Sustainable Development in Automobile Industry: Challenges and Opportunities

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Abstract

The automobile industry plays a pivotal role in the global economy, with millions of vehicles produced and sold annually. In recent years, there has been a growing emphasis on sustainability within the automobile sector. The automobile industry entails a thorough assessment of the industry's carbon footprint, encompassing emissions of greenhouse gases, air and water pollution, and its contribution to resource depletion. Greenhouse gas emissions from the transportation sector, according to the U.S. Environmental Protection Agency (EPA), account for about 29% of U.S. greenhouse gas emissions. Passenger vehicles account for the largest share of emissions from the transportation sector, at about 58%. According to the World Health Organization (WHO, 2022), air pollution from vehicles causes an estimated 7 million premature deaths each year. Supporting this data, global vehicle sales (OICA data) reached 80.6 million units in 2022, marking a significant increase from the previous year when sales were 66.7 million units.

At the same time, the automobile industry is contributing to sustainable development in a number of ways. This includes developing and producing electric vehicles and other fuel-efficient vehicles, investing in renewable energy and energy efficiency measures at manufacturing plants, and working to reduce the environmental impact of their supply chains. As a result, global electric vehicle sales (IEA, 2022) reached 10.5 million units in 2022, representing a 108% increase from the previous year. In 2022, 75% of automakers had sustainability programs in place for their supply chains, up from 60% in the previous year.

The main aim of this paper is to provide a comprehensive examination of the automobile industry's role in sustainable development. It underscores the multifaceted challenges and transformative opportunities that lie ahead on the industry's journey towards sustainability. The contribution of this paper can be valuable for policymakers, consumers, and international organizations to shed light on the challenges it faces and the opportunities it presents for a more sustainable future aligned with the United Nations' Sustainable Development Goals (SDGs)."

Keywords: *sustainability, carbon footprint, greenhouse gases, pollution, environmental impact*

Introduction

The global push towards sustainable development has brought significant changes to various industries including the automobile sector. The rapid growth of urbanization and increasing concerns over environmental issues have highlighted the need for cleaner and more efficient modes of transportation. The global automobile industry, a key player of the world economy, plays a pivotal role by facilitating mobility, generating employment, and propelling technological advancement. Nevertheless, it confronts

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a host of formidable challenges, particularly concerning its ecological footprint and sustainability. In a world grappling with urgent concerns like climate change, resource depletion, and urban pollution, the notion of sustainable development has surged to the forefront of the automobile industry's agenda. According to the World Health Organization (WHO, 2022), vehicular air pollution is responsible for an alarming estimate of 7 million premature deaths annually, underscoring the pressing need for sustainable practices within the industry.

Interestingly, even as the automobile industry is implicated in environmental issues, it paradoxically contributes to sustainable development through various avenues, notably the development and production of electric vehicles (EVs) and fuel-efficient automobiles. The global shift toward cleaner mobility solutions is evident in the rising demand for electric vehicles. For instance, India registered 9,013,640 EV units between January and August 18, 2023, according to the government's Vahan dashboard. However, a pressing concern arises in the Indian context, where a significant portion of electricity production relies on coal. The Ministry of Coal reports that 75% of electricity in India is coal-generated, with coal-based power contributing to approximately 50% of the country's fuel-related CO2 emissions.

Top of Form

Recent years have witnessed an escalating recognition of the imperative for sustainable practices across the entire lifecycle of vehicles—from manufacturing to disposal. According to a report by the International Energy Agency (IEA) in 2021, governments, consumers, and industry leaders are increasingly advocating for environmentally friendly solutions that promote cleaner and more efficient mobility. This paradigm shift has prompted a profound transformation within the automobile industry, as companies endeavor to create greener alternatives and align with the principles of sustainable development.

Another significant challenge is the affordability of electric vehicles (EVs). While the cost of EVs has been decreasing over the years, they still typically have a higher upfront cost compared to traditional vehicles. This cost disparity is often attributed to the expensive batteries used in these vehicles. A 2021 report by the International Energy Agency (IEA) highlights this issue and notes that the financial burden of purchasing an EV can be a barrier for many potential customers, hindering the widespread adoption of sustainable transportation. Furthermore, the limited range of EVs remains a challenge. Despite advancements in battery technology, the range is still lower compared to traditional vehicles with combustion engines. This limitation may deter customers who require long-range capabilities or frequently travel to remote areas without access to charging stations. The IEA's report on electric mobility also addresses this range limitation.

In addition to these challenges, there are environmental concerns associated with EVs. The manufacture and disposal of EV batteries can have environmental impacts. Extracting and processing the raw materials used in batteries can have adverse effects, and the disposal or recycling of spent batteries requires appropriate management to prevent environmental pollution. These environmental challenges are discussed in a 2020 study by the European Environment Agency on the environmental impact of electric vehicles. These challenges span from the reduction of greenhouse gas emissions and the enhancement of fuel efficiency to the promotion of electric mobility, the implementation of responsible supply chain practices, and the improvement of recycling and disposal methods. The industry must navigate this intricate landscape to fulfill its role in fostering a sustainable and eco-conscious future for transportation, as emphasized in various reports and studies by environmental agencies and organizations.

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Literature review

Shigeta and Hosseini (2020): Conducted a study on sustainable development in the automobile industry in the United States, Europe, and Japan, focusing on vehicle power sources. Their findings highlight active innovation in electric vehicles (EVs) by manufacturers in these regions to reduce emissions. Notter et al. (2010): Conducted a comprehensive study on the environmental impact of lithium-ion batteries in electric vehicles. Based on life cycle assessments (LCA) and sensitivity analyses, their research suggests that electric mobility is environmentally advantageous compared to conventional internal combustion engine vehicles (ICEVs). The study emphasizes that the Li-ion battery in a Battery Electric Vehicle (BEV) does not negate the benefits of higher efficiency in BEVs compared to ICEVs, highlighting the viability of electric mobility as an eco-friendly option. Franzo and Nasca (2021): Evaluated the environmental impact of electric vehicles using a life cycle-based framework applied to various multi-country scenarios. Their results consistently indicate that the lifecycle CO2 emissions of EVs are lower than those of comparable ICEVs within the same vehicle segment and scenario. The use phase of EVs, regardless of the vehicle segment, is identified as the most impactful phase. Abas et al. (2019): Conducted a techno-economic analysis and assessed the environmental impact of electric vehicles in Brunei. Their study underscores that, despite EVs producing zero-tailpipe emissions, they still contribute significantly to greenhouse gas (GHG) emissions when accounting for energy generation, transmission losses, and charging efficiency. This finding emphasizes the importance of considering the entire energy ecosystem when evaluating the environmental impact of EVs.

Weeberb J. Requia et al. (2018) conducted a study on the cleanliness of electric vehicles and their impact on air pollutants, greenhouse gas emissions, and human health. Their findings suggest that in general, EVs may play a role in reducing air pollution and its effects on human health. They emphasize that a key aspect of human exposure is the shift of traffic-related air pollution from the road to energy generation stations. The spatial distribution of the population, including urban and rural areas, is a crucial consideration. The overall positive benefits of EVs in reducing atmospheric emissions and human exposure depend on the type of EV and the source of energy generation. Yujin Beak et al. (2019) conducted a study in South Korea, investigating the factors influencing customers when purchasing electric vehicles. Their analysis revealed several key findings. First, consumers are influenced by battery-related technologies, such as the type of battery charging and charging time, when deciding to purchase EVs. Second, the CO2 reduction rate of EVs does not significantly impact consumer choices. Third, when EVs are charged with 100% renewable energy, contributing to a 100% CO2 reduction rate, the effect on the market growth of EVs is small, but it results in a substantial reduction of CO2 emissions in the transportation sector in South Korea.

Yang Liu, Zhe Ouyang, and Peng Cheng (2019) conducted a study on predicting consumers' adoption of electric vehicles during a smog crisis in a city. Their study indicates that the adoption of EVs can be determined by protective behavior, stakeholder involvement, and risk perceptions. Lower perception of resource-related attributes can increase individuals' acceptability of EVs over time and their immediate purchase intentions. Morsy Nour et al. (2020) conducted a study reviewing the positive and negative impacts of electric vehicle charging on electric power systems. Their findings highlight that uncontrolled EV charging can lead to undesirable negative impacts on power systems, particularly distribution networks, necessitating infrastructure upgrades.

Antonio Rosato et al. (2016) conducted a study on the energy, environmental, and economic effects of electric vehicle charging on the performance of a residential building-integrated micro-trigeneration system. Their research investigated the annual operation of this system while varying the electric vehicle charging profile. Xiuhong He and Wenjie Zhan (2017) conducted a study on how to activate moral norms to encourage the adoption of electric vehicles in China. Their empirical study suggests that the impact of

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personal norms on the intention to adopt EVs is influenced by external costs, with different dimensions of external costs having inconsistent effects. Perceived price, as a monetary cost, was found to negatively moderate the influence of personal norms on consumers' intention to adopt EVs.

In summary, these studies collectively emphasize the significance of comprehending the environmental impact and sustainability of electric vehicles, considering factors like regional preferences, energy sources, and the entire lifecycle of these vehicles. They offer valuable insights into the challenges and benefits related to the adoption of EVs as part of the quest for sustainable mobility solutions.

Objectives of the study

To analyze the challenges faced by the consumers of electric vehicles.

To assess the advantages and disadvantages of electric vehicles.

Methodology

The study is focused on Mangalore City, chosen as the primary geographical area of interest for this research.

Data Sources

Primary Data: Primary data collection is carried out through the use of structured surveys conducted with 50 customers who currently use electric vehicles within Mangalore City. The sample selection follows the simple random sampling method to ensure representativeness.

Secondary Data: Secondary data sources encompass a wide range of materials, including information provided by electric vehicle distributors in Mangalore, government publications, E-Vahan data, academic journals, newspaper articles, and relevant literature.

Expert Consultations: To enhance the depth and accuracy of the analysis, consultations with experts well-versed in electric vehicle technologies and sustainable transportation practices are planned. Insights from these experts will provide valuable perspectives and expertise in understanding the subject matter.

Data Analysis

The data was collected through a structured questionnaire in the city of Mangalore. Personal interviews were conducted, and Google Forms were circulated. The respondents were the owners of two-, three-, and four-wheeler EVs.

Table 1

Age of the Respondents

Age Group	No. of Respondents	Percentage
15-25	9	18
26-35	11	22
36-45	16	32
46-55	12	24
Above 55	2	4
Total	50	100

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Table 1 displays the age distribution of the respondents. Among the respondents, 32% fall into the 36-45 years age group, making it the largest segment. The next highest user group in the sample is the 46-55 age group, comprising 24% of the respondents. Additionally, 22% of the respondents are in the 26-35 age group. A smaller percentage of people in the study are using EVs above the age of 55, with only 4%. Furthermore, 18% of EV users belong to the 15-25 age group.

Chart 1 Employment Status

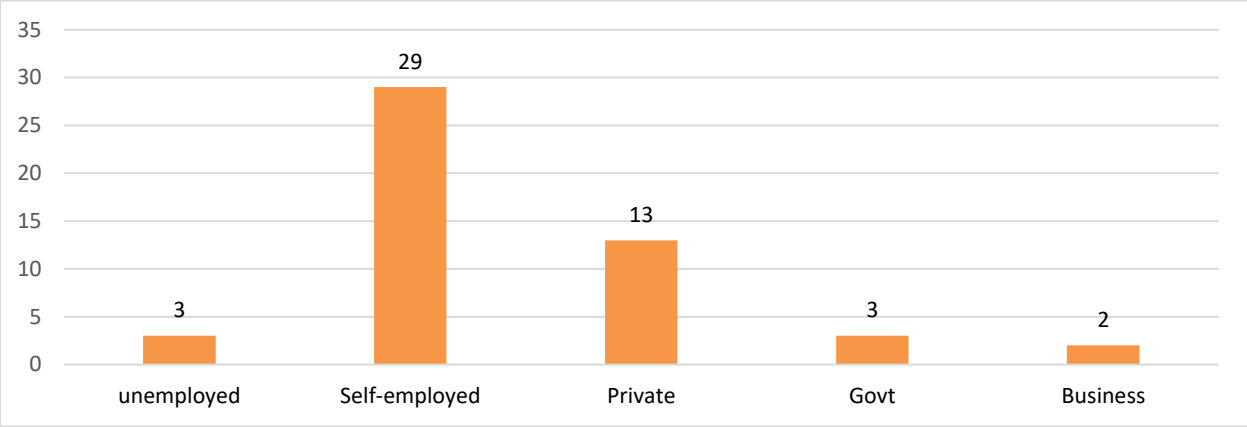

Chart 1 examines the employment status within the study sample of 50 individuals. Among these participants, 29 are self-employed, including auto-rickshaw drivers, sales personnel, small entrepreneurs, shopkeepers, and others. There are 13 individuals working in private jobs, encompassing roles in private financial institutions, hospitals, schools, and colleges. Additionally, 3 individuals are employed in government services, while 2 individuals are engaged in their own businesses. Lastly, 3 participants within the sample are currently unemployed.

Table 2

Type of Vehicles Used for the Study

Type of vehicle	Number	Percentage
2-wheeler	17	34
3-wheeler	25	50
4-wheeler	8	16
Total	50	100

Table 2 illustrates the types of vehicles used to explain EV usage in this study. Among the respondents, autorickshaws are the most popular and frequently used EVs, accounting for 50% of the total. Two-wheelers make up 34% of the EVs used, while four-wheelers represent 16% of the vehicles in the study.

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Chart 2 Years of EV Usage

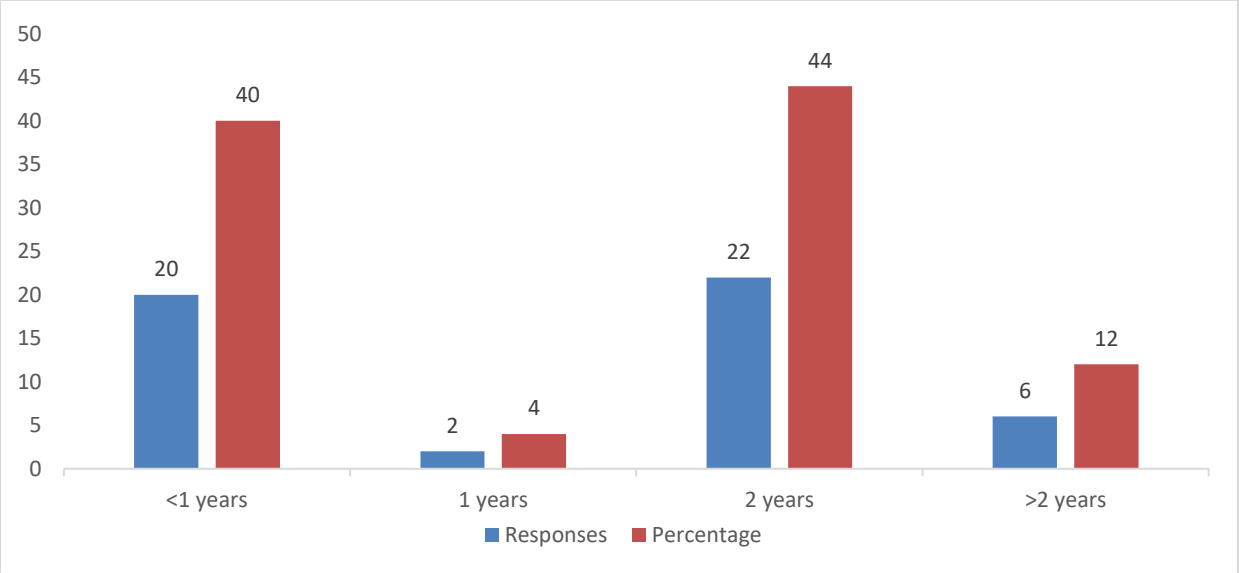

Chart 2 presents an analysis of the years of EV usage in this study. Among the respondents, 40% have been using EVs for less than one year, 4% have been using them for exactly one year, 44% have been using them for two years, and 12% have been using them for more than two years. This timeframe was chosen for the study because EVs are most popular within two years in general.

Table 3

Level of Satisfaction by Using EV's

Level of Satisfaction	No. of response	Percentage
Happy	43	86
Unhappy	7	14
Total	50	100

Table 3 outlines the level of satisfaction among the respondents regarding EV use. It indicates that 86% of the respondents are content with their EV experience, while 14% of them are dissatisfied due to various reasons.

Table 4

Reasons for Happiness while Using EVs

Reasons	**Frequency**	**Percentage**
Cost effective	5	12
Good mileage	9	21
Environment friendly	4	9
Cost effective; Environment friendly	5	12
Cost effective; Good mileage	7	16
Cost effective; Good mileage; Environment friendly	8	19
Good mileage; Environment friendly	5	12
Total	43	100

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Table 4 provides a comprehensive overview of the factors contributing to respondents' happiness regarding EV use. Among the users, 12% express happiness due to good mileage, 21% are content with the cost-effectiveness, 9% appreciate the environmental friendliness, 12% cite both cost-effectiveness and environmental friendliness as reasons for their satisfaction, 16% are happy because of both cost-effectiveness and good mileage, 19% find satisfaction in the combination of cost-effectiveness, good mileage, and environmental friendliness, and finally, 12% of the respondents express happiness based on the combination of good mileage and environmental friendliness.

Table 5

Difficulties Experienced by EV Users

Difficulties	No. of Responses	Percentage
It's costly	2	28
Less battery backup than expected	3	43
Other reasons	2	29
Total	7	100

Table 5 details the difficulties experienced by the respondents in using EVs. According to the respondents, 28% find EVs costly, 43% express dissatisfaction due to less battery backup than expected, and 29% mention various other reasons for their difficulties, such as difficulties in finding spare parts, servicing issues, time-consuming charging, jerking while driving, limited working hours due to battery charge, problems with the charging device, charging issues, power reduction as mileage decreases (after a certain point), easy depletion of the battery, and the inability to travel long distances.

Table 6

Reasons to think EVs Beneficial

Reasons	Responses	Percentage
No fuel cost	7	16
Easy to manage; First investment will be the last investment	8	19
Easy to manage; No fuel cost	16	37
Easy to manage; No fuel cost; First investment will be the last investment	4	9
Easy to manage	3	7
First investment will be the last investment	5	12
Total	43	100

In this study, 86% of the respondents believe that electric vehicles (EVs) offer benefits, while 14% express concerns about their negative effects. Table 6 highlights the reasons for the perceived advantages of EV usage: 16% of respondents are drawn to EVs due to their cost-saving nature with no fuel expenses, 19% value the ease of management and see the initial investment as a long-term commitment, 37% find EVs favorable for their combination of easy management and cost savings, 9% appreciate the trifecta of easy management, no fuel costs, and a one-time investment, 7% specifically cite the ease of managing EVs, and 12% emphasize that the initial investment in EVs is also the final investment, contributing to their positive perception of these vehicles.

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Chart 3 Concerns in EV Usage

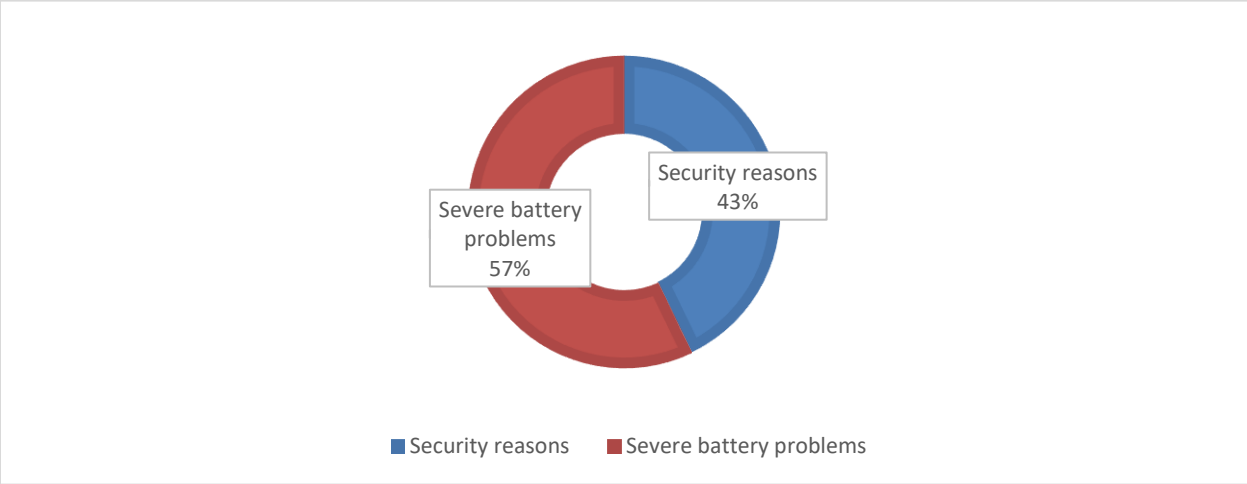

Chart 3 illustrates the reasons behind the non-beneficial use of electric vehicles (EVs). Among the 14% of respondents who have concerns about the ill effects of EV usage, 57% cite battery problems as a significant issue, and 43% express worry about the security aspect, highlighting these issues as key factors contributing to their negative perceptions of EVs.

Table 7

Environmental Advantages

Reasons	Response	Percentage
No pollution	13	26
No pollution; Any other	10	20
No pollution; Being a reason for clean environment	11	22
No pollution; Not a reason for fossil fuel use; One time investment then it is cheap; Being a reason for clean environment	2	4
No pollution; One time investment then it is cheap	4	8
Not a reason for fossil fuel use; One time investment then it is cheap; Being a reason for clean environment	2	4
It's Cheap	3	6
Being a reason for clean environment	2	4
No pollution; Not a reason for fossil fuel use	3	6
Total	50	100

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Table 7 delves into the environmental advantages of electric vehicle (EV) usage as perceived by the respondents. It reveals that 26% of the participants associate EVs with a reduction in pollution, while 20% see this benefit alongside other environmental considerations. Additionally, 22% view no pollution as a significant contributor to a cleaner environment, with 4% emphasizing the dual benefits of no pollution and decreased reliance on fossil fuels, combined with the advantages of one-time investments and affordability. Another 8% appreciate the absence of pollution and consider it as a cost-effective and one-time investment that fosters environmental cleanliness. Furthermore, 4% underline the importance of avoiding fossil fuels, making a one-time investment, ensuring affordability, and contributing to a cleaner environment. Additionally, 6% recognize the cost-effectiveness of EVs, and 4% highlight their role in promoting a cleaner environment. Lastly, 6% attribute environmental benefits to both no pollution and the absence of reliance on fossil fuels. These diverse responses collectively illustrate the multifaceted environmental advantages that respondents associate with the use of EVs.

Table 8

environmental Disadvantages

Disadvantages	Responses	Percentage
Power Usage to charge batteries	16	32
Production stage environmental impacts	6	12
Battery production and environmental damages	8	16
Battery waste and pollution	11	22
Environmental risks of dead batteries	9	18
Total	50	100

Table 8 sheds light on the environmental drawbacks observed by electric vehicle (EV) users in the sample, providing insights into the concerns raised by respondents. Notably, 32% express apprehension about the environmental impact of using grid electricity for charging EV batteries, as it often relies on fossil fuel sources, raising concerns about the environmental implications of increased electricity demand as more EVs hit the roads. Additionally, 12% worry about production inefficiencies and their associated environmental impacts, while 16% are specifically concerned about the environmental footprint of battery manufacturing. Furthermore, 22% highlight the environmental consequences of battery waste and degradation, emphasizing the need for sustainable disposal and recycling practices. Finally, 18% stress the environmental risks posed by used batteries, underscoring the importance of responsible disposal to mitigate potential environmental hazards. These responses collectively underscore the varied and significant environmental challenges and considerations linked to electric vehicle technology.

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Chart 4 Electricity Usage for Charging EVs

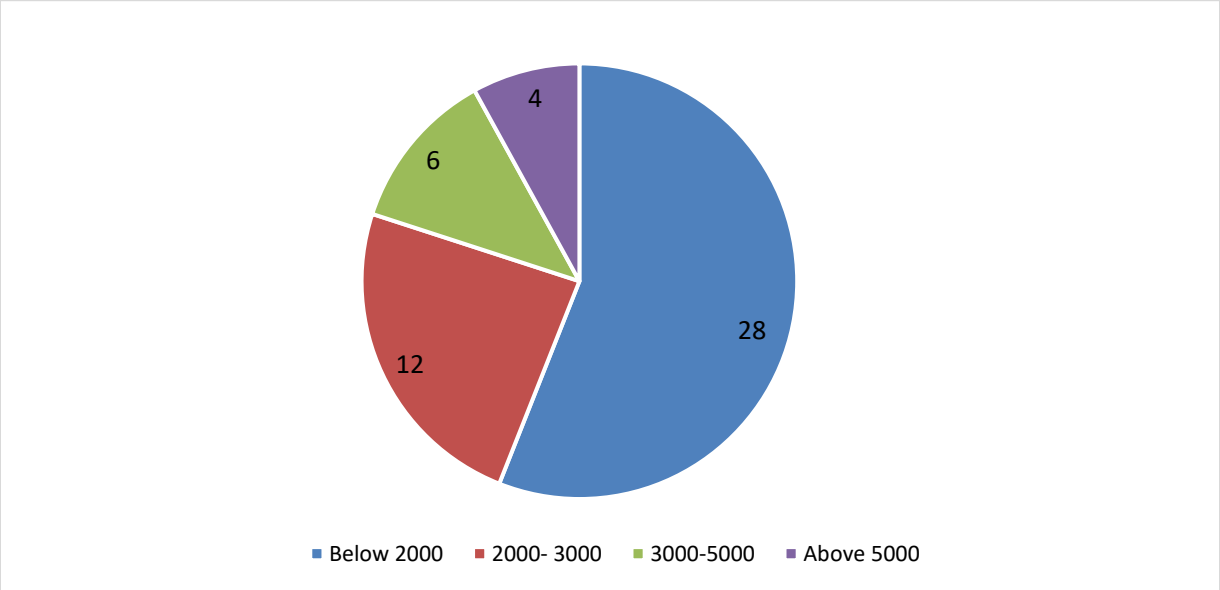

Chart 4 provides insights into the amount of electricity expenditure incurred by respondents for charging their electric vehicles. The data indicates that 28 respondents spend less than 2000 rupees, 12 respondents spend between 2000 and 3000 rupees, 6 respondents spend between 3000 and 5000 rupees, and 4 respondents spend more than 5000 rupees on electricity for charging their vehicles. This distribution offers a glimpse into the varying levels of electricity costs associated with EV usage among the surveyed individuals.

Chart 5 Various Opinion on Purchase of EVs

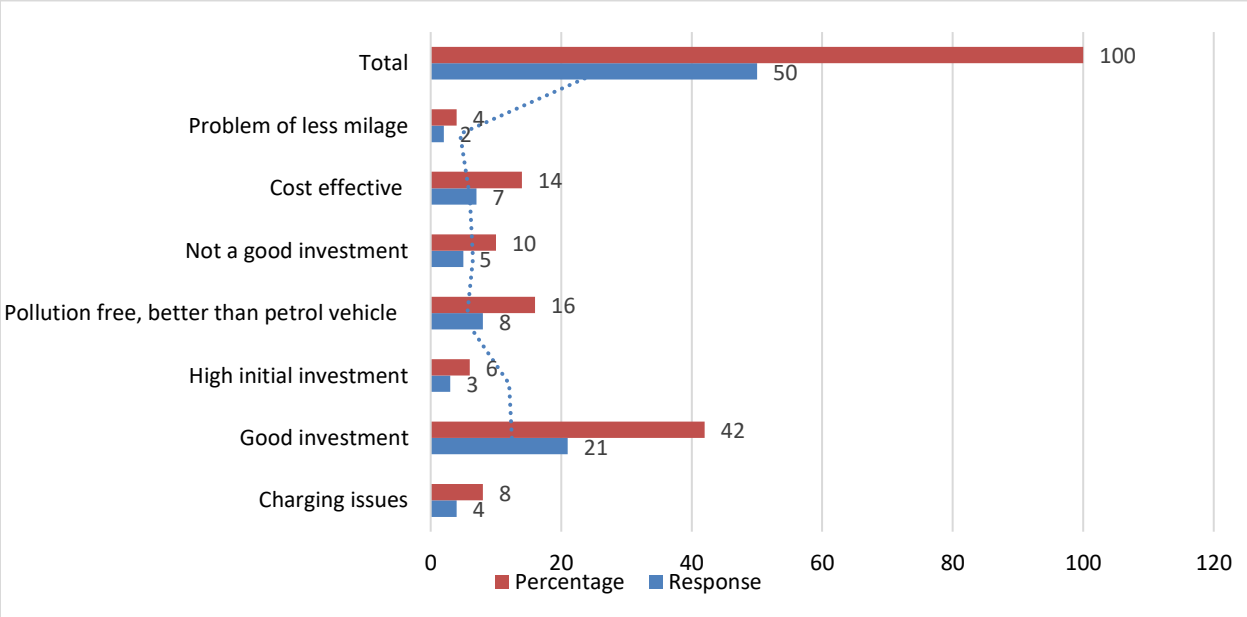

Chart 5 offers an array of opinions expressed by respondents regarding the purchase of electric vehicles (EVs). A small percentage, 4%, voice concerns about EVs' mileage, while 10% harbor doubts about their suitability as an investment. Another 6% are deterred by the high initial investment required for EVs, and

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8% raise concerns about charging issues, which act as a disincentive for purchasing EVs. On the positive side, 14% view EVs as cost-effective, 16% appreciate their pollution-free attributes, and a significant 42% believe in the benefits of EVs as a sound investment, actively advocating for their purchase. These diverse opinions shed light on the complex array of factors that influence individuals' decisions when it comes to adopting electric vehicles.

Table 9

Suggestions from the Respondents for Improvement

Suggestions	Response	Percentage
Improve charging device	14	28
Upgrade the battery	21	42
Improve the physical health of the vehicle	9	18
Ensure more mileage	6	12
Total	50	100

Table 9 encapsulates the valuable suggestions put forth by the respondents in the study. A notable 28% of the participants stress the need for improvements in the charging devices used for electric vehicles, while a substantial majority, comprising 42%, recommend upgrading battery technology, a crucial component in EVs. Furthermore, 18% highlight the importance of enhancing the physical health and condition of the vehicles, and 12% advocate for stricter measures to ensure that electric vehicles can achieve greater mileage. These suggestions collectively reflect the respondents' insights into areas where improvements are needed to enhance the efficiency, reliability, and overall appeal of electric vehicles.

Significance of the Study

The significance of the study lies in its comprehensive exploration of electric vehicle (EV) usage and perception among a diverse group of respondents. The study sheds light on the environmental benefits and disadvantages associated with EV usage, helping to understand the real-world implications of adopting this green technology. It also underscores the concerns surrounding electricity generation and battery production, which are crucial considerations in the transition to a sustainable transportation system. By capturing the opinions and satisfaction levels of EV users, the study offers insights into what aspects of EV ownership are viewed positively and negatively. This information is invaluable for manufacturers and policymakers seeking to better align EV offerings with consumer preferences and concerns. Understanding the respondents' suggestions for improvements in charging devices and infrastructure is crucial for the continued growth of EV adoption. This data can inform decisions related to charging station deployment and technology development. The study delves into financial aspects, such as initial investments and ongoing costs associated with EV ownership. This information is vital for individuals considering EVs and for businesses and governments aiming to make electric vehicles more financially accessible. The study's findings can inform policymakers in making informed decisions about incentives, regulations, and investment in EV infrastructure. It provides a real-world perspective on the challenges and benefits of EV adoption, helping to tailor policies that encourage cleaner transportation options. The recommendations from respondents regarding battery upgrades and vehicle health improvements offer valuable guidance for EV manufacturers and researchers, potentially driving

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innovation and improvements in EV technology. In summary, this study provides a multi-faceted understanding of EV usage, encompassing environmental, financial, consumer, and technological aspects. The insights garnered from this research can be instrumental in promoting the growth of the electric vehicle market and advancing sustainable transportation solutions.

Scope for Future Studies

The scope for future studies in the field of electric vehicles (EVs) is promising and can lead to a deeper understanding of the technology's adoption and impact. Here are some potential areas for further research:

Rural-Urban Comparison: Conducting a study on understanding how EV adoption differs in rural environments, where charging infrastructure and transportation needs may vary significantly, is critical for developing tailored strategies for rural electrification.

Hybrid Electric Vehicles: As hybrid electric vehicles (HEVs) represent a unique and transitional technology in the EV landscape, a dedicated study on HEV usage and user perceptions can offer insights into their role in the transition to full electrification. This research could explore user preferences, and environmental impacts associated with HEVs.

Charging Infrastructure Development: Research into the planning, implementation, and effectiveness of charging infrastructure, including fast-charging networks and smart grid integration, is crucial.

User Behavior and Acceptance: Investigating the behavioral patterns, motivations, and challenges of EV users is a dynamic field of study. Research could explore how users adapt to and interact with EVs over time, addressing issues related to range anxiety, charging habits, and the adoption of sustainable driving practices.

Policy and Regulatory Analysis: Analyzing the effectiveness of policies, incentives, and regulations in promoting EV adoption is essential. Studies can assess the impact of government incentives, emission standards, and market incentives on EV market growth.

These potential avenues for future research can contribute to a more holistic understanding of electric vehicles' role in sustainable transportation and inform strategies to accelerate their adoption and environmental benefits.

Conclusion

In conclusion, this study provides a nuanced and multifaceted exploration of electric vehicle (EV) usage, perceptions, and environmental impacts within the context of the city of Mangalore. The findings underscore the growing popularity of EVs, with a majority of respondents expressing satisfaction and recognizing the significant benefits, such as cost-effectiveness, reduced pollution, and the potential for a cleaner environment. Yet, it also highlights crucial challenges, including concerns about charging infrastructure, battery technology, and the environmental footprint of electricity generation. These insights are invaluable for shaping future policy decisions, technological advancements, and urban planning efforts as we navigate the transition to a more sustainable and eco-friendly transportation system.

Moreover, this study acts as a stepping stone, inviting further research to broaden the scope of our understanding. Future studies could expand the geographical coverage, encompass rural areas, and

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explore the intricacies of hybrid electric vehicles. As EV technology continues to evolve, there remains a wealth of opportunities for research, innovation, and collaboration to accelerate the transition towards a greener, more efficient, and more sustainable mobility future. Ultimately, the study reaffirms that the electrification of transportation is not just a technological shift; it represents a pivotal step toward a more environmentally conscious, economically viable, and responsible approach to our global transportation needs.

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