



## Electric Vehicle Adoption in India: Assessing Current Status and Customer Perceptions

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### ABSTRACT

The electric vehicle (EV) market in India is undergoing rapid transformation driven by government initiatives such as the FAME scheme, aimed at incentivizing EV adoption and infrastructure development. This paper explores the current status and customer perceptions regarding EV adoption in India, highlighting challenges and potential strategies for promoting sustainable mobility. Despite significant progress, barriers like high upfront costs and limited charging infrastructure hinder widespread adoption. The study combines primary survey data and secondary research to analyze consumer familiarity with EVs, concerns about performance and reliability, satisfaction with available EV models, opinions on charging infrastructure, and views on cost justification and environmental impact. Findings underscore the importance of addressing affordability, expanding charging infrastructure, promoting environmental benefits, and enhancing public awareness to accelerate EV adoption in India. This research contributes valuable insights for policymakers, industry stakeholders, and researchers aiming to promote sustainable transportation solutions in the evolving EV market.

**Keywords:** Electric Vehicles (EVs), EV Adoption, Charging Infrastructure, Consumer Perceptions, Sustainability

### Introduction

The electric vehicles (EV) market in India is rapidly evolving, buoyed by supportive government policies like the FAME scheme, which incentivizes EV adoption and infrastructure development. Dominated by electric two-wheelers and three-wheelers for urban mobility, this sector faces challenges such as high upfront costs and limited charging infrastructure, yet it holds immense potential for growth and innovation. Key players, both domestic and international, are investing in EV technology, and startups are emerging with innovative solutions. Despite obstacles, the future outlook is promising, driven by environmental concerns and advancements in battery technology, signaling a transformative shift towards sustainable mobility in India.

The global electric vehicle (EV) market is experiencing a transformative shift driven by the imperative to reduce carbon emissions, mitigate climate change, and enhance energy efficiency in transportation. EV adoption is gaining momentum worldwide, fueled by advancements in battery technology, government incentives, and increasing consumer awareness. Key players in the automotive industry are investing heavily in electric mobility, with major automakers committing to ambitious electrification targets. This dynamic market landscape is characterized by rapid technological innovations, expanding charging infrastructure, and a growing range of EV models across various segments including passenger cars, buses, trucks, and two-wheelers. As countries prioritize clean transportation and sustainable development goals, the global EV market is poised for substantial growth, offering economic, environmental, and societal benefits on a global scale.

The environmental impact of Electric Vehicles (EVs) compared to Internal Combustion Engine (ICE) vehicles differs significantly. EVs produce zero tailpipe emissions during operation, reducing air pollution and greenhouse gas (GHG) emissions, especially when powered by renewable energy sources. In contrast, ICE vehicles emit pollutants like carbon dioxide (CO<sub>2</sub>), nitrogen oxides (NO<sub>x</sub>), and particulate matter (PM), contributing to air pollution and climate change. Additionally, EVs are more energy-efficient due to the direct conversion of stored energy into propulsion, whereas ICE vehicles waste significant energy as heat. While EVs have environmental impacts associated with battery production and electricity generation, advancements in battery technology and the shift towards renewable energy sources are improving the overall lifecycle emissions of EVs. Furthermore, EVs contribute to reducing noise pollution in urban areas due to their quieter operation compared to ICE vehicles. Overall, transitioning to EVs can play a crucial role in mitigating environmental challenges associated with transportation and promoting sustainability on a global scale.

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## Review of Literature

Bhattacharyya et al. (2023) in their study identifies and ranks challenges hindering the adoption of electric vehicles (EVs) in India, emphasizing inadequate charging infrastructure as a significant hurdle. Challenges such as the cost of batteries, limited range, and high prices of EVs impact consumer acceptance and market growth, further complicated by broader industry downturns and government reluctance to adopt EVs. Using the Triangular Fuzzy Number (TFN) method, the study ranks 12 influential challenges faced by manufacturers in India, providing insights for policy formulation and industry development. The objective is to facilitate the transition towards a sustainable transportation system by addressing critical manufacturing and sales obstacles in the EV sector, ultimately contributing to a more environmentally friendly mobility landscape.

Asokan et al. (2023) explored the impact of electric vehicle (EV) deployment in India, focusing on waste management challenges associated with EV batteries. It identifies India's lack of adequate infrastructure for handling increasing EV battery volumes, highlighting concerns around safe disposal and recycling. The study projects a substantial rise in EV sales by 2030, particularly for two-wheelers and four-wheelers, leading to significant lead-acid and lithium-ion battery waste. It emphasizes the need for an extended producer responsibility (EPR) system, safe working environments, and national waste crime tracking mechanisms. The article calls for research and policy efforts to address socio-environmental implications and ensure fair transitions, advocating for circular economy approaches and equitable policies to support sustainable and inclusive EV deployment in India amidst rapid industrialization and EV adoption initiatives. The methodology involves model analysis using a Gompertz Curve approach to forecast EV sales and associated battery waste, underscoring the urgency of proactive waste management strategies.

Chidambaram et al. (2022) examined the barriers to electric vehicle (EV) adoption in developing countries, emphasizing critical factors such as battery technology, vehicle performance, charging infrastructure, consumer behavior, and government support. A Consumer Perception Survey (CPS) highlights the importance of charging infrastructure and cost. Using SWARA and TOPSIS methodologies, it prioritizes barriers, identifying the lack of charging infrastructure and high overall cost as major obstacles. The study underscores the role of government policies and recommends introducing incentives and fostering collaborations to promote EV growth. By integrating consumer perceptions and robust analytical tools, the research provides actionable insights for policymakers, industry experts, and consumers, facilitating the transition towards sustainable future mobility in developing nations.

James et al. (2022) identified technical challenges as the primary barrier to electric mobility in India, particularly issues related to battery technology, charging infrastructure, driving range, and power availability. Using Analytic Hierarchy Process (AHP) and Decision Making Trial and Evaluation Laboratory (DEMATEL) methodologies, it assigns significant weight (48.8%) to technical barriers and shows their influence in causing other barriers. Market, economic, policy, and infrastructure barriers are also identified as distinct challenges to electric vehicle (EV) adoption. The hybrid AHP-DEMATEL approach provides insights for policymakers and manufacturers to develop effective strategies addressing these barriers and promoting widespread EV adoption in India, thus tackling technological, social, and economic hurdles hindering EV implementation.

Goel et al. (2021) in their study presented an in-depth exploration of barriers inhibiting the adoption of electric vehicles (EVs) in India, despite governmental initiatives aimed at promoting them. A comprehensive literature review identifies 35 distinct barriers encompassing economic, infrastructural, psychological, and societal factors. Surprisingly, pricing does not emerge as a major concern for consumers, with issues like unclear government policies and insufficient post-purchase maintenance support identified as significant obstacles. The review contextualizes India's efforts within the global push towards EVs for environmental sustainability, citing schemes like FAME and GST rate reductions. While past studies stress the pivotal role of government support in driving EV adoption, India's EV sales remain low, necessitating a deeper understanding of consumer behavior. The study's innovative approach integrates psychological and societal factors into the analysis to comprehensively identify barriers to EV adoption. Leveraging the DEMATEL method, the research aims to visualize and prioritize these barriers, offering actionable insights for policymakers and stakeholders. This study's meticulous literature review establishes a robust groundwork for dissecting and addressing barriers to EV adoption in India, emphasizing the nuanced dynamics of consumer decision-making and advocating for targeted interventions to expedite EV uptake nationwide.

Kumar et al. (2021) investigated barriers to electric vehicle (EV) adoption in India and proposed a decision-making framework tailored for policymakers, utilizing a multi-criteria decision-making approach to identify and prioritize critical barriers and emphasize their interrelationships. The study conducts a thorough literature review on global initiatives and challenges in EV adoption, particularly focusing on India's commitment to electric mobility. While previous studies have identified barriers and suggested policy recommendations, quantitative assessments of barriers and their interdependencies remain limited. This paper addresses this gap by offering insights specific to the Indian context, acknowledging the complexity of EV adoption dynamics and advocating for region-specific approaches. The review effectively summarizes the paper's contributions within the broader discourse on EV adoption, highlighting the significance of the research while acknowledging its limitations. Further elaboration on specific findings could enhance the review's depth, but overall, it provides a solid overview of the paper's importance and implications for policymakers and researchers.

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## Research Gap

A significant research gap exists in understanding the mismatch between the perceived benefits of electric vehicles (EVs) and consumer hesitancy towards their adoption. Despite the environmental advantages and technological advancements of EVs, there remains a disconnect between these benefits and consumer preferences. Studies focusing on the underlying factors contributing to consumer reluctance, such as concerns over charging infrastructure, range anxiety, upfront costs, and uncertainty about battery longevity, are essential. Moreover, exploring effective strategies to bridge this gap by addressing consumer perceptions and fostering confidence in EV technology could provide valuable insights for policymakers, industry stakeholders,

and researchers aiming to promote sustainable transportation solutions. Understanding and addressing these research gaps is crucial for accelerating EV adoption and achieving broader societal acceptance of electric vehicles.

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## Statement of Problem

The continued reliance on Internal Combustion Engine (ICE) vehicles poses significant environmental and societal challenges, including air pollution, climate change, and energy inefficiency. The combustion of fossil fuels in ICE vehicles results in the emission of pollutants that degrade air quality, contribute to respiratory illnesses, and accelerate global warming. Additionally, the finite nature of fossil fuel resources raises concerns about energy security and geopolitical stability. Transitioning to Electric Vehicles (EVs) is imperative to mitigate these issues by reducing greenhouse gas emissions, improving air quality, and promoting energy efficiency. However, barriers such as high upfront costs, limited charging infrastructure, and concerns over battery technology must be addressed to facilitate the widespread adoption of EVs and realize their potential benefits for a sustainable transportation future.

Despite the environmental and technological advancements associated with Electric Vehicles (EVs), widespread adoption and acceptance among consumers remain hindered by several key factors. One primary concern is the high upfront cost of EVs compared to conventional Internal Combustion Engine (ICE) vehicles, which creates a barrier to entry for many potential buyers. Additionally, limited charging infrastructure and range anxiety contribute to consumer hesitancy, as individuals worry about the availability and convenience of charging stations, especially for long-distance travel. Moreover, uncertainties surrounding battery durability, performance in extreme conditions, and concerns over the environmental impact of battery production and disposal contribute to skepticism among consumers. Addressing these challenges through enhanced affordability, infrastructure development, technological advancements, and comprehensive education is essential to accelerating EV adoption and fostering a sustainable transportation paradigm.

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## Research Methodology

### Research Objectives

- To analyze customers opinions regarding buying electric vehicles. (all your study findings)
- To understand the current charging infrastructure and battery life of electric vehicles. (secondary data)
- To examine the role of government in incentivizing EV adoption (secondary data)
- To suggest measures for greater adoption of electric vehicles. (primary and secondary data)

### Sampling Technique

**Sampling Technique:** Simple Random Sampling method was used to gather data for this study. This way, everyone had an equal chance to participate, thus giving diverse views across different places. To ensure the study reflects various perspectives, participants from different age groups were included. This diversity helped to uncover possible variations in preferences and experiences. By using a random sampling technique, biases could be avoided.

**Sample size:** The sample size consisted of 59 respondents.

### Source of Data Collection

**Source of data collection:** Data collection utilized both primary and secondary sources. Primary data was acquired through a questionnaire, while secondary data includes information sourced from the internet and published research papers and articles.

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## Data Analysis and Interpretation

**Table 1:** Gender wise distribution of respondents

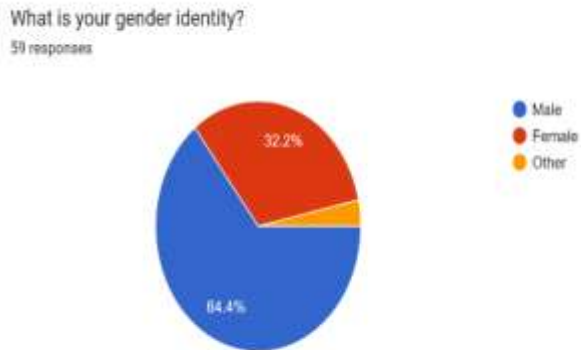
Gender	No. of respondents	Percentage
Male	38	64.4%
Female	19	32.2%

Other	2	3.4%
<b>Total</b>	<b>59</b>	<b>100%</b>

Source: Primary Data

**Analysis:** The survey sample is predominantly male, with males comprising 64.4% of respondents, followed by females at 32.2%, and individuals of other genders at 3.4%.

**Graph 1:** Gender wise distribution of respondents



Source: Primary Data

**Inference:** The gender imbalance in respondent distribution suggests potential variations in perspectives and responses based on gender, emphasizing the importance of considering diverse demographic representations for comprehensive survey analysis.

**Table 2:** Familiarity of people with electric vehicles and their benefits

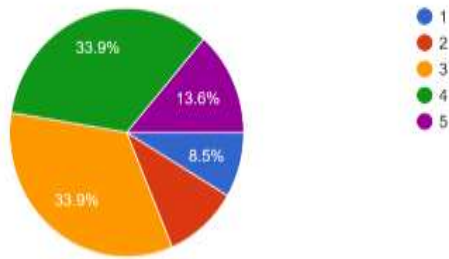
Familiarity	No. of respondents	Percentage
1	5	8.5%
2	6	10.2%
3	20	33.9%
4	20	33.9%
5	8	13.6%
<b>Total</b>	<b>59</b>	<b>100%</b>

Source: Primary Data

**Analysis:** The majority of respondents (67.8%) rated their familiarity with electric vehicles (EVs) and their benefits as either a 3 or 4 on a scale of 1 to 5, indicating a moderate to high level of awareness and understanding.

**Graph 2:** Familiarity of people with electric vehicles and their benefits

How familiar are you with E.V. and their benefits as compared to traditional ICE vehicles? (On the scale of 1-5)  
59 responses



Source: Primary Data

**Inference:** The distribution suggests that a significant portion of respondents have a decent level of familiarity with EVs, which may influence their attitudes and perceptions towards electric vehicle adoption and related benefits.

**Table 3:** Concerns faced by people regarding the performance and reliability of EV

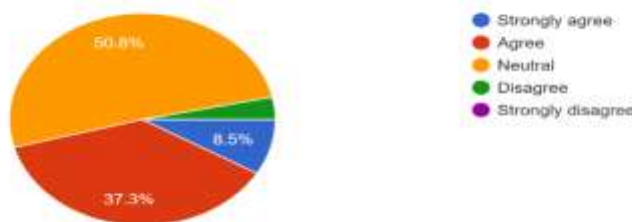
Choices	No. of respondents	Percentage
Strongly disagree	0	0%
Disagree	2	3.4%
Neutral	30	50.8%
Agree	22	37.3%
Strongly agree	5	8.5%
<b>Total</b>	<b>59</b>	<b>100%</b>

Source: Primary Data

**Analysis:** The table indicates that a majority of respondents have some level of concern regarding the performance and reliability of electric vehicles (EVs), with 37.3% agreeing and 50.8% remaining neutral on this issue

**Graph 3:** Concerns faced by people regarding performance and reliability of EV

Did you ever faced any concerns regarding the performance and reliability of E.V.?  
59 responses



Source: Primary Data

**Inference:** The high percentage of respondents expressing concern suggests that perceptions about EV performance and reliability are significant factors influencing consumer attitudes towards adopting electric vehicles, highlighting areas that need to be addressed to enhance consumer confidence in EV technology.

**Table 4:** Satisfaction of respondents regarding current availability of EV models and options in India

Choices	No. of respondents	Percentage
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Strongly disagree	2	3.4%
Disagree	15	25.4%
Neutral	26	44.1%
Agree	15	25.4%
Strongly agree	1	1.7%
<b>Total</b>	<b>59</b>	<b>100%</b>

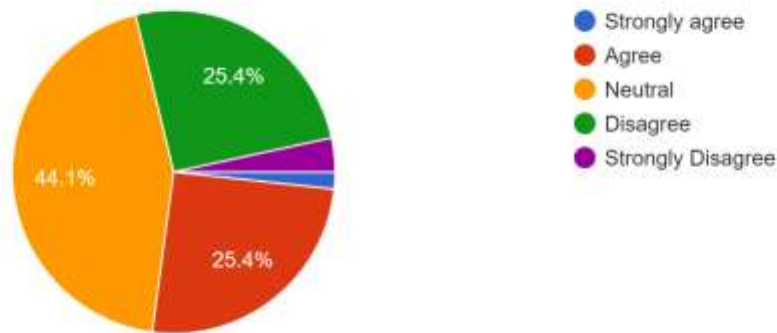
Source: Primary Data

**Analysis:** The majority of respondents do not find the current availability of electric vehicle (EV) models and options in the Indian market satisfactory, with 25.4% disagreeing and 44.1% remaining neutral.

**Graph 4:** Satisfaction of respondents regarding current availability of EV models and options in India

Are you satisfied with the current availability of E.V. models in the Indian Market?

59 responses



Source: Primary Data

**Inference:** The dissatisfaction or neutrality towards the existing range of EV models indicates a need for increased variety and accessibility of electric vehicle options to better meet consumer preferences and promote EV adoption in the Indian market.

**Table 5:** Opinions regarding convenience and sufficiency of current charging infrastructure

Choices	No. of respondents	Percentage
Strongly disagree	10	16.9%
Disagree	22	37.3%
Neutral	18	30.5%
Agree	9	15.3%
Strongly agree	0	0%
<b>Total</b>	<b>59</b>	<b>100%</b>

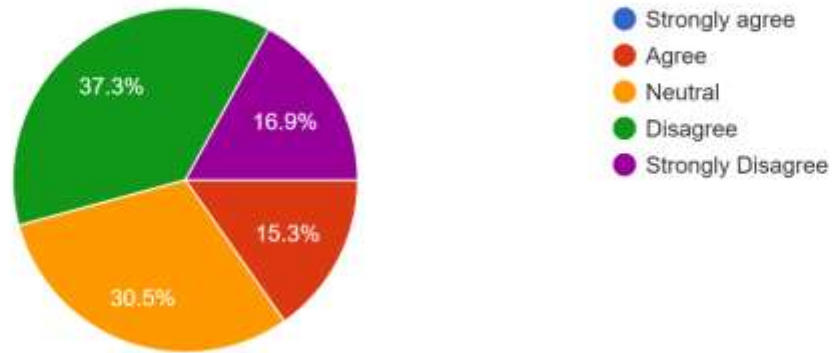
Source: Primary Data

**Analysis:** The table reveals that a majority of respondents (54.2%) either disagree or strongly disagree with the current charging infrastructure's convenience and sufficiency for electric vehicles (EVs).

**Graph 5:** Opinions regarding convenience and sufficiency of current charging infrastructure

### Do you find current Charging Infrastructure sufficient and convenient?

59 responses



Source: Primary Data

**Inference:** The dissatisfaction with the charging infrastructure underscores the importance of expanding and improving charging facilities to address consumer concerns and facilitate greater adoption of electric vehicles.

**Table 6: Influence of lack of sufficient charging infrastructure while buying EV**

Choices	No. of respondents	Percentage
Strongly disagree	0	0%
Disagree	5	8.5%
Neutral	14	23.7%
Agree	25	42.4%
Strongly agree	15	25.4%
<b>Total</b>	<b>59</b>	<b>100%</b>

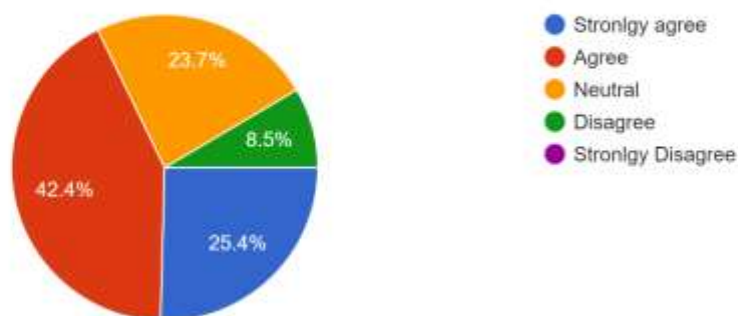
Source: Primary Data

**Analysis:** The table indicates that a significant majority of respondents (67.8%) agree or strongly agree that the lack of charging infrastructure influences their decision when considering buying an electric vehicle (EV).

**Graph 6: Influence of lack of sufficient charging infrastructure while buying EV**

### Does the lack of charging Infrastructure influence your decision of buying E.V.?

59 responses



Source: Primary Data

**Inference:** The influence of charging infrastructure on purchasing decisions highlights the critical role of accessible and reliable charging facilities in promoting electric vehicle adoption and addressing consumer concerns about EV ownership.

**Table 7:** Respondents concerns about range anxiety and battery life

Choices	No. of respondents	Percentage
Strongly disagree	0	0%
Disagree	1	1.7%
Neutral	16	27.1%
Agree	33	55.9%
Strongly agree	9	15.3%
<b>Total</b>	<b>59</b>	<b>100%</b>

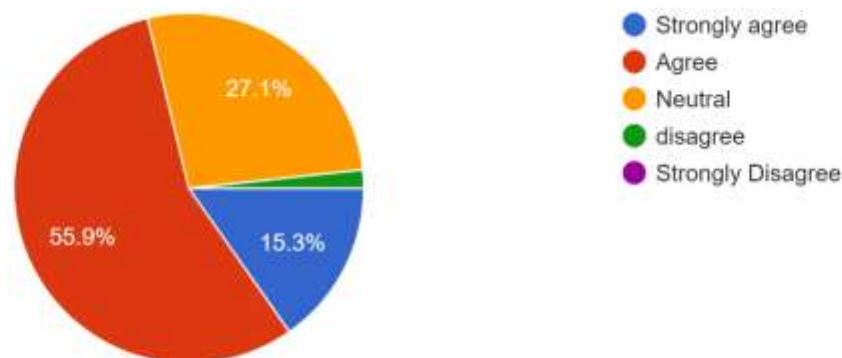
Source: Primary Data

**Analysis:** The table reveals that a majority of respondents (71.2%) either agree or strongly agree with concerns about range anxiety and battery life when considering purchasing an electric vehicle (EV).

**Table 7:** Respondents concerns about range anxiety and battery life

Are you concerned about issues such as range anxiety and battery life when considering the purchase of E.V. vehicles?

59 responses



Source: Primary Data

**Inference:** The prevalence of concerns regarding range anxiety and battery life underscores the importance of improving EV battery technology and infrastructure to address consumer apprehensions and promote greater confidence in electric vehicle adoption.

**Table 8:** Views on cost justification regarding premium payment and future battery replacement

Choices	No. of respondents	Percentage
Strongly disagree	4	6.8%
Disagree	6	10.2%
Neutral	33	55.9%
Agree	16	27.1%
Strongly agree	0	0%



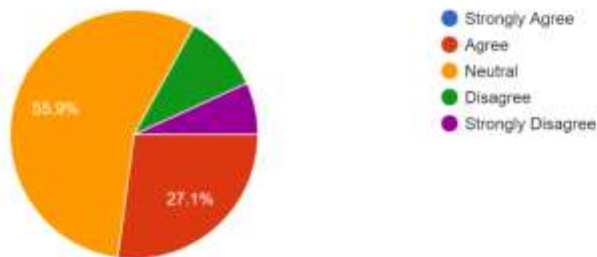
<b>Total</b>	<b>59</b>	<b>100%</b>
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Source: Primary Data

**Analysis:** The majority of respondents either disagree or are neutral about finding the premium for electric vehicles (EVs) and future battery replacement costs justified.

**Graph 8:** Views on cost justification regarding premium payment and future battery replacement

Do you think premium price on E.V. and a battery replacement cost in the future is justified?  
59 responses



Source: Primary Data

**Inference:** The results suggest that a significant portion of respondents are hesitant or uncertain about the economic justification for paying a premium for EVs and considering future battery replacement costs, indicating a need for cost-related incentives or improvements to enhance EV affordability and value proposition.

**Table 9:** Respondents views on environment impact of ICE vehicles in buying EV

S.no	Choices	No. of respondents	Percentage
1	Strongly disagree	5	8.5%
2	Disagree	7	11.9%
3	Neutral	24	40.7%
4	Agree	17	28.8%
5	Strongly agree	6	10.2%
	<b>Total</b>	<b>59</b>	<b>100%</b>

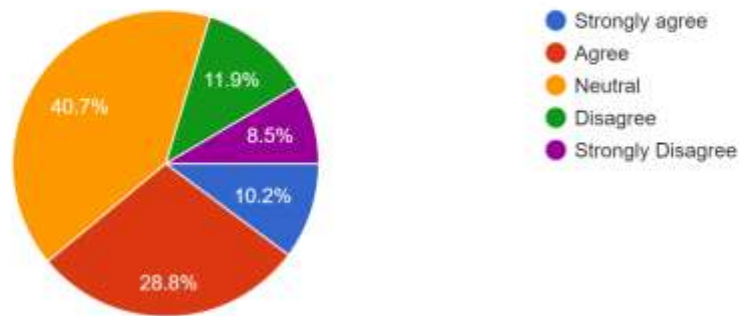
Source: Primary Data

**Analysis:** The table indicates that a majority of respondents (39%) either agree or strongly agree that the environmental impact of internal combustion engine (ICE) vehicles influences their decision to consider buying an electric vehicle (EV).

**Graph 9:** Respondents views on environment impact of ICE vehicles in buying EV

## Does the environment Impact of ICE vehicle pushes you to buy a E.V.?

59 responses



Source: Primary Data

**Inference:** The influence of environmental concerns on EV purchase decisions highlights the growing awareness and importance of sustainability factors in driving consumer preferences towards electric vehicles as a more environmentally friendly transportation option.

### Summary of Findings

- A notable portion of respondents (33.9%) rated their familiarity with EVs and their benefits as a 3 on a scale of 1 to 5, indicating moderate awareness. However, a significant percentage (47.5%) rated their familiarity as a 4 or 5, suggesting a relatively high level of understanding among a substantial portion of respondents.
- A majority of respondents (88.1%) expressed some level of concern regarding the performance and reliability of EVs, with 45.8% agreeing or strongly agreeing with these concerns. This highlights a key area where perceptions about EV technology need to be addressed to improve consumer confidence.
- The survey revealed a mixed sentiment regarding the availability of EV models in the Indian market, with only 26.1% of respondents expressing satisfaction (agree or strongly agree). This suggests that there is room for improvement in the variety and accessibility of EV options.
- A significant portion of respondents (54.2%) find the current charging infrastructure insufficient or inconvenient, and a majority (67.8%) indicated that the lack of charging infrastructure influences their decision to buy an EV. This underscores the critical importance of expanding and enhancing charging infrastructure to facilitate greater EV adoption.
- The majority of respondents (71.2%) expressed concerns about range anxiety and battery life when considering purchasing an EV. This highlights the need for advancements in battery technology and infrastructure to address consumer apprehensions.
- A significant percentage (55.9%) of respondents are neutral about whether premium EV pricing and future battery replacement costs are justified, suggesting uncertainty or lack of clarity on the economic aspects of EV ownership.
- A considerable portion of respondents (39%) acknowledged that the environmental impact of internal combustion engine (ICE) vehicles influences their decision to consider purchasing an EV. This underscores the role of environmental awareness in shaping consumer attitudes towards sustainable transportation choices.

### Recommendation

The compiled recommendations reflect a range of perspectives on how to encourage greater adoption of electric vehicles (EVs) in India. Several respondents emphasize the importance of lowering upfront costs and increasing financial incentives, suggesting that enhancing government subsidies and direct incentives for purchasing EVs could make them more affordable and attractive to consumers. Others highlight the environmental benefits of EVs, emphasizing reduced emissions and improved air quality as compelling reasons to promote their adoption. Suggestions to improve EV infrastructure, including expanding charging stations and ensuring faster charging times, are widely cited to alleviate range anxiety and enhance convenience for EV owners. Marketing and public awareness campaigns are also recommended to educate consumers about the benefits of EVs and shift preferences towards sustainable transportation options. Overall, addressing affordability through incentives, expanding charging infrastructure, promoting environmental benefits, and enhancing public awareness are key strategies proposed by respondents to accelerate EV adoption in India.

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## Conclusion

In conclusion, the compiled recommendations and responses reflect the multifaceted landscape of considerations and challenges surrounding the adoption of electric vehicles (EVs) in India. While there is a notable interest in the environmental benefits, lower operating costs, and convenience associated with EVs, concerns such as upfront costs, charging infrastructure, and vehicle performance remain significant barriers for many potential consumers. The suggestions provided by respondents emphasize the critical need for government support in terms of financial incentives and subsidies to make EVs more affordable. Additionally, expanding and improving charging infrastructure, coupled with effective marketing and public awareness campaigns, are essential strategies to address consumer concerns and promote the benefits of EV adoption. To achieve widespread adoption of EVs in India and realize the associated environmental and economic benefits, concerted efforts are required to tackle these challenges through policy interventions, technological advancements, and infrastructure developments tailored to the unique needs and preferences of Indian consumers.

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## References

1. Chidambaram, K., Ashok, B., Vignesh, R., Deepak, C., Ramesh, R., Narendhra, T. M., ... & Kavitha, C. (2023). Critical analysis on the implementation barriers and consumer perception toward future electric mobility. *Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering*, 237(4), 622-654.
2. James, A. T., Kumar, G., Pundhir, A., Tiwari, S., Sharma, R., & James, J. (2022). Identification and evaluation of barriers in implementation of electric mobility in India. *Research in Transportation Business & Management*, 43, 100757.
3. Bhattacharyya, D., & Pradhan, S. (2023). Barriers in Replacement of Conventional Vehicles by Electric Vehicles in India: A Decision-Making Approach. *International Journal of Decision Support System Technology (IJDSST)*, 15(1), 1-20.
4. Asokan, V. A., Teah, H. Y., Kawazu, E., & Hotta, Y. (2023). Ambitious EV policy expedites the e-waste and socio-environmental impacts in India. *Resources, Conservation and Recycling*, 190, 106829.
5. Goel, P., Sharma, N., Mathiyazhagan, K., & Vimal, K. E. K. (2021). Government is trying but consumers are not buying: A barrier analysis for electric vehicle sales in India. *Sustainable Production and Consumption*, 28, 71-90.
6. Tarei, P. K., Chand, P., & Gupta, H. (2021). Barriers to the adoption of electric vehicles: Evidence from India. *Journal of Cleaner Production*, 291, 125847.