THE INFLUENCE OF SOCIO-ECONOMIC FACTORS ON ELECTRIC VEHICLE ADOPTION IN UTTAR PRADESH

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ABSTRACT

Using electric vehicles (EVs) is vital to the global plan to fight climate change and cut carbon emissions. In Uttar Pradesh, one of India's most populous and economically varied states, this study investigates the impact of socioeconomic factors on the adoption of electric vehicles. Using a mixed-methods approach that includes stakeholder interviews and surveys from various socioeconomic strata, the research highlights important factors such as infrastructure availability, government incentives, education levels, and income levels. The results show that growing EV use correlates with the income of EV owners and educational achievement, mainly because of improved access to resources and information. However, significant obstacles to widespread adoption include insufficient infrastructure for charging and the meagreness of government incentives. The study also emphasizes how important it is for governments to create infrastructure, run awareness programs, and offer incentives to encourage the use of electric vehicles. These findings are essential for stakeholders and policymakers who want to increase the use of electric vehicles in Uttar Pradesh and support the larger goals of environmental preservation and sustainable development.

Keywords: *Electric Vehicles, Socio-Economic Factor, Regression, Adaptation, Income Level, 3-Wheeler Electric Vehicles*

1. INTRODUCTION:

Global consumer demands, environmental concerns, and technological advancements are causing a fundamental shift in the automobile business. At the core of this shift is the introduction of electric vehicles (EVs), which have the power to change the way we think about transportation fundamentally. Gas, gasoline, diesel, and natural gas release carbon dioxide (CO_2) into the atmosphere when used for transportation. CO_2 is harmful to the health of humans as well as the environment. Other greenhouse gases (GHGs) produced by human activities also rise in concentration with CO_2, which adds to global warming. The regular fluctuations in crude oil prices worldwide and the loss of this valuable resource are among the adverse consequences of using fossil fuels to power human activities. In many countries, governments are tackling these problems by reducing their reliance on cars that run on fossil fuels and transitioning to more environmentally friendly modes of transportation. The manufacture and promotion of electric and hybrid vehicles (EVs) represent important turning points in this strategy. They save gasoline, improve air quality, and reduce noise pollution. EV owners gain a lot of advantages as well. For example, in India, the government offers a range of incentives for EV owners, including income tax deductions, reduced toll fees, and free parking. This, coupled with EVs' lower maintenance and operational costs, makes them a more attractive option for consumers. Individuals in India can purchase electric cars (EVs) and trade in their conventional cars for EVs since they qualify for these government incentives.

Demand for electric cars (EVs) is increasing as governments, corporations, and consumers emphasise sustainability more. Understanding the factors impacting consumer behaviour is essential for stakeholders looking to capitalize on the possibilities of this expanding industry. For instance, the Ministry of Heavy Industry successfully implemented a strategy that involved Faster Adoption and Manufacturing of Electric and Hybrid Vehicles in India (FAME) to encourage the adoption of EVs. This strategy was effective because of the mission's sustainable approach. Consumer research on electric vehicles considers several aspects, from mass adoption barriers to demographic shifts and impulsive purchases. This thorough approach examines how different demographic groups perceive and use EVs, what motivates them to purchase one, and how external factors like regulations, financial incentives, and technological advancements impact their choices. Instead of being purely a matter of personal preference, adopting electric vehicles is impacted by a complex interplay of societal values, economic conditions, and technological breakthroughs. Businesses and politicians may better customize their strategies to hasten the transition to a more sustainable transportation environment by looking into consumer attitudes, behaviours, and expectations. Understanding the current situation of the EV market and projecting its future trajectory is critical to the efficacy and inclusivity of the shift to electric mobility.

1.1 Electronic Vehicles in India: Status and Mission

India revealed its ambitious 2030 decarbonization target during COP-26. This means that by 2030, the energy industry must achieve 500 gigawatts of clean energy production and cut its carbon emissions by fifty per cent. It also means joining the worldwide EV30@30 campaign. India wants to triple its existing renewable capacity to do this, and the EV30@30 campaign explicitly focuses on ensuring that by 2030, at least thirty per cent of new vehicle sales will be electric vehicles (EVs). The necessity of switching to electric mobility was recognized in India among the numerous issues brought about by using fossil fuels, including the rapid depletion of these resources, growing energy costs, the environmental impact of motor vehicles, and worries about climate change. An estimated 375 million tonnes of direct CO_2 emissions, or almost 10% of all GHG emissions in India, are expected to be caused by the transportation industry in 2022.4 Beginning in the mid-1990s, several EVs were built and marketed throughout the nation, but because to problems with supply and demand, their use remained limited. These include a dearth of domestic manufacturing ecosystems and supply chains for component parts, a shortage of EV options, expensive cars, problems with the car's and the battery's performance, and a lacklustre infrastructure for battery charging. Without a vision statement or comprehensive development plan for the EV industry, the government only promoted EVs through short-term, focused programs at that time.

The National Mission for Electric Mobility (NMEM) was established in 2012 by the Indian government's Department of Heavy Industry in response to growing environmental issues and to lower obstacles to a wider use of EVs. Its objective was to encourage homegrown production and create the framework required for using electric and hybrid cars (xEVs). By 2020, the project aims to sell 6-7 million xEVs overall. The Department of Heavy Industry developed and launched the "Faster Adoption and Manufacturing of Electric and Hybrid Vehicles in India" (FAME India) program in two stages, starting in 2015 and lasting nine years (until 2024) to advance the EVs Market. The program's name implies that it seeks to reduce vehicle emissions by promoting the use of non-polluting automobiles. This goal is being met through technology development, the generation of demand, and the availability of infrastructure for charging, as shown in Table 1. The completion of the tasks envisaged under the two stages has been assigned an amount (investment) of INR 108.95 billion. Most of the expenditure is given to EV buyers as a buying incentive. The program is advertised through e-mobility discussion platforms, facilitating idea sharing between state and federal government authorities and business executives.

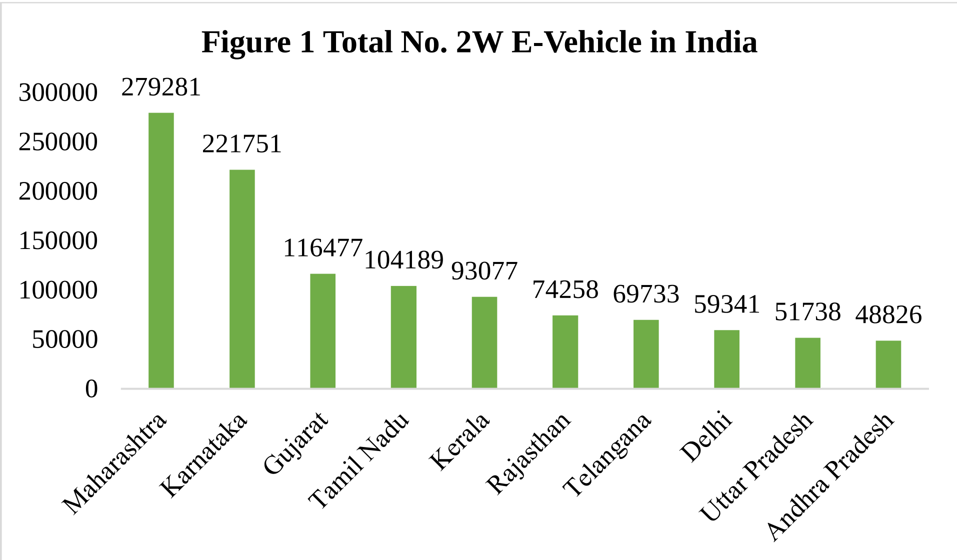
Table 1 Foundation of the FAME India Program

	FAME I (2014-2019)	FAME II (2019-2024)
Objectives	Minimize reliance on fossil fuels and deal with the problem of vehicle emissions	Promote the more rapid acceptance of hybrid and electric cars.
Emphasis	Provide mass transit options that are both economical and environmentally beneficial.	Enable shared and public transportation to run on electricity.
Focus Area	Innovation in technology, generation of demand via rewards, test projects, and infrastructure for charging.	upfront discounts on EV purchases, as well as facilities for charging EVs in a few localities and along important thoroughfares.

Source: *Ministry of Heavy Industries, (GoI, 2021-22)*

1.2 Market Status of EVs in India

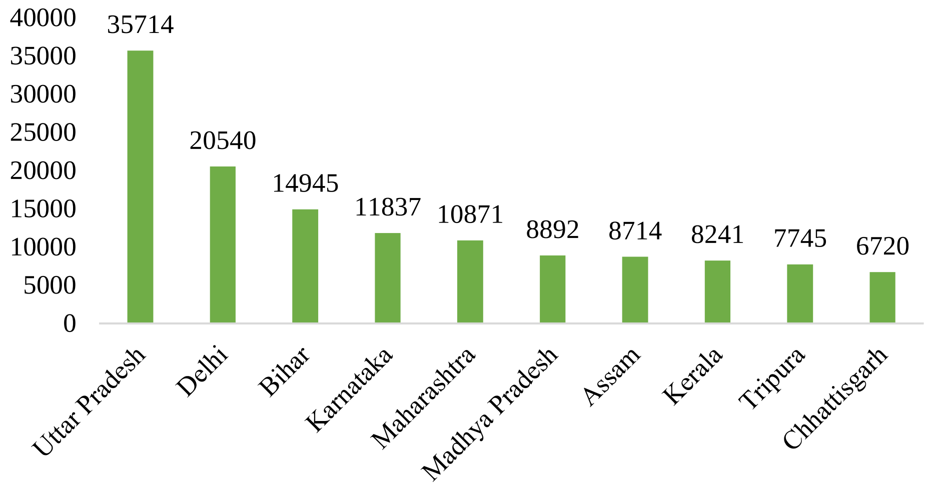
As of 2023, the Indian EV market is growing rapidly, although it still represents a small percentage of the nation's overall automobile market. The Society of Manufacturers of Electric Vehicles (SMEV) reports that the Indian EV industry has expanded at a compound annual growth rate (CAGR) of about 40% during the last five years. The most popular category of electric two-wheelers has a significant portion of the market for EVs. Electric three-wheelers comprise a sizeable portion, primarily used for business purposes. Electric buses and four-wheelers are growing in popularity, but more slowly than two- and three-wheelers. Several major automakers, such as Tata Motors, Mahindra & Mahindra, and Hyundai, have launched electric car models in response to the growing demand. With 279,281 e-2W vehicles in figure 1, Maharashtra has the highest number. This suggests a high level of market penetration and customer acceptance in the state. Numerous factors, such as the growth of the infrastructure, successful government initiatives, and a high level of urbanization, are responsible for the high number. Next, with 221,751 motorcycles, is Karnataka. The government's supportive policies and focus on technology innovation have made the state a significant participant in the e-2W market. Gujarat has 116,477 motorcycles, placing it third. The state's strategic actions, which include subsidies and incentives to support electric vehicles, have greatly increased adoption. With 104,189 e-2Ws, Tamil Nadu showed its dedication to environmentally friendly transportation options. The growth of the industry and advantageous legislation have been crucial elements.



Sources: *https://vahan.parivahan.gov.in/ vahan4dashboard/ (11 June 2024)*

The above bar chart in figure 2 displays the total number of three-wheeler (3-W) electric vehicles (EVs) in each of the several Indian states. This information shows the distribution and uptake of electric three-wheelers around the country. This is a comprehensive analysis of the figure. Uttar Pradesh leads the market in the number of 3-wheel electric vehicles with 35,714, a significant margin. The state's dominance is due to its dense population, extensive use of three-wheelers for public transportation, and pro-three-wheeler legislative initiatives. The national capital's 20,540 electric three-wheelers make it second. The city's high adoption rate of electric vehicles is likely primarily due to Delhi's aggressive efforts to minimize air pollution and its array of incentives and subsidies for electric vehicle users. With 14,945 electric three-wheelers, Bihar ranks third. The state's notable adoption is the growing need for reasonably priced, eco-friendly transportation choices in urban and semi-urban regions.

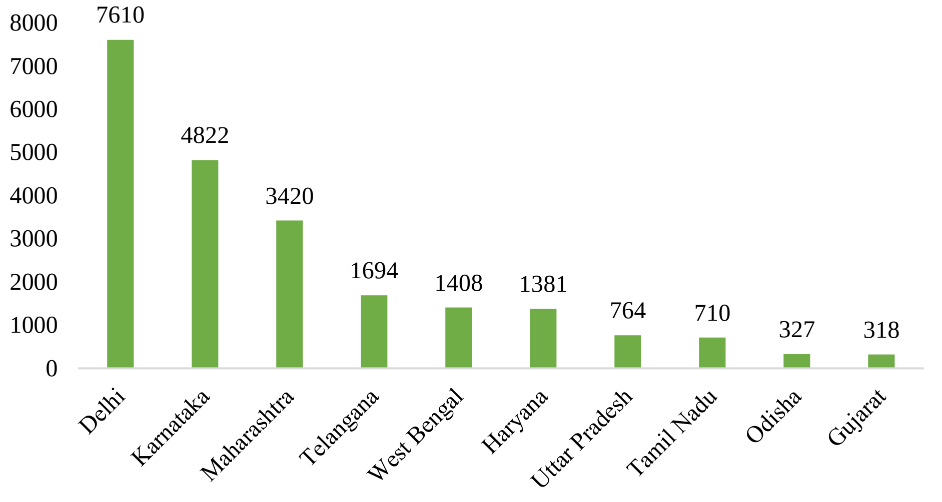
Figure 2 Total No 3-W E-Vehicle in India



Sources: *https://vahan.parivahan.gov.in/ vahan4dashboard/ (11 June 2024)*

The total number of 4-wheeler (4-W) electric vehicles (EVs) in the different Indian states is depicted in the bar chart in Figure 3. This data illustrates how electric four-wheelers are distributed and how widely they are adopted in various parts of the nation. This is a thorough examination of the figure. Delhi has the most four-wheeler electric vehicles (7,610), leading the market by a strong margin. Delhi's vigorous air pollution reduction initiatives and a range of incentives and subsidies for electric vehicle (EV) customers are the main causes of the city's high adoption rate. These figures clearly demonstrate the city's dedication to sustainable urban mobility. Karnataka, a state in southern India, comes in second with 4,822 electric four-wheelers. Karnataka is investing in EVs and focusing on becoming a hub for electric mobility. Maharashtra has 3,420 electric four-wheelers, making it a major player in the EV sector. This increase is made possible by the state's progressive legislation, EV adoption incentives, and the presence of significant automakers. There are 1,694 electric four-wheelers in this state. Telangana's adoption rate indicates its pro-EV policies and efforts to create a reliable infrastructure for charging them, especially in cities like Hyderabad.

Figure 3 Total No 4-W E-Vehicle in India



Sources: *https://vahan.parivahan.gov.in/ vahan4dashboard/ (11 June 2024)*

This research is based on the 3-wheeler EV owners in Uttar Pradesh because Uttar Pradesh holds the first position in registered 3-wheeler EVs in India. This research examines the socio-economic analysis of 3-wheeler EV owners in Uttar Pradesh. The rest of the paper is categorised in the review of the literature and theoretical framework in section 2. Section 3 is related to materials and methods; section 4 is results and discussion, and section 5 is conclusion and policy recommendation.

2. LITERATURE REVIEW AND THEORETICAL FRAMEWORK

Few studies have used empirical data to examine the factors influencing adoption rates of EVs because they were only briefly sold in the 1990s and entered the broader consumer market in 2010. Therefore, much of our understanding of these pertinent elements comes from expressed preference studies. However, there is concern that the "attitude–action gap" (Lane & Potter, 2007) may prevent consumer survey data from significantly impacting the purchase of low-emission vehicles. This highlights the importance of research studies such as the one we carried out for our paper, which looks at real-world consumer behaviours. HEVs provide a valuable baseline for EVs because of their common qualities, such as a powertrain based on an electric motor and battery and reduced environmental effects, even though they are not as innovative as EVs. Since HEVs have been available for purchase since the late 1990s, several studies have used revealed preference data to investigate the factors driving customer penetration of these cars.

The technology category includes battery pricing and performance attributes (driving range and charging time) related to electric vehicles. The biggest barrier to widespread EV diffusion has been determined to be EV purchase prices, which rely highly on battery costs (Brownstone et al., 2000). According to IEA (2011), buying an EV with a 30-kWh battery would cost $10,000 more than a comparable internal combustion engine vehicle (ICEV). This would equate to about 85 miles of driving range at a rate of 0.17 kWh/mile. The cost of the batteries also affects an EV's driving range. An EV's driving range and purchasing price rise in tandem with an increase in the battery's capacity (measured in kWh). Consequently, even though consumers are sensitive to a limited driving range (Lieven et al., 2011), this factor must be weighed against the cost of the vehicle's battery. Vehicle charging time is another element that affects consumer acceptance. While most ICEVs can be refuelled in around 4 minutes, EVs need 30 minutes at a fast-charging station and, depending on the size of the battery, up to several hours to charge from a 110 or 220 V outlet (Saxton, 2013). The high initial cost, constrained driving range, and lengthy charging time of an EV all have a detrimental effect on adoption rates compared to a comparable ICEV.

Consumer traits are one of the elements that affect uptake in addition to EV-related considerations. Research has revealed a positive correlation between the chance of purchasing an EV (Hidrue et al., 2011) and education, income, and environmentalism levels. However, buyers frequently place more value on car cost and performance features like those mentioned in the previous paragraph than on these considerations, particularly environmentalism (Lane and Potter).

In our research, we have classified context variables as a group of parameters that are external to both the vehicle and the consumer and have been found to affect adoption rates in the literature. In several studies, fuel prices (gasoline or diesel) are among the most significant predictors of adopting HEVs (Gallagher & Muehlegger, 2011). They have also been found to impact agent-based models that forecast the diffusion of EVs (Eppstein et al., 2011). Power costs are related to gasoline prices but are less frequently included in assessments. These two parameters determine Most EV running costs, which also affect adoption rates (Zubaryeva et al., 2012; Dijk et al., 2013). According to several studies (Struben & Sterman, 2008), the accessibility of charging stations is a significant factor in determining the consumer's adoption of alternative fuel cars, such as electric automobiles. The amount of urbanization in a nation may encourage the adoption of more EVs since shorter average travel lengths may permit a larger utilization of the vehicles' constrained driving range (IEA, 2011). Furthermore, several EV-specific factors could affect adoption rates: vehicle diversity, or the variety of models available to consumers (Van den Bergh et al., 2006); local involvement, or the existence of a local manufacturing plant (IEA, 2013); and public visibility, or the duration of time that EVs have been on the market (Eppstein et al., 2011).

1. MATERIALS AND METHOD

This section explains the methodology used to examine EV adoption rates using a set of socio-economic characteristics across several samples.

Table 2 Variables Description and Measurement Unit

Variables	Measurement Unit	Definitions
Income of EV owner	Rupees	The financial earnings or revenue generated by the individual or household that owns one or more electric vehicles.
Age of the Owner	Year	The age of individuals who own electric vehicles.
Marital Status	Dummy (Married=1, other=0)	The legal and social status of individuals who own electric vehicles in relation to marriage.
Education Level	Schooling in Years	the highest level of education completed by individuals who own electric vehicles.
Maintenance cost of EVs	Rupees	The total expenditure incurred by EV owners for routine maintenance, repairs, replacements of parts, and any other related services specific to electric vehicles.

Subsidy Received	Rupees	Financial incentives or support provided by governments, organizations, or other entities to individuals who purchase or own electric vehicles (EVs)
Charging cost	Rupees	It encompasses the various costs incurred by EV owners or users when charging their vehicles at home, public charging stations, or other means.
Ride per day	Number	Average number of journeys or trips that electric vehicles (EVs) undertake in a single day. Understanding usage patterns, charging needs, and overall efficiency of electric vehicles in various settings such as personal commuting, commercial transport, or public transportation fleets.
Distance covered by EVs at full Charge	Kilometre	Maximum distance an electric vehicle (EV) can travel on a single full charge of its battery. This variable is crucial in understanding the range of capabilities of EVs, which directly impacts their usability, convenience, and operational efficiency.
Price of EVs	Rupees	Cost associated with purchasing electric vehicles (EVs). the economic aspects of electric vehicle ownership and adoption. Here are the key elements that define the price of EVs.
Toll tax	Rupees	A fee is charged for using certain roads, bridges, tunnels, or highways. It is a user fee where motorists or vehicle operators pay a specific amount to access and use infrastructure maintained by the government or private entities.
Licences	Dummy (Yes=1, No=0)	The permits, certifications, and documentation required for electric vehicles (EVs) to operate legally on public roads. These licenses ensure that EVs comply with regulatory standards and safety requirements.

Driver	Dummy (Yes=1, No=0)	The individual who operates or drives an electric vehicle (EV). This variable encompasses several aspects related to the person responsible for controlling and managing the EV during its operation.

3.1 Data Collection

Data is collected through the structured questionnaire conducted in Lucknow and Gautam Buddha Nagar districts of Uttar Pradesh. This survey was limited to only 3-wheeler owners in selected areas of the study. This study did not include the 2-wheeler and 4-wheeler owners because this study wanted to know about the socioeconomic factors affecting electric vehicle adaptation. Multistage sampling is adopted for the study, which emphasises purposively selecting the study areas per the study's convenience and gathering data from the sample.

3.2 Sample Size Determination

Ultimately, 198 samples were chosen using a sampling method known as probability proportional to sample size. Following the Yamane formula, this selection was based on the population of vehicle owners in Uttar Pradesh. The sample size was obtained using the formula Yamane provided.

$$n = \frac{N}{1+(e^2)N} \qquad \textbf{(1)}$$

Let n represent the sample size, N represent the number of vehicle owners in both districts, and e represent the necessary degree of precision, which was determined to be 8%.

Table 3 Sample Information

Sample District	**Sample Size**
Gautam Buddha Nagar	89
Lucknow	110
Total Sample	**198**

Source: Field Survey (2024)

3.3 Model Specification

To standardize the ride of EV distributions, the variables from Table 3 were incorporated into an ordinary least squares (OLS) regression with a log transformation of the dependent variable. This transformation is appropriate when data are bounded, such as with a proportion or skewed (Lesaffre et al., 2007). The model specifications are provided as follows:

$$\ln \_Ride = \alpha + \beta_1 Education\ level + \beta_2 Age_{EVs} Owner + \beta_3 MaritalStatus + \beta_4 Maintainance\ of\ EVs + \beta_5 Subsidy\ Received + \beta_6 Charging\ Cost + \beta_7 Distance\ at\ full\ Charge + \beta_8 Price\ of\ EVs + \beta_9\ Tolltax + \beta_{10} Licence + \beta_{11} Driver + \varepsilon_i \quad \textbf{(2)}$$

where ε is an error term, and the sample is indicated by the subscript i.

4. RESULTS AND DISCUSSION

This section contains the results of the statistical model mentioned above, together with a matrix of variables utilized in the model and a descriptive analysis of factors particular to EVs. Lastly, we review the ramifications of the findings, which give us an idea of how various policy initiatives like gasoline taxes, consumer subsidies, and the placement of charging stations can affect the uptake of electric vehicles.

Table 4 Regression results for 2023-24 electric vehicle adoption in Uttar Pradesh

	Lucknow	**Gautam Buddha Nagar**
Income of EVS owner	0.0048*	0.6201*
	(0.0029)	(0.0102)
Age of the Owner	0.0392	0.032
	(0.9829)	(0.2094)
Marital Status	0.2391	0.0493
	(0.8312)	(0.3920)
Education Level	0.0392	0.0657
	(0.4303)	(0.4932)
Maintenance cost of EVs	-0.0396***	-0.0934**
	(0.0059)	(0.0389)

Subsidy Received	0.0081	0.0124
	(0.0291)	(0.0782)
Charging cost	-0.1642***	-0.0067*
	(0.0548)	(0.0037)
Distance covered by EVs at full Charge	0.1493***	0.0088***
	(0.0421)	(0.0041)
Price of EVs	-0.5638	-0.013
	(0.9410)	(0.044)
Toll tax	-0.2224***	-0.3496*
	(0.0331)	(0.2821)
Licences	0.0244	0.0928
	(0.0613)	(0.0569)
Driver	0.9453***	0.0663**
	(0.2343)	(0.0293)
R^2	0.6430	0.793
Adjusted R^2	0.4939	0.3902
Observations	110	89

Source: field survey, 2023-24; ******, ** and * significant at 1, 5 and 10% respectively***

4.1 Positive Factors of EV Adaptation

The distance driven by EVs at full charge, the income of EV owners, and the presence of drivers (either hired or owned) all have a positive correlation with the number of EV rides, and these factors together are responsible for an increase in the frequency of EV rides. The number of EV rides increases in tandem with the income of EV owners, according to a positive regression coefficient for income. The income variable's p-value shows a statistically significant at 10% level. This indicates that it is improbable that the positive relationship between income and the number of EV rides is the result of chance. As an illustration, the income coefficient in the Lucknow data is 0.0048, and the p-value is 0.0029, which suggests a strong positive link. The number of rides grows with the EV range, according to a positive regression coefficient for the distance EVs drive when fully charged. This variable indicates a statistically significant at 1% level. This implies that EVs are used more frequently the farther they can drive on a single charge. A positive regression coefficient for the presence of drivers indicates a higher frequency of electric vehicle trips when a driver is present, whether they are hired or owned. An association is statistically significant at 1% level. This suggests that EV rides increase dramatically when a driver is available.

4.2 Negative Factors of EV Adaptation

A negative regression coefficient for maintenance costs indicates that fewer EV rides are taken as EV maintenance costs increase. If the p-value for the maintenance cost variable is at 1% level, a statistically significant relationship is shown. This suggests that the negative effect of maintenance expenses on the number of EV rides is unlikely to result from random chance. The financial strain on EV owners rises in tandem with the vehicle's maintenance expenses. This can deter regular use of the car in order to save money.

In order to stay within their budgets, owners of EVs may use them less frequently due to higher maintenance expenditures. A negative toll tax regression coefficient indicates that fewer electric vehicle trips are taken as tolls increase. Using EVs for frequent travel becomes more costly due to higher toll levies that raise the overall cost of transportation. By making toll roads more expensive, owners may be discouraged from utilizing them, which would lower the number of rides. This results in rapid changes in behavior. EV owners may select less convenient alternate routes to avoid paying hefty toll charges, which would result in fewer trips with the vehicle. Owners may choose to travel less to save money on high toll costs. When EV charging costs climb, the number of EV journeys declines, according to a negative regression coefficient for charging costs. Increasing charging expenses immediately increases an EV's operating costs, making regular use of an EV less cost-effective. Sensitive owners may cut back on consumption in order to avoid paying excessive fees. Increased expenses may cause owners to charge their EVs less frequently, restricting their use to necessary travel. Owners may restrict their rides out of fear over usage and range issues brought on by worries about the expense of charging.

5. CONCLUSION AND POLICY RECOMMENDATION

There is a statistically significant positive correlation between the number of EV rides taken, EV owners' income, the distance EVs drive when fully charged, and the presence of drivers (either hired or owned). This suggests that these variables consistently lead to a higher frequency of electric vehicle rides. By focusing on the important variables that affect EV acceptance and usage, stakeholders, legislators, and marketers can create more effective strategies to encourage EV usage and infrastructure development by better understanding these important relationships. Because of the higher financial load and operating costs imposed by these elements, there is a negative link between the number of EV trips and the cost of EV maintenance, toll taxes, and charges. EV owners face financial obstacles due to these rising expenses, which makes them use their cars less frequently. In order to encourage EV uptake and usage, governments and other stakeholders must be aware of these detrimental effects. These cost-related obstacles can be removed by providing subsidies, incentives, or better infrastructure, which will promote the wider shift to more environmentally friendly modes of transportation and encourage the usage of EVs more frequently. Based on the statistically significant relationships and the impact of various factors on the frequency of EV rides, the following policy recommendations are proposed:

- To make EV ownership more accessible, give lower-income people specific subsidies and financial incentives.
- To lower the total cost of ownership, provide tax credits or rebates to EV owners, especially those with lower incomes.
- Encourage advancing battery technology through research and development to extend the range of fully charged electric vehicles (EVs).
- Invest in developing fast-charging stations to reduce range anxiety and improve the convenience of EV use, especially in urban areas and along key routes.
- By offering financial incentives to encourage the hiring of EV drivers, you may encourage owners to use their cars more regularly.
- Subsidies and incentives for ride-sharing firms that employ electric vehicles can help promote the usage of EVs in carpooling and ride-sharing services.
- Reduce the cost of EV maintenance services for owners by providing subsidies or coupons. Develop technician and mechanic training programs to expand the pool of qualified and reasonably priced EV maintenance services.
- Providing financial assistance for installing home charging stations will encourage owners to charge their EVs more frequently and affordably.

- Collaborate with utility providers to provide EV chargers with discounted electricity, particularly during off-peak hours.
- To reduce the total cost of travel and promote more frequent use, toll tax exemptions or discounts for electric vehicles should be implemented.
- Create initiatives that provide regular rebates or toll breaks to EV users to incentivize them to use EVs.
- Initiate public education initiatives aimed at informing consumers about the extended financial advantages, ecological advantages, and enhanced functionality of electric vehicles.
- Clearly communicate the available subsidies, incentives, and support programs to ensure that both present and prospective EV owners can fully benefit from them.

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