



# Integration of Renewable Energy with EV Charging Infrastructure: A Sustainable Approach for Delhi

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## Abstract

**Purpose** – the purpose of this study is to find the barriers that Indian EV industry is facing for last 10 years. The purpose of this study is also to analyse the EV problems and how to overcome through this study in future. The design used in this paper is the literature review papers previously published. We used secondary data for this paper. This study found many EVs issues and barriers that Electric Vehicle industry is facing for the last 10 years in India. Some findings in EV industry are manufacturing of EV, sales, customer perception, EV range, EV dealer point of view and age factors. Through this study the barriers can be overcome in the upcoming years in India. Electric vehicles can be more adoptable by customers after these barriers reduced in India. This study was limited to the literature review of secondary data but on primary data. We only took last 10 years research papers in this study. This is a study to elaborate the customers with EV industry to overcome these barriers in Indian market for a greener and Eco-friendly car for consumers.

**Keywords** – Electric Vehicle technology, Eco friendly issues, Barriers, charging facilities, consumer awareness.

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## I. Introduction

The Indian automotive industry has been on verge of disruption because of the four main barriers reasons driven in electric vehicles are battery technology, charging Electric Vehicles Stations, infrastructure setups and other barriers.

Electric vehicles took place in Indian market in late 1990s, due to the lack of shortage for gasoline ([www.energy.gov](http://www.energy.gov) 2014). Electric Vehicles also granted a fresh air for sustainable development of environment. First Electric Vehicle of India was VIKRAM SARA, a three-wheeler, made by Scooter's India Pvt Ltd. A four - wheeler Electric Bus was invented by BHEL India ([www.etrion.in](http://www.etrion.in)). Hence the Electric Vehicles was invented in 19's as an option to fulfil the requirement of gasoline. At that time EV had issues like Raw materials, manufacturing factories and many more. As the Electric Vehicle was not so popular at that time and had low demand in between 2010 – 2014. As the world required a clean energy source rather than fossil fuel vehicles to clean energy vehicles like Electric Vehicle. The world showed again interest in electric vehicle and the demand also came in demand. After the year 2014 the Indian government showed interest by seeing the worlds interest in Electric Vehicles. As the requirement is initiated the factors like barriers, problems and issues also occurred. The barriers in EV are described by (Tarei et al., 2021), like technical factor, infrastructural factor and challenges faced in adoption of Electric Vehicles. To overcome this barriers India is aiming at 70% EV @2030 for faster electric vehicles adoption. Some authors stated that electric vehicles automobile establishment is not a big issue

as the customer and other brands in the Indian market (**Bhattacharyya & Thakre, 2020**). According to some study the sales of electric vehicles was very low due to the barriers and issues as compared to US dollars. Due to the inappropriate information and lack of consumer willingness the sales been low in India (**P. Goel et al., 2021**). The strength and weakness of Electric Vehicles is described by the author and the option of choice to reduce these challenges been described (**Raslavicius et al., 2015**). The growth of Electric Vehicles is highlighted by (**Raut., 2022**) with major issues in Maharashtra India.

Electric vehicles are operated with an electric motor power, which is stored in its motor. Which provide population to the car. Electric Vehicles is operated with an entire power of electricity with several varieties in India. Some Indian commercial HEVs are Toyota Prius, Honda Civic Hybrid etc. while referring the literature, authors stated that Electric Vehicles have smaller battery capacity compared to larger battery capable of HEVs, with a distance range of 20 to 60 miles.

As we searched through researching that Price was also a major factor for customers in adopting electric two, three and four-wheeler. The customers are also switching or purchasing bigger and better fossil fuels cars instead of Electric Vehicle cars due to the high price of electric vehicle. This also includes some taxes, maintenance costs and batteries service (**Indiatimes.com**).

In India Electric two-wheeler is the front runner in mobility in automobile market. We reviewed the literature and familiarize the available charging technologies and related specifications of EV. Over the years many researchers had developed many other frameworks to explain the user tendency of EV. We also established that there was a lack of literature covering the EV adoption, mainly in Indian context. In Indian context, there were very few articles on the charging technologies used by Indian vehicle manufacturers.

We have seen that most of the studies have been focused on reducing total cost with a focus of narrow down perspective. The conventional vehicles (CVs) have Internal Combustion Engines that is operated on petroleum fuel and releases a large amount of greenhouse gasses. Hence, Electric Vehicles have potential advantages but few EV barriers remain in the widespread adoption in EV technology in India currently. It also shares a small market in EV servicing. According to United States policymakers, the large electric vehicles adoption can be a sustainable solution in growth of economic with energy concerns in transportation. In the world's top three market like United States, China and Europe, the population per thousand people are around 1.6, 2.6 and 3.4 respectively. Social barriers also play a vital role as the problem in technical development of EVs in the consumer market. With an aim to manufacture EV in India and to become the global leader in EV manufacturing, **Department of Heavy Industry (2023)**. Ministry of heavy industry launched 'National Electric Mobility Mission Plan' 2020 (NEMMP) to encourage local and national EV adoption in India. Around 3% of total sales of EVs were sold in 2019, which attracted the researcher's attention about the factors effecting the adoption of Electric Vehicles. Extent literature defines many other barriers to EV. The battery range is one of the critical issues as it decides the range to be covered by the EV in a single charge. Usually, EVs have a smaller range than the equivalent ICE vehicles. Past literature indicates that the battery range has a negative influence on buying behaviour towards EVs.

India is producing its electric energy on coal-based production units. This is also a major concern that customers are preferring for solar energy-based power stations. We have also found on the literature analysis that switching behaviour is not on the basis of environmental concerns or green vehicle, but due to high prices and very few EV players in the market. The electric four-wheeler cars are expensive due to lack of technology factors also.

It cannot be denied that coal leaves behind harmful gasses by-production upon combustion. The increase in the number of electric vehicles is likely to increase the demand for electricity, which may result in a rise in emissions from thermal power plants, thus offsetting the reductions in tailpipe emissions (**Wang et al., 2018**). Perceived risk, Perceived usefulness and current financial incentive policies on consumer's are also a factor to adopt less EVs using an extended technology acceptance model. Attitude and intention also play a vital role in adoption of Electric Vehicles (**Li et al., 2017**). Consumer intentions are also a major factor in barriers to the adoption of Battery Electric Vehicles. Demographic, situational and psychological factors also separately effect BEVs (**Mohanty & Kotak, 2017**). The desired results give higher cost of EVs, challenges in battery technology, limited range of EVs, and the lack of infrastructure including consumer mindset. Some barriers have been listed out below and how they are formed by different situations are given.

### **Lack of Infrastructure Barrier**

Indian companies are trying to build the charging stations with fast and super charging in India. It will take 5 more years to establish this network. The planning of this network is under process and government is also taking part. Tata motors is the upcoming in this race which will establish around 1000 stations in Indian cities and plan to go further in future. This is due to the Lack of infrastructure gap in India. Some of the reasons behind the establishment of charging stations are new technology, lack of funds, subsidies and customers. Cheap labour and government support plays a vital role in this filed. India is capable to achieve this goal but in the upcoming years.

### **Extended charging time barrier**

While a petrol/diesel car is filled within minutes, it takes 6-8 hours to charge the electric car at home. Even with fast chargers and bigger batteries it takes between 35 and 60 minutes to get an 80% charge. EV battery technology is traded between five major attributes like cost, energy, safety, longevity and safety. The storage of energy and density determine the mass and range of battery system, respectively. These barriers are generally occurring due to the technology gap in India. Some features are started to provide functions like swapping of batteries at public shops and engagement with local service providers for faster charged batteries to be exchanged.

### **Innovations**

The innovation technics are also a factor for switching behaviour of customer for Electric Vehicles rather than hybrid electric vehicles for fast charging, wireless charging, charging stations etc, **according to (government fleet.com). (Jain et al., 2022)** described that use of technology and expected performance of EVs is also an issue among customers. Innovation is important in electric vehicles expansion and adoption. Less innovation in that technology also plays a role in barriers formation.

### **Government laws**

Government commitment, and financial constraints are the top crucial prioritized barriers for the development of the electric vehicle market in India. According to **(Digalwar and Giridhar, 2015)**. The government is focusing on 70% EV by 2030 but the main reason is the high competition among the petrol vehicle and barrier due to high taxation on EV parts and manufacturing units in India **(Chaturvedi et al., 2022)**. **(Goel et al., 2021a)** the primary concern is the government policies in Indian market is unclear for EV. Which also depends on availability and service support. **(Nimesh et al., 2021)** concluded that India, USA, and Indonesia EV acceptance are slow due to such barriers occurring. The central level policies provided to state level would play a vital role in development of EV market in India. Cheap and affordable electricity is required for charging stations in India. This process can be done in various ways like making reusable energy stations, wind power energy sources, solar powered and bio fuel gas operated converted electric stations for the development of EV market. High rate of interest on EVs around the world is also a major concern.

### **Charging infrastructure**

Charging infrastructure are divided into three categories namely as public, private, and semi-public charging infrastructures. A private spot is used by household person. Public charging spot is used by everyone and semi charging spots are only used by some registered or restricted persons only. Public charging spots are required for faster EVs and hybrid vehicles adoption, according to **(Zhang et al, 2018)**. While travelling through EV, there is a need of charging infrastructure stations to charge EVs during trips. Therefore, a high power of energy is required because they transform into motive force for vehicles acceleration. Charging infrastructure contains cables, battery charger, adapters, technology and all other things that fit to unable a plugged-in vehicle charging. This is the mainstream issue and backbone problem of less adoption of EV in urban areas. **(Koch et al., 2021)** established a challenge of local charging stations supply in Nor Wein. EV Demand has also occurred as an issue in their local.

### **SAFETY**

Concerns regarding public safety and resiliency are among the challenges that EV is facing. This is due to the storage of energy in batteries, which has higher safety risks like explosion due to overcharging and heating. New battery types, such as Lithium batteries, possess a higher energy density and thus have a higher risk. This happens when there is a temperature increase due to electricity flow, and this high temperature further influences the temperature of nearby cells, thereby leading to explosion or fire.

### **External Barriers**

Electric Vehicles are supposed to bring us more safety, relaxation, and sustainability than traditional vehicles. Electric vehicles have been introduced, but they still facing many issues and barriers such as limited travel range and lack of existing charging stations infrastructure to accommodate the increase in their numbers. **(Shalender & Sharma, 2021)** India is in intense pressure to reduce its carbon emissions which can be decreased by the Electric Vehicle's adoption and less dependence on the foreign gasoline and crude oils. They tested this model on 326 customers on purchasing EVs.

**(Nimesh et al., 2020)** The rapid increase in population and urbanization has led to an enormous increase in the overall vehicular demand. In India, most vehicles run on conventional fuels producing harmful gases and particles, causing an adverse effect on the human health & environment. Most urban cities in India are witnessing a rapid increase in the level of urban air pollution. India, 57.3% of electricity is produced through coal thermal power plant.

## II. OBJECTIVES

The objective behind this literature review is to analyse and digging out about all the critical and significant barriers of Electric Vehicles in their performance and functions. Along with that the secondary objective is to analyse the critical pain point in consumer adoption of EV in Indian persona and to Analyse the EV barriers in Indian context. To analyse the problems occurring in the wide spread of electric vehicle in India.

Q1. Why certain Electric vehicles barriers are occurring in Indian market?

Q2. What have been the points to overcome these barriers in India.

## III. METHODOLOGY

This study is based on systematic review approach, which describes about the topic of this study. We have studied various types of Electric Vehicles papers exiting at present in India and the World. Besides this, we have figured out the barriers of EV in the Indian market. The literature examined by this study contains research papers, articles and online content. The Research contains EV barriers, problems, availability of EV in market. Google scholar has been used to extract the data from research papers, articles and books content with Scopus.

## DATABASE TERMINOLOGY

The search terms included in this research is financial problems, EV price and battery issues. Based on the study and patterns, this was also the keywords searched on google scholar.

| S.no | Author(s)                    | Methodology                                                                 | Findings                                                                                                                                                           |
|------|------------------------------|-----------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1.   | Government policies          |                                                                             |                                                                                                                                                                    |
|      | (Singh et al., 2021a)        | SWOC technic was used to define the barriers.                               | No policies against high cost of lithium batteries and availability of raw materials in India.                                                                     |
|      | (Jaiswal et al., 2021)       | TAM (technology acceptance model) was used.                                 | Stated that EV are directly influenced by financial incentives, attitude of people and perceived risk.                                                             |
|      | (Sahoo et al., 2022)         | Primary and secondary data was used.                                        | Stated the barriers like subsidies and incentives with tax waive offs with central or state government.                                                            |
|      | (Chhikara et al., 2021)      | Primary data used with matric analysis.                                     | High cost of manufacturing due to raw material imports and technical issues related to product.                                                                    |
|      | (Shrimali, 2021)             | Primary and secondary data is used.                                         | Government subsidies needs to be specific and more cost-effective options for two and four wheeler Electric Vehicles.                                              |
| 2.   | Technology barrier           |                                                                             |                                                                                                                                                                    |
|      | S. Goel et al., 2021         | The author used secondary data to conduct his study.                        | Resulted that vehicle to grid technology barrier in Indian context.                                                                                                |
|      | (Tyagi & Vishwakarma, 2022)  | MMAT (mixed methods appraisal tool) is used.                                | Highlighted that technology for economic and social factor is required for betterment and development of EV infrastructure with government policies.               |
|      | (Akhtar & Patil, 2022)       | Both primary and secondary data used.                                       | Socio economic issues, government framing policies with safety of drivers.                                                                                         |
|      | (Mohanty & Kotak, 2017)      | The author used primary data for his study.                                 | Resulted that customer mindset is also affected due to the higher cost of EVs and challenges in battery technology.                                                |
|      | Khurana et al., 2020         | The author used SEM model in his study.                                     | The author explored that (ATT) attitude is a barrier in adoption of EV.                                                                                            |
| 3.   | Infrastructure barriers      |                                                                             |                                                                                                                                                                    |
|      | Tarei et al., 2021           | A literature review on Best Worst Method on the existing literature papers. | The author focused on technological, infra-structural and external barriers in Indian.                                                                             |
|      | Shukla et al., 2014          | Used Markel framework and primary data used.                                | Resulted those financial incentives for electric vehicles is a barrier in improvement of infrastructures for charging EV.                                          |
|      | (Savari et al., 2020)        | The author used primary and secondary data.                                 | Charging infrastructure is becoming a barrier in EV adoption.                                                                                                      |
|      | (Singh Patyal et al., 2021a) | MICMAC technic was used.                                                    | Recharging time, high cost, battery range are the main barriers in Electric Vehicles adoption.                                                                     |
|      | (Majumdar et al., 2015)      | Primary data was used                                                       | Electric Vehicles infrastructure is a barrier in Kolkata and it can be implemented along with road transport system to reduce this barrier at national level also. |
| 4.   | External barriers            |                                                                             |                                                                                                                                                                    |
|      | (Kesari et al., 2019)        | A literature review on EV strategies was conducted                          | More effort was needed to ensure that easy access to the local EV strategies as well as national level can be taking place.                                        |
|      | (Sankaran et al., 2020)      | The author used the primary data in his study.                              | Results indicated that Driving Range, Battery cost and Customer Pain points in EV Purchase are the challenges in India.                                            |

|  |                               |                                                          |                                                                                                                           |
|--|-------------------------------|----------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------|
|  | (Bhattacharya et al., 2022)   | The author used secondary data.                          | Results concluded that higher initial investments in buying the EVs, long term maintenance cost of EV parts.              |
|  | (Naor et al., 2015)           | The author used semi-structured interviews in his study. | This concluded that functional factors like usage, value, and risk, are the barriers in EV.                               |
|  | (S. Palaniswamy et al., 2022) | The author used secondary data in his study.             | More efforts were needed to ensure the social, economic, and environmental barriers effecting electric vehicles in India. |
|  | (Jena, 2020)                  | Primary and secondary data was used.                     | Price, maintenance and safety factors was analysed.                                                                       |

## THEMATIC ANALYSIS

In Environmental concerns the manufacturing of Electric batteries causes environmental pollution in air. So, there is a policy gap in between the government and manufacturing organisations (Vidhi & Shrivastava, 2018). It's been explored that battery swapping has to be added to public charging but users have to wait for expensive charging infrastructure to be built in India (Jhunjhunwala et al., 2018). Lack of Cost concerns can be seen in establishing large infrastructure units (Biresselioglu et al., 2018). Large scale industry landscape infrastructure is required in Indian context (Luthra et al., 2018). The strategies policies need to be emerged in Indian market as well as in global market for EVs (Singh et al., 2021b).

It is examined that Electric vehicles in India is affected by Consumer perception also (Shweta Vishwakarma., 2021). It is well observed that there is a causal relationship amongst the identified barriers. This concluded that pricing of EV is not a major issue but the consumers are more concerned about the availability and maintenance support on purchasing the vehicles (P. Goel et al., 2021). Customer demand is another factor of not increasing the sales of electric vehicles. Limited resources, re-sale anxiety and recharge time are the issues that is faced by EV customers today (Singh Patyal et al., 2021b). Customer intention and Service cost are the customer barriers in EV. Lack of social awareness blocking EV adoption in India (Michael et al., 2022). It is also concluded that Battery technology, Vehicles performance, charging station establishment cost is also very high. This also stated that sales and customer preferences are not changing towards EV (Chidambaram et al., 2022).

The next barrier in electric vehicle is Lack of confidence in customers for EV performance and safety standard measures. This also included in the customer behavioural usage of intention of EV (Bryla et al., 2023). After the customers, the dealers are also facing total cost of ownership and dealership experience based on purchasing EVs (Kumar & Alok, 2020). The individual factor also effected Electric Vehicles in the purchase intention of customers. EV barriers are also faced in aftermarket sales and have negative effect on Electric Vehicles purchasing (Krishnan & Koshy, 2021).

## IV. RESULTS

We have found that electric vehicles barriers such as charging stations, price of EV, battery replacement and infrastructure are temporary, can be over comes in future. This study also found that infrastructure and EV switching behaviour of customers are main issues faced in the adaptability of EV.

## V. CONCLUSION

On the basis of literature review and referring more than 120 papers, my study finds out that EV barriers are temporary but not permanent. This study finds out that some common factors that are affecting large EV adoptions are price of EV, customer financial situations, public charging stations. Thus, connecting with the stake holders can improve in EV sales and faster EV adoption. While applying EV adoption model in new Delhi India, it can be a role model for other states of India for faster and infrastructure establishment of electric vehicles. Government must therefore start funding in the national industries and markets by seeing the current situations of Electric Vehicles. Innovation and supply chain demand is highly required for the establishment of manufacturing units in India. Government should focus on renewable energy sources and solar charging stations in India. The research objective of exploring the local people necessities for EVs in the market was achieved through this study by analysing the EV barriers and literature review. This also conclude that while applying in smart and high-tech cities of India like Haryana, Gurugram, Delhi and UP, EV manufacturing can be at a large scale in future. This is also a research gap and further study can be done on this. The increased demand for EVs, it is necessary to analyse the main customers of EVs in the future. We hope that this study in future will help in the emerging economy of India.

## LIMITATION OF STUDY

This study is limited to Indian regions only. Only the barriers of electric vehicles have been found out. Few barriers have been excluded, due to not relevant to the study. This study mainly focuses on Delhi regions for a future role model of electric cars in India. This study is focused on the current barriers in India and not much more barriers in the last few years. Few barriers are repeatedly used in previous studies and this study also. Some barriers were found out to be temporary but not permanent. Few Indian study with global studies is also been

taken to measure the Indian barriers are as same as the others are facing. We focused on the four-wheeler segment cars in India and Delhi region.

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