution (NDC) in August 2022 includes a target of reducing its GDP emission intensity by 45% by 2030 compared to 2005 level, and a lot of steps are taken to reach to this goal, one of them is to reduce fossil fuel consumption and mitigate emissions by facilitating the production of Electric Vehicles (EVs) in India.

Under the vision of Viksit Bharat by 2047 the country should have 30% of new vehicle sales be electric by 2030. The reason primarily for this urgent switch is that Vehicular pollution contributes to 40 per cent of pollution in the country. Automobiles are the primary source of air pollution in India's major cities. The transportation sector alone emits an estimated 261 tonnes of CO₂, of which 94.5% is contributed by road transport and Automotive air pollution will intensify with increasing urbanization around the world (Khandar & Kosankar, 2014).

The increasing urgency to address climate change all around the world has placed electric vehicles (EVs) at the core of discussions on reducing transportation-related emissions. As transportation accounts for a significant portion of global CO₂ emissions, EVs offer a cleaner alternative to conventional internal combustion engine vehicles (ICEVs).

The surging dependence of the transportation sector on fossil fuels around the globe contributes significantly to global greenhouse gas emissions, particularly in road transport, which accounts for over 70% of domestic and international transport emissions in major economies like Europe (Anastasiadou & Gavanis, 2022).

Electric vehicle (EV) adoption from a consumer's perspective is influenced by a variety of economic, social, and technological factors and today globally all the new manufacturers have released one or more EV models that have changed the equation of the Auto Industry. Electric vehicles (EVs) can help with several interconnected issues, including air pollution, the depletion of non-renewable energy sources, rising oil imports and pricing, and the need for "green" development (Singh & Sharma, 2014). Automobiles that are completely electric (EV) emit no emissions. In terms of efficiency, electric vehicles can transmit roughly 60% of the electrical energy from the grid to the wheels, but gasoline or diesel vehicles can only transmit 17%–21% of the energy in the fuel to the wheels. That is an 80 percent waste. Fully electric vehicles have no tailpipe emissions even when power production is factored in; in contrast, vehicles powered by gasoline or diesel release more than three times the amount of carbon dioxide equivalent to that of an average electric vehicle (Alanazi, 2023).

2.1 Evolution of Electric Vehicles (EV) Market:

EVs are divided into four varieties based on the technology used: plug-in hybrid electric cars (PHEVs), battery electric vehicles (BEVs), extended-range battery electric vehicles (E-REVs), and hybrid electric vehicles (HEVs). While analyzing the processes, that have contributed to the shaping of the key factors of EV adoption, it is important to examine the evolution of the EV market both globally and in India. The worldwide market for EVs has grown rapidly over the last decade due to technological advancements, like Lithium-ion and solid-state batteries which have increased the energy density while reducing charging times, making EVs more practical for both personal and commercial purposes. (Berkeley et al., 2017). Along with the integration of vehicle-to-grid (V2G) technology, which allows EVs to not only draw power but also contribute back to the grid, especially during peak demand. This, combined with renewable energy sources such as solar and wind power, is boosting the sustainability and appeal of EVs (Richardson, 2010).

Nickel-metal hydride cells have been replaced with lithium-ion technology that improves vehicle range and brings down charging times (O'Neill et al., 2018). However, increased competition from key players such as Tesla, Nissan and BYD, government incentives, and the recently launched California ZEV initiatives, paved the way for the commercial viability and acceptability of EVs (Biresselioglu et al., 2018).

In India, the adoption of EVs has been relatively slower because of infrastructural, economic and behavioral issues but the market has emerged briskly. The *Faster Adoption and Manufacturing of Hybrid and Electric Vehicles* (FAME) induction policy, launched by the government of India in 2015, has motivated both consumers and manufacturers toward electric mobility (Prakash et al., 2018). Within this framework, incentives for EV acquisition as well as charging station establishment strategies cancel out the adoption's upfront costs and endowment with an extensive installation network to encourage use. The emergence of local EV manufacturers, such as Tata Motors and Mahindra along with their collaborations with global players has gradually improved the structure of Electric Vehicles in India.

Another question of interest relates to the influence of strategic government interventions on the development of the EV market. Around the world, the majority of early adopters of electric vehicles reside in areas with alluring legislative incentives. The most often noted incentive in prior studies has been purchase subsidies, which are acknowledged as a highly significant factor in

encouraging consumer adoption in the US, China, Germany, Norway, the Netherlands, and France, among other nations (Künle & Minke, 2020).

Countries such as Norway and China have also spearheaded the global push toward EVs, with aggressive Policy frameworks. According to Ziegler and Abdelkafi, 2021, Norway has applied a relatively large tax. There are incentives to encourage EV owners, which makes electric cars cheaper than their counterparts of traditional internal combustion engines (Greene et al., 2014). In the meantime, China is investing highly into both EV production and charging infrastructure and has made it the world's largest EV market. The "Made in China 2025" initiative chases the improvement of competitive advantages of China in the electric mobility sector That underscores the strategic importance of state-backed initiatives (She et al., 2017).

As a policy, India initiated its National Electric Mobility Mission Plan with a target to promote 30% EV penetration by 2030. Complementing this, state-level policies like Karnataka's EV policy and the clean mobility initiatives of Delhi are offering from tax cuts to free Parking facilities for electric vehicles would easily ease the transition towards electric mobility. Policy Execution remains relatively fragmented, whereby growth takes place rather unevenly across the various states (Nair et al., 2017).

In addition, coordination between car makers, battery manufacturers, and energy providers is of paramount importance in addressing the challenges posed by EVs. For example, Tesla's partnership with Panasonic for battery production and Volkswagen's investment in Electrify America had more than tripled the charging infrastructure.

2.2 Categorization of factors for EV adoption:

Other major factors that have spurred the adoption of electric vehicles in many countries include tax benefits such as tax reduction, exemption from road tax, parking, and toll fee waiver, cuts in acquisition and value-added taxes, among others. For instance, using data on EV market share and policy incentives in 20 countries, Xue et al. (2021) demonstrated that tax exemptions exerted a larger effect on the adoption of EVs among consumers than direct purchasing subsidies and fostered their wide use.

Technological issues, more so the performance of vehicles, also occupy an important position in the adoption of EVs. "Range anxiety" is the other challenge of fear concerning a limited number of kilometres an EV can travel before one has to recharge it. Brückmann et al. (2021) and Graham-Rowe et al. (2012) explain that the inconvenience arises from the longer time taken for charging compared to refueling a traditional internal combustion engine (ICE) vehicle. It tends to disrupt regular driving schedules, particularly for those who need swift filling in long-distance or time-sensitive journeys.

Carley et al. (2013) and She et al. (2017) say that financial motives do not favor the adaptation of EVs because EVs remain expensive to buy mainly because of the high-tech solutions demanded in their production. While the purchase price of electric vehicles, and electric buses, is higher than that of ones using an internal combustion engine, the TCO per kilometer of EVs will reduce when the usage of the vehicle is increased. According to Onat et al. (2019), despite the significantly greater costs at acquisition, EVs have superior environmental performance.

One of the concerns regarding the environmental sustainability of EV batteries is that, considering the assertions by scholars like Egbue & Long (2012) and Ziegler (2021), who believe that the question of battery recycling and disposal will be very important as long as EV adoption scales up, the problem of lack of a robust battery recycling infrastructure will offset the benefits on environmental sustainability accrued to EVs. These issues are already being addressed in countries like Japan, where industry and government efforts focus on closed-loop recycling systems for lithium-ion batteries.

2.3 Barriers to the adoption of EVs:

In the context of global momentum toward electromobility, Indian market conditions are unique and shape the adoption of electric vehicles into the local market. In order to encourage the adoption of EVs, the Indian government has set headline goals for a number of programs. These projects face a number of obstacles, including high costs, issues with the purchase and charging of batteries, EVs' limited range, inadequate incentive programs, and potential customers' ignorance of the advantages of EVs (Singh et al., 2021). The major deterrent against the adoption of EVs in India continues to be the scarcity of charging infrastructure. The unavailability of a comprehensive and

reliable network of charging points continues to be one of the major discouraging factors for prospective EV consumers primarily away from cities (Tiwari et al., 2021)

Environmental considerations are also an important factor in encouraging adoption of EVs, particularly among more highly educated consumers. For instance, Yeh (2007) report that environmentally concerned consumers who wish to minimize the carbon footprint for their purchases are likely to consider buying an EV.

Without a consistent and widely deployed charging network, consumers are less likely to buy EVs. It has been discovered that this, popularly known as "range anxiety," heavily influences consumer decisions. This appears to be particularly true in China, India, and Norway. (Pamidimukkala et al., 2023) It also aligns with the observed disparities in EV adoption between different Indian states, where regions with better infrastructure and policy support, such as Maharashtra and Karnataka, tend to have higher EV usage, compared to states like Bihar Chattisgarh and Orissa, which lack such support (Vidhi & Shrivastava, 2018c).

A variety of economic, social, and technological factors also influence EV adoption. Archsmith et al. (2022b) identify three critical determinants: intrinsic demand growth, government subsidies, and declining production costs. Societal influence is a factor that can either encourage or hinder EV adoption. As electric vehicles become more mainstream, positive societal perceptions and social norms around environmental responsibility may increase the likelihood of adoption.

Contrary to popular belief, the high initial cost of EVs is not a primary deterrent for Indian consumers. Instead, the availability of maintenance services and the long-term reliability of the vehicles were seen as more critical factors (Goel et al., 2021). Non-fiscal incentives such as preferential parking and dedicated corridors for EVs can also promote adoption, especially in urban fleet operations. This aligns with global trends toward electrifying fleet vehicles to optimize infrastructure planning and reduce environmental impact. (Sinha et al., 2020).

Delhi, like many other developing-nation cities, has a serious issue with transportation management. Numerous secondary issues are brought on by this main problem, including increased energy consumption, traffic congestion, decreased productivity, an increase in the number of accidental deaths, parking shortages, and environmental degradation. Delhi may save

about ₹1,225.25 crores (about USD 28.16 million) a year by implementing electric cars (EVs). This amount is now spent on gasoline (Ahmad & Dewan, 2007b).

The growth of the EV ecosystem in Gujarat is one of the fastest in the country, with increased investments in manufacturing, charging infrastructure, and battery technology, EV sales have surged, growing 714% from 2021-23 in Gujarat attracting major car manufacturers like MG Motors, Maruti Suzuki, and Tata Motors to set up their manufacturing units. However, safety concerns persist, particularly with EV fires during charging. Incidents in Ahmedabad and Surat have raised alarms about the safety of EV charging stations, especially in underground parking areas. There is a need for stricter safety regulations in the country to balance growth in the EV sector while putting in place proper government regulations addressing these risks.

3. Research Gaps

The current body of research on electric vehicle (EV) adoption highlights several important drivers and barriers, but there remain critical areas that have been insufficiently explored, especially in the Indian context. Much of the global literature focuses on infrastructural and policy interventions, consumer perception, and environmental benefits in countries like China, Qatar and the U.S. (Biresselioglu et al., 2018; Ziegler & Abdelkafi, 2021; Greene et al., 2014). However, India's unique socio-economic and infrastructural challenges require a more granular understanding of EV adoption trends and the role of state-level variations in shaping this adoption.

Very few studies have compared the wide range of factors that influence EV Adoption among different Indian states using an index, the factors that shape consumers' attitudes in different demographics and across all the sub-regions of the country. This makes it important to identify and categorize the reasons why certain Indian states have higher EV penetration and compare them with states where EV adoption remains low despite strong government backing.

While the literature identifies broad factors such as high initial costs, range anxiety, and inadequate charging infrastructure as primary barriers, there is a limited understanding of how demographic diversity across India's states impacts consumer perceptions and motivations regarding EV adoption. States like Maharashtra and Karnataka have emerged as leaders in EV adoption due to

stronger government policies and better infrastructure, while others, such as Bihar and Odisha, have lagged.

Indian states are varied in terms of the income distribution, literacy levels, urbanization rates, and the level of environmental awareness critical determinants of consumer behaviour and willingness to purchase electric vehicles. It could simply be due to economic reasons and aspirations to be environmentally friendly in states like Gujarat where the government has sound policies concerning the environment. However, Uttar Pradesh is an exception. It too has traveled a far cry from this path. The state has also contributed toward the rate of adoption through the provision of electric public transport along with incentives for middle and low-income groups.

This gap in the literature is significant because consumer preferences and behavioral factors vary across these demographically distinct regions. A deeper understanding of these differences is crucial for developing state-specific policies and targeted interventions that could boost EV adoption across the board. Furthermore, while past studies have often focused on overarching factors like cost, range anxiety, and charging infrastructure at a national or global level, very few have explored these factors in conjunction with socio-demographic profiles that vary greatly across Indian states.

This research, therefore, aims to fill these gaps by conducting a comparative analysis of EV sales across Indian states, correlating these trends with pollution levels to uncover regional disparities in EV adoption. Additionally, a Multi-Criteria Decision-Making (MCDM) index will be used to assess and compare the factors influencing EV adoption across two major demographically different states—Gujarat and Uttar Pradesh—, allowing for a more detailed understanding of the policy, infrastructural, and consumer dynamics at play.

4. Research Question

1. What is the impact of Electric Vehicle sales trends on pollution levels across Indian states over the past five years?
2. How do the attribute scores of electric vehicle indexes differ between demographically distinct states like Gujarat and Uttar Pradesh?
3. What are the key factors, such as infrastructure, policy support, and market conditions, that contribute to differences in EV adoption rates across these states?

5. Research Objective

1. To analyze the comparative trends of electric vehicle (EV) sales across Indian states over the past five years (2019-2024) and their corresponding effects on pollution levels.
2. To study and compare the attributes scores for EV indexes in demographically distinct states.
3. To explore how the electric vehicle index values reflect the effectiveness of state-specific policies and infrastructure development in Gujarat and Uttar Pradesh, and how these factors contribute to their contrasting EV adoption rates.

6. Methodology

6.1 Comparative Analysis of EV Sales Among Indian States

The first phase of the study will involve a comparative analysis of electric vehicle sales in different states across India over the last five years (2019-2024) along with the levels of pollution in the said states. These have been accumulated from secondary sources that include government reports, industry white papers, online databases, SIAM, and EV Vahan Dashboard. An attempt will be made to find out trends, patterns, and correlations between rates of adoption of EVs in different states and their effects in terms of decreasing pollution levels; and the focus will be on the states that have seen a spurt in EV adoptions and those such as Bihar and Odisha that have low adoption rates.

6.2. Comparing the EV Index scores for two demographically different states

This research shall, therefore, offer broad comparative insights as well as localized perspectives on the adoption of electric vehicles in India by way of a multi-faceted methodology. The prior studies, such as Patil and Majumdar (2021), exhaustive index-based analysis of the Hyderabad EV market 2022, have already created some good ground to identify the most important factors that matter for the adoption of EVs; this study compares two quite different regions: Gujarat and Uttar Pradesh. Primary research in these states will enable us to capture regional socio-demographic factors and understand drivers or hinders of the adoption of EVs in various parts of India.

6.3 Primary Research

The research will employ an explanatory research approach. To achieve this, primary surveys will be administered in Gujarat and Uttar Pradesh with a sample size of 100 respondents in each state. Stratified random sampling will be employed to generate responses from different socio-economic groups. The sample size of 100 respondents will ensure capturing of different attitudes by consumers toward EVs. Choosing a consistent sample size for both states maintains the advantage of comparability between Gujarat and Uttar Pradesh and therefore decides the necessity to explain factors behind differences in adoption of electric vehicles within the two regions. It helps to strike an imperative between representing the sample using available time and resources for detecting significant trends and correlations while allowing deep data collection and analysis.

Questionnaires will attempt to outline how various socio-demographic factors like income level, environmental awareness, access to the EV infrastructure, and technological perception influence the adoption of EVs in the regions. During the development of questionnaires, a detailed analysis would be considered that includes:

- **EV Perception:** Analyzing public sentiment regarding the advantages and disadvantages of EVs, such as 'range anxiety', the cost of maintaining and repairing, among others.
- **Economic Factors:** Assessing how buy-in rewards, subsidies, and comprehensive cost of ownership affect consumer choice.
- **Technological Factors:** It informs how consumers view technology behind EVs. This consists of battery life, charging infrastructure, and vehicle performance.
- **Environmental and Social Awareness:** Quantifying the contribution of air pollution and carbon emissions as an environmental concern in the electric car adoption.

Analysis of these responses against the EV index would show the comparison between the two states. Gaps in data in both states related to policies, incentives, and infrastructure development would be identified to tailor different sets of policies, incentives, and infrastructure development tailored towards promoting the uptake of EVs more effectively.

6.4 Rationale for State Comparison

There is justification for this comparison because it is related to how the overall socio-demographic and infrastructural factors have influenced and behaved differently in various regions of India while adopting EVs. Although various barriers like cost, charge provision, and performance expectancy have already been established in the literature, there is a need for a more detailed analysis of factors like regional development, consumer liking, and policy practice at the localized level. Therefore, this research intends to take a study of Gujarat and Uttar Pradesh using existing MCDM indices to account for variations and similarities in particular states in patterns of adoption.

Gujarat and Uttar Pradesh were chosen for this study due to their distinct profiles in electric vehicle (EV) adoption, economic features, and their policy approach. Both states have high rates of electric vehicle (EV) penetration; however, there are differences in consumer behaviour and policies even at the state level. This makes it possible to study the factors pertaining to any given EV acceptance in different socioeconomics and policy conditions. While, Gujarat has been among the most active states in encouraging the use of electric vehicles through a series of favourable industrial policies, both to manufacturers and end users, UP being the most densely populated state in India has enunciated policies that are primarily concerned with creating the requisite charging infrastructure for the electric vehicles. The different approaches taken towards policy in these states allow for the examination of variations in uptake of EVs by different consumers based on government subsidies and infrastructure development.

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