

Retrofitting of Fossil Fuel Vehicles into Electric Vehicles: An Assessment Regarding the State of Readiness Among the Vehicle Users in India

Pushkar Ram Kulkarni*, Manisha Paliwal**, Dimple Saini***, Pooja****, Omkar Bapat*****

Abstract

Rising prices in fossil fuels petrol, diesel, etc., are contributing to the interest in the Indian consumer for electric vehicles, in the form of stock-built electric vehicles, hybrid electric vehicles or aftermarket retrofitted electric vehicles. These innovations are in the early maturity phase in India, as interest in this is on the rise. The purpose of this paper is to gauge the level of the state of readiness, among the general vehicle users and owners in India, for retrofitting their conventionally fuelled vehicles into electrically powered vehicles. The findings reveal that the consensus level is rather positive, but further decisions in this area by the policy makers may need the navigation of a few challenges whose objective solution can enable the creation of a cleaner tomorrow.

Keywords: Electric Vehicle Retrofitting, Retrofitting Kits, Running Cost, Internal Combustion Engine Vehicles, Consumer Choice

Introduction

In recent times, a sort of consensus is being developed regarding the usage of eco-friendly modes of transportation, which are cleaner and sustainable, in comparison with the conventional modes of transport that use fossil fuels, over the rising concerns for the environment (Shah et al., 2021). Researchers have stated that conventionally fuelled (petrol, diesel, CNG) vehicles, although priced less than electric vehicles (purchase cost), have a higher running cost than the latter due to

the complex nature of the machinery and moving parts associated with the conventionally fuelled vehicles (Cunanan et al., 2021). There are several options when it comes to purchasing electric vehicles, such as stock-built electric vehicles, hybrid vehicles (electric + conventional engine) and retrofitting of ICE vehicles into electric vehicles using purpose-made kits. Researchers indicate that interest is high in retrofitting kit options for electric vehicles due to reasons related to price, convenience and customer sentiments for their existing vehicles (Cignini et al., 2020).

As of 2028, there will be 25,000 sales of EVs in the world (Barbier et al., 2024). On one side, new EVs are being manufactured exponentially, where 20 million EVs will be on the road by the end of 2025 (IEA, 2025). India has 22 vehicles per thousand individuals, according to information disclosed by leading experts in the sector in (Abbas & Auto, 2018), and this number is expected to increase in the future. The majority of the vehicles in the country are conventionally fuelled vehicles powered by petrol, diesel and CNG due to reasons of availability, convenience, and familiarity (Shangliao, 2023).

It is to be noted that the actual numbers of electrically powered vehicles in India rapidly in the last decade, due to reasons such as fuel economy, convenience and concern for the environment and as per latest data shared by the Government of India, India is home to 13,92,265 electric vehicles, as on date 03-08-2023 (PIB, 2022) but compared

* Associate Product Manager, Genzeon (India) Pvt. Ltd. Email: pushkarkulkarni27@gmail.com

** Head, R&D Cell, Sri Balaji University, Pune, Maharashtra, India. Email: mnpaliwal@gmail.com

*** Dean, Sri Balaji University, Pune, Maharashtra, India. Email: dsaini@sbup.edu.in

**** Research Associate, R&D Cell, Sri Balaji University, Pune, Maharashtra, India.

Email: pooja02panwar@gmail.com (Corresponding author)

***** Assistant Professor, R&D Cell, Sri Balaji University, Pune, Maharashtra, India. Email: omkr01@gmail.com

to the numbers of non-electric vehicles, teeming in the millions, the speed of their growth is not on par with their oil and CNG consuming counterparts (Pti, 2022).

When it comes to electric vehicles, customers have the option of purchasing stock-built electric vehicles or hybrid electric vehicles or getting their existing conventionally fuelled vehicles converted or retrofitted into electric vehicles, an alternative which is more economical, compared to outright purchasing of electric vehicles (Abdelkareem et al., 2021). As an alternative, retrofitting is an economic option, but researchers have indicated that there are a few challenges or kinks that need to be solved so as to smooth the path for the customers, enabling this technology to become mainstream today (Hoeft, 2021).

Interest in this technology is catalysing greater research and developmental activities into retrofitting so as to increase the number of electric vehicles, in a way that is beneficial for the citizens, economically as well as ecologically. Research studies in the realm of electric vehicle ownership in India have not yet assessed the state of readiness, within the Indian vehicular customer, regarding retrofitting of electric vehicles, and this study aims to fill in this gap to understand what the Indian vehicular consumer thinks regarding retrofitting of electric vehicles in the country. This study can be useful for policymakers, industry experts and other stakeholders as it can assist them in making decisions regarding retrofitting technologies and their myriad applications, along with designing policies regarding the same, to benefit the customer on the road in a way that is both beneficial to the country economically and ecologically.

Literature Review

Need for Electric Vehicles in India

India is one of the fastest-growing countries in the world. The rapid pace of development is necessitating the rise in the number of vehicles, as through these means of transportation, the country is catalysing its pace of growth today (Saxena et al., 2014). However, rising costs in fuel costs are necessitating the investigation of alternative options to conventionally fueled vehicles in the country. The researchers identified the following reasons for the above, post discussion with the samples and analysis of various literary studies in this topic area. They are:

- *Environmental Concerns:* As a country with a large population, India has to face several challenges regarding the ecological costs of development. The challenges include rising temperatures, noxious fumes released by conventionally fueled vehicles and the associated problems, such as the psychological effects of pollution, such as stress, anger, rage, etc. and other diseases and health conditions, such as asthma, skin conditions, stomach problems, etc. (Jain et al., 2022). Electric vehicles are comparatively cleaner than their conventionally fueled counterparts and do not cause many diseases/problems to their users or the general public. Studies have also indicated that electric vehicles play a role in the mitigation of climate change.
- *Energy Security:* India is not a major producer of vehicular fuel like petrol, diesel, CNG, etc. and has to import the same from other countries, which is not cheap for the economy. Electric vehicles, in comparison, are more economical as the main component, lithium and other energy-producing metals and compounds, are not as expensive as fuels and can last for a longer time, enabling greater savings in the long run (Digalwar et al., 2022).
- *Running Costs:* Conventionally fueled vehicles have a higher running cost than electric vehicles due to the complex nature of the engines, drive trains and other associated components. Electric vehicles. Although their initial purchase price is higher, their long-run cost is less, enabling greater economy for the vehicular customers (Bhosale et al. 2022). In addition, electric vehicles qualify for subsidies, tax exemptions and other benefits from the government, which can bring the running cost to a more economical degree.
- *Greater Convenience:* An electric vehicle is easier to learn and produces less noise than its conventionally fueled counterparts. In addition, technological advances in motor, battery and charger technology have led to improvements in terms of motor power, longer range batteries and faster charging, which is beneficial to the consumers in the long run (Jaiswal et al., 2021).
- *Government Incentives:* Electric Vehicles qualify for incentives, subsidies and other benefits such as the incentives under the Faster Adoption and

Manufacturing of Electric Vehicles (FAME) scheme of the government of India, which can result in greater savings for the customers (Singh et al., 2021). Further, investment in electric mobility technologies is resulting in the generation of new employment opportunities and the discovery of new niches in the markets, which is beneficial for the country in the long run.

Retrofitting of Vehicles Along with Their Associated Benefits and Drawbacks

The process of retrofitting involves the outright replacement of the vehicular engine with a powerful electric motor (connected directly to the drivetrain shaft, with some modifications) or a powerful battery bank, for powering up the motors bolted to the wheels. In retrofitting only, the necessary changes are made to the vehicle, preserving the original 'look' of the vehicle to ensure a similar driving experience, as had before when it was conventionally fueled (Hoeft, 2021). The following benefits and drawbacks of this alternative were identified after discussion with the samples and analysis of the literature in this topic area and are described here as follows:

Benefits of Retrofitting

The following benefits were disclosed by the samples with which the researchers interacted during the course of the study, along with studying the literature in the field. The benefits are:

- *Greater Economy and Cost Effectiveness:* Retrofitting is more economical and cost effective, as no major changes (other than replacement of the conventionally fuelled engine and associated parts) are made to the vehicle, and is an economical alternative to purchasing stock-built electric vehicles (De Santis & Regis, 2021; Zidan et al., 2025).
- *Customization:* Retrofitting permits the customers to customize their vehicles to their convenience, needs and preferences, and they can choose from various options such as the type of battery, nature and type of motor, etc., as per their convenience and the building of the vehicle (Kokate et al., 2020). In addition, if

the original design or build of the vehicle is a vintage one, through customization, one can retain the same look of the vehicle without many changes and at the same time ensure that the vehicle will run in a way beneficial to the customer.

- *Convenience to the Customer:* Customers looking to purchase electric vehicles can opt for retrofitting as it is more beneficial to them, as its overall cost is less than the outright purchase of stock-built electric vehicles, and it makes use of their existing vehicles in a good way (Aznar et al., 2021).
- *More Ecologically Friendly:* Retrofitting is more ecologically friendly as it makes use of the existing resources and can ensure a smaller ecological footprint for the vehicle, once it is retrofitted. Also, retrofitting can qualify for environmental subsidies, benefits and other options offered by the governments, leading to more money remaining in the customer's pocket (Kumar et al., 2021; Nguyen et al., 2025).

Drawbacks of Retrofitting

The following challenges were disclosed by the samples with which the researchers interacted during the course of the study, along with studying the literature in the field. The challenges are:

- *Technical Complexity of the Process:* The process of retrofitting, on paper seems simple but in practice is a complex one as the process involves making of changes of fundamental type into the vehicle, which has to be done by an expert in the field who knows the methods, processes and nuances associated with the batteries, types of motors, methods of wiring and expertise in removal and integration of the new components in ways which do not compromise the safety and the building of the vehicle to ensure compliance with the technological and regulatory standards (Watts et al., 2021).
- *Age of the Vehicle and Running Costs:* Experts have identified that there is a connection between the actual age of the vehicle (to be retrofitted) and the long-term cost of running the retrofitted vehicle, and have stated that the age of the vehicle affects deciding how cost-effective it will be in operating in

the long run. i.e. older the vehicle higher the long-term running cost (Darekar et al., 2021).

- **Compatibility Issues:** Not all vehicles can be retrofitted economically, and major changes or modifications may need to be made in exact congruence with the vehicular frame and build, for retrofitting, which might not be cost-effective for owners of such vehicles. In addition, the changes can cast doubts on the long-term viability of the vehicle if not done in a careful way (Deepak & Malladi, 2023).
- **Legal Consequences:** Retrofitting (if not done/or authorized to be done by the actual company that manufactured the vehicle) can void the vehicle's warranty. Customers can face problems, particularly related to the legal aspects of accidents and collisions, as they might face rejection from the insurance companies, due to clauses related to third-party modifications voiding the insurance claims. In addition, retrofitting will require certification and approval by the vehicular safety and regulatory agencies so as to ensure that the vehicle is safe to run on the roads (Pathak et al., 2022).
- **Difficulty in Finding Technical Expertise and Quality Kits:** Researchers state that retrofitting cannot be done by novices, as only qualified, knowledgeable and expert technical personnel can perform the changes in ways that ensure the integrity of the retrofitted vehicle in the long run. Such technical personnel are difficult to find, making this process a difficult one, as along with the qualified personnel, customers can also face difficulties in finding quality retrofitting kits compatible with their vehicle's build and design (James et al., 2022).

There is scope for future research into these challenges, so as to provide viable solutions for these lacunae, which can increase the probability of retrofitting kits being introduced on a mainstream basis for the Indian vehicular customers.

Research Model and Variables in the Study

Independent Variables: a) Vehicular safety. b) Regulatory compliance. c) Cost of ownership. d) Vehicular efficiency

Dependent Variable: a) Readiness level for retrofitting



Fig. 1: Model Created by the Researchers Depicting the Relationship Between the Variables

Hypothesis Statement

- **H1:** An increase in the level of introduction of retrofitting kits, recognized as 'safe' by the vehicular safety and regulatory authorities, can lead to a growth in the level of adoption of retrofitting as an option, regarding the acquisition of electric vehicles.
- **H2:** An increase in the level of legal compliance, as laid down by the vehicular safety and regulatory authorities regarding the build quality of the retrofitting kits, can motivate greater levels of adoption of retrofitting kits as an option for the acquisition of electric vehicles.
- **H3:** Reduction in the costs associated with battery technologies can lead to the customers choosing retrofitting as an option against outright purchase of stock electric vehicles, as it can enable them to save more money, in terms of the vehicle running costs in the long run.
- **H4:** An increase, in terms of battery mileage and on-road efficiency, can be enabled through the aegis of retrofitting kits, enabling the customers to consider the kits as a serious option, regarding the selection of electric vehicles.

Research Methodology

The researchers followed a research design, combining the elements of qualitative and quantitative data gathering (stratified random sampling) for collecting data about the samples identified by the researchers for the study.

A sample size of 200 respondents was identified by the researchers from the population in the district of Pune, Maharashtra, for the study. A questionnaire was prepared by the researchers in the form of a 'Google Form' and was shared with the samples via email and WhatsApp messaging. The questions were designed in a way, incorporated replies in the form of quantitative data in the form of a Likert scale, like responses (1 out of 5 options to be selected) from the samples. 20 questions were listed in the questionnaire, shared with the samples. Apart from the questionnaire, data were also gathered in the form of in-depth interviews with the samples by the researchers. The data gathered from the samples were subjected to a statistical analysis for the acquisition of information from the raw data, of use for the researchers so as to support the claims made by them in the study. The data gathered from the samples were subjected to a statistical analysis for the acquisition of information from the raw data, of use for the researchers, so as to support the claims made by them in the study.

Statistical Analysis of Data

Reliability Analysis of the Data

A test of internal consistency was conducted to assess the extent to the extent which the data is reliable. The results revealed a figure of '0.914', which is a measure of high reliability and indicates that the data is very consistent and is of use for the researchers, for the statistical analysis of the data for performance of accurate and meaningful measurements.

Table 1: Reliability Analysis of the Data

Cronbach's Alpha	No. of Items
0.914	20

Model Summary

Interpretation: R (Correlation Coefficient) Value: 0.821. The Correlation coefficient value is a quantity which measures the strength and the direction of the relationship of the actual values of the dependent variable along with the predicted values by the model of regression in actual terms, and in this case the value '0.821' displays a strong positive correlation, which means that there is a similar level increase in the predicted value in the 'Readiness for retrofitting' variable in congruence with the actual level increase in the variable, suggesting that the regression model is very effective in capturing the hidden relationship between the independent and the dependent variables in the study.

R Square (Coefficient of Determination): Value: 0.668. This value shows the proportion of the variance in the dependent variable that has been explained by the independent variables. In this study, approximately 67.4% of the variability in the dependent variable is explained by the model.

The Adjusted R Square value is '0.668'. The Adjusted R Square penalises the inclusion of the less relevant predictors, which in this case is 66.8% which is slightly lower than the R Square.

Table 2: Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.821	.668	.668	0.52804

ANOVA

Interpretation: The total variability within the dependent variable (Readiness level for retrofitting), which could be explained by each independent variable and residual (unexplained) variability. In this case, the Regression Sum of Squares is 124.522, which means that four independent variables combined tell us that 67.4% of the variability in readiness. The Residual Sum of Squares is 60.227, which says that 32.6% of the variability in Readiness level for

retrofitting is unexplained by the independent variables. Mean Square for Regression is 31.131, and Mean Square for residual is 0.279. The Mean Square for Regression (MSR) and the Mean Square for Residual are key measures in ANOVA that help assess the effectiveness of a regression model. MSR represents the explained variability, while MSE represents the unexplained variability.

A high MSR and a low MSE indicate a good-fitting model. In this case, the F-statistic is 111.648, which is significant at the .000 level, proving that there is a relationship

between the independent and dependent variables in the study. The 'p' value is .000, which is a figure less than .05, making the measure a statistically significant one, proving that the relationship between the independent and dependent variables is not due to chance. The results of this ANOVA indicate that the four independent variables (Vehicular Efficiency, Regulatory Compliance, Cost of ownership, Vehicular efficiency) have a significant effect on the dependent variable (Readiness level for

retrofitting). This means that these four variables are important predictors of the dependent variable, Readiness level for retrofitting. The value of F-statistics is very high (111.648), and the p-value is very low (.000), which further supports the conclusion that these variables are important predictors of the dependent variable, Readiness level for retrofitting. The model is a good fit, and it can be used to make accurate predictions about the dependent variable based on the four independent variables.

Table 3: ANOVA

	Model	Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	124.522	4	31.131		
	Residual	60.227	216	0.279	111.648	.000 ^a
	Total	184.749	220			

a) Predictors: (Constant), Vehicular safety, Regulatory compliance, Cost of ownership and Vehicular. efficiency.

b) Dependent Variable: Readiness level for retrofitting.

Coefficients

Interpretation: The unstandardized regression coefficients are the quantities that depict the change within the dependent variable, associated with a one-unit change, in the corresponding independent variable, while at the same time, holding other variables constant and providing a direct measure of the relationship between the variables in the regression model, in terms of the effect size and direction of the relationship. In this case, the coefficient for Vehicular safety is '.195', which means that for an increase in this variable on a one-unit basis, there will be a corresponding increase at a similar level in the dependent variable. The Coefficient for Regulatory compliance is '.013', which means that a one-unit increase in this variable will increase a similar volume within the dependent variable.

The Coefficients for Cost of ownership and Vehicular efficiency are .459 and .424, respectively, indicating that

a one-unit increase in either of these variables will lead to a .459 or .424 unit increase in the dependent variable. The value of the intercept is '-0.386', which means that when all the independent variables are equal to zero, the predicted value of the dependent variable is also -0.386. With reference to the data, all the coefficients are positive, indicating that all the independent variables have a positive relationship with the dependent variable. The magnitude of the coefficients also provides information about the relative strength of relationships. In this case, the coefficient for Cost of ownership (.459) is the largest, followed by the coefficient for Vehicular efficiency (.424), then Vehicular safety (.195), and finally Regulatory compliance (.013). This suggests that Cost of ownership and Vehicular efficiency have the strongest relationships with the Readiness level for retrofitting, followed by Vehicular safety and Regulatory compliance, which have the weakest relationship, among the other variables.

Table 4: Coefficients

	Model	B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	T	Sig.
1	(Constant)	-0.386	0.205		-1.88	0.061
	Vehicular safety	0.195	0.063	0.166	3.102	0.002
	Regulatory compliance	0.013	0.066	0.01	0.193	0.847
	Cost of ownership	0.459	0.059	0.424	7.741	0
	Vehicular efficiency	0.424	0.071	0.343	5.957	0

a) Predictors: (Constant) vehicular safety, regulatory compliance, cost of ownership, vehicular efficiency.

b) Dependent variable: Readiness level for retrofitting.

Summarized Table of Hypothesis

Interpretation: Based on the coefficients and the significance test we got the result that the Hypothesis H2 (An increase in the level of legal compliances, as laid down by the vehicular safety and regulatory authorities regarding the build quality of the retrofitting kits can motivate greater levels of adoption of retrofitting kits as an option for acquisition of electric vehicles) is rejected because of the significance value for this hypothesis statements is more than 0.05.

Whereas Hypothesis statements H1 (An increase in the level of introduction of retrofit- ting kits, recognized as

‘safe’ by the vehicular safety and regulatory authorities can lead to a growth in the level of adoption of retrofitting as an option, regarding acquisition of electric vehicles), H3 (Reduction in the costs associated with battery technologies can lead to the customers choosing retrofitting as an option against out- right purchase of stock electric vehicles, as it can enable them to save more money, in terms of the vehicular running costs in the long run) and H4 (An increase, in terms of battery mileage and on road-efficiency can be enabled through the aegis of retrofitting kits, enabling the customers to consider the kits as a serious option, regarding selection of electric vehicles.), are accepted because of the significance value for these hypothesis statements being less than 0.05.

Table 5: Summarized Table of Hypotheses

<i>Hypothesis</i>	<i>Reliability Statistic</i>	<i>Significance Value</i>	<i>Difference Identified</i>	<i>Result</i>
H1	0.914	0.002	0.912	Accepted
H2		0.847	0.067	Rejected
H3		0.00	0.914	Accepted
H4		0.00	0.914	Accepted

Recommendations

From the discussions made with the samples, the researchers found that there was a positive sort of interest and curiosity, regarding retrofitting kits as an economically viable option for electric vehicle mobility, as this option satisfies the customers in terms of ecology (electric vehicles are less polluting) and economy (retrofitting kits are priced less than stock build electric vehicles).

The Researchers would like to recommend that marketers should focus on other factors, apart from the safety factor of the electric vehicle retrofitting kits as the additional assurances regarding the kits, such as customer testimonies in form of videos, message posts and other related content, shared on social networks such as YouTube, Instagram, Facebook, Reddit, etc. could create a good level of publicity for the kits advertised by them, in a way which could increase the curiosity amidst the potential customers, increasing the chances of the kits to be adopted by the general public in a greater level. The researchers would like to recommend that the manufacturers and marketers of the electric vehicle retrofitting kits should create a positive word of mouth for their products in the market, via the option of free testing being offered

to prominent influencers, as the same can motivate their followers to test and verify for themselves, the features regarding safety, surety and convenience so offered by the kits, as the customers cannot be expected to rely only on the certificate of safety and legal compliances as given by the vehicular safety and regulatory authorities.

The researchers state that more investments should be directed towards vehicular battery technologies as it could result in the development of batteries which are more economical, reliable, powerful and long-lasting as these factors can motivate the potential customers to consider with a greater level of seriousness, the electric vehicle retrofitting kit as an option in case they may wish to purchase electric vehicles.

In addition, investments into the technical and non-technical aspects of the retrofitting kits can lead to rising levels of improvements in the build quality and cross-technological compatibility aspects of the kits, enabling customers to activate their kits using smartphone-based apps for extra safety or security. Future research studies can cover the above aspects so as to enable these recommendations to be transformed into reality in the days ahead.

Conclusion and Scope for Further Research

Rising costs of conventional fuel and the convenience of electric vehicles are increasing the demand for electric mobility on the roads. However, their numbers compared to their conventional fuel counterparts are low. It is to be noted that solutions are being found to the lacunae, leading to an electrifying change on the roads in India, such as increasing the number of EVs and their necessary infrastructure, along with online/offline courses related to electric vehicle management, repair and maintenance, etc. With reference to electric vehicles, customers have the option to choose from pure battery-powered vehicles, conventional fuel electric (hybrid) vehicles and retrofitting kit options for their vehicles.

Amidst these three options, retrofitting is the most economical and convenient option as it can result in the vehicle owner using his/her own vehicle for the process, resulting in savings of money and resources. In addition, retrofitting is also beneficial for the environment as the existing resources are utilized, which could increase its potential as a possible contender for electric mobility, through smart marketing campaigns done by the company's manufacturing or marketing the kits. It is to be noted that retrofitting as an alternative for electric mobility has its share of challenges, which need to be addressed, to increase its appeal to the masses and the same can be done through dedicated research studies, investments and other technical changes or developments, in congruence with the data collected from the customers and the potential customers as it can lead to beneficial changes down the road which can increase its appeal amidst the general public and can pave the way for a greener tomorrow.

There is scope for further research into the topic of retrofitting electric vehicles (EVs), and future research studies can focus on areas such as 1) Development of better and more reliable non-lithium-based batteries and battery packs. 2) Manufacturing factory-built EV powertrain conversion kits by the vehicle companies themselves, based on their popular vehicle brands. 3) Integration of electricity components such as motors, controllers, etc., into the existing vehicular architecture as part of research into the development of EV vehicle conversion kits, etc. There are more areas open to research into this topic, which will no doubt lead to many interesting research

papers and articles in the days ahead, which can pave the way for the creation of a better tomorrow.

Acknowledgement

The authors would like to acknowledge all individuals and sources that directly or indirectly supported the completion of this research.

Funding Disclosure

The authors conducted this work independently without external financial support.

Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this manuscript.

AI Disclosure

The authors confirm that no AI-based tools were utilized in conducting this research or writing the manuscript. All content is original and reflects the authors' own work.

References

- Barbier, A., Salavert, J. M., Palau, C. E., & Guardiola, C. (2024). Analysis of the Euro 7 on-board emissions monitoring concept with real-driving data. *Transportation Research Part D: Transport and Environment*, 127(2024), 104062.
- Abbas, M., & Auto, E. (2018, December 12). India has 22 cars per 1,000 individuals: Amitabh Kant. Retrieved from <https://auto.economictimes.indiatimes.com/news/india-has-22-cars-per-1000-individuals-amitabh-kant/67059021>
- Abdelkareem, M. A., Elsaid, K., Wilberforce, T., Kamil, M., Sayed, E. T., & Olabi, A. (2021). Environmental aspects of fuel cells: A review. *Science of the Total Environment*, 752, 141803. doi:<https://doi.org/10.1016/j.scitotenv.2020.141803>
- Aznar, A., Belding, S., Bopp, K., Coney, K., Johnson, C., & Zinaman, O. (2021). *Building Blocks of Electric Vehicle Deployment: A guide for developing countries*. doi:<https://doi.org/10.2172/1785089>
- Bhosale, A. P., Sharma, S., & Mastud, S. (2022). Characterizing the economic competitiveness of

- battery electric vehicles in India. *Asian Transport Studies*, 8, 100069.
- Cignini, F., Genovese, A., Ortenzi, F., Alessandrini, A., Berzi, L., Pugi, L., & Barbieri, R. (2020). Experimental data comparison of an electric minibus equipped with different energy storage systems. *Batteries*, 6(2), 26.
- Cunanan, C., Fowler, M., Lee, Y., Kwok, S., Leung, V., & Fowler, M. (2021). A review of Heavy-Duty vehicle powertrain technologies: diesel engine vehicles, battery electric vehicles, and hydrogen fuel cell electric vehicles. *Clean Technologies*, 3(2), 474–489. doi:<https://doi.org/10.3390/cleantechnol3020028>
- Darekar, R., Gawande, N., Karkaria, V., & Karandikar, P. B. (2021). Analysis of critical issues in retrofitting of ICE vehicles. *Journal of Physics: Conference Series*, 2070(1), 012151.
- De Santis, M., & Regis, F. (2021). *Modeling, simulation, and techno-economic analysis of a retrofitted electric vehicle*. 2021 IEEE International Conference on Environment and Electrical Engineering and 2021 IEEE Industrial and Commercial Power Systems Europe (EEEIC / I&CPS Europe), Bari, Italy (pp. 1-6). doi:<https://doi.org/10.1109/EEEIC/ICPSEurope51590.2021.9584594>
- Deepak, M., & Malladi, L. S. (2023). *Analysis of critical issues in retrofitting of IC vehicles to electric vehicles: A technical review*. 2023 International Conference on Advanced & Global Engineering Challenges (AGEC), Surampalem, Kakinada, India (pp. 137-140). doi:<https://doi.org/10.1109/AGEC57922.2023.0003>
- Digalwar, A. K., Saraswat, S. K., Rastogi, A., & Thomas, R. G. (2022). A comprehensive framework for analysis and evaluation of factors responsible for sustainable growth of electric vehicles in India. *Journal of Cleaner Production*, 378, 134601.
- Hoeft, F. (2021). Internal combustion engine to electric vehicle retrofitting: Potential customer's needs, public perception and business model implications. *Transportation Research Interdisciplinary Perspectives*, 9, 100330.
- International Energy Agency, Electric vehicles (IEA, 2025). Retrieved from September 1, 2025, from <https://www.iea.org/energy-system/transport/electric-vehicles>
- Jain, N. K., Bhaskar, K., & Jain, S. (2022). What drives adoption intention of electric vehicles in India? An integrated UTAUT model with environmental concerns, perceived risk and government support. *Research in Transportation Business & Management*, 42, 100730.
- Jaiswal, D., Kaushal, V., Kant, R., & Singh, P. (2021). Consumer adoption intention for electric vehicles: Insights and evidence from Indian sustainable transportation. *Technological Forecasting and Social Change*, 173, 121089.
- 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.
- Kokate, V. L., Uttekar S. S., Karandikar, P. B., & Holmukhe, R. M. (2020). *Retrofitting of auto rickshaw to e-rickshaw - A feasibility study*. 2020 First International Conference on Power, Control and Computing Technologies (ICPC2T), Raipur, India (pp. 229-234).
- Kumar, N. A., Navaneeth, M., & Joseph, A. S. (2021). *Retrofitting of conventional two-wheelers to electric two-wheelers*. 2021 13th IEEE PES Asia Pacific Power & Energy Engineering Conference (APPEEC), Thiruvananthapuram, India (pp. 1- 8).
- Nguyen, J., Bouillass, G., Saidani, M., & Yannou, B. (2025). When and how can electric retrofit of vehicles be beneficial? A critical review of environmental, circularity, and economic performances.
- Pathak, A. A., Chandrasekaran, S., & Annamalai, B. (2022). Analysis of motor vehicle accidents: Comparison between before and during the COVID-19 lockdown in Maharashtra, India. *Transportation Research Record*, 2677(4), 503–516.
- PIB, Government of India, (05 AUG 2022). Electric vehicles. Retrieved from <https://pib.gov.in/PressReleasePage.aspx?PRID=1947389>
- Pti. (2022, August 4). Over 21 crore two-wheelers, 7 crore four-wheelers and above category of vehicles registered in India. *The Economic Times*.
- Saxena, S., Gopal, A., & Phadke, A. (2014). Electrical consumption of two-, three- and four-wheel light-duty electric vehicles in India. *Applied Energy*, 115, 582–590. doi:<https://doi.org/10.1016/j.apenergy.2013.10.043>
- Shah, K. J., Pan, S., Lee, I., Kim, H., You, Z., Jin, Z., & Chiang, P. (2021). Green transportation for sustainability: Review of current barriers, strategies, and innovative technologies. *Journal of Cleaner Production*, 326, 129392

- Statista. (2023, September 18). Statista. Retrieved from <https://www.statista.com/statistics/664729/total-number-of-vehicles-india/>
- Singh, V., Singh, V., & Vaibhav, S. (2021). Analysis of electric vehicle trends, development and policies in India. *Case Studies on Transport Policy*, 9(3), 1180–1197. doi:<https://doi.org/10.1016/j.cstp.2021.06.006>
- Watts, R., Ghosh, A., & Hinshelwood, J. (2021). Exploring the potential for electric retrofit regulations and an accreditation scheme for the UK. *Electronics*, 10(24), 3110.
- Zidan, H. A., Manzoor, H. U., Azeem, F., & Manzoor, T. (2025). Evaluation of electric vehicle retrofitting challenges through a design, operation, and charging infrastructure assessment framework. *Energy Science & Engineering*.