International Journal for Multidisciplinary Research (IJFMR)
E-ISSN: 2582-2160 ● Website: www.ijfmr.com ● Email: editor@ijfmr.com

Impact of Electric Vehicles in Kolkata for Better City's Air (Selected Routes)

Dr. Ranita Ghosh[1], Anushree Saha[2]

[1]Faculty, Department of Geography, Vivekananda College for Women.
[2]Former Student, Department of Geography, Vivekananda College for Women.

Abstract:
Road transport is an important sector in the development of a nation. Public transport systems in India run predominantly on fossil fuels. This leads to high levels of pollution in urban areas and contributes to the growing current account deficit arising from high fuel imports. The consumption of liquid fuel in transport sector has been increasing rapidly along with increase in population and industrialization. The continuous increase in the price of fuel, gradually depleting sources of natural reserves and increasing pollution level have added to the concerns of the country. The present study examines the possible impacts on economy and environment by the implementation of battery electric vehicles (BEVs) along with the conventional road transport system in metropolitans with a case study of selected routes of Kolkata. The objectives of the present study were to examine: a) To study the growth trends of Electronic Vehicles(EV) in India and Kolkata.b) To analyse the factors responsible for EV adoption in Kolkata.c) To discuss the impact social, economic, and environmental impacts of electric vehicles (EVs), d) To highlight factors which acted as a hindrance for EV adoption and e) Some suggestions for more adoption of EVs. The present study is conducted for different types of public transportation vehicles of Kolkata like - buses (6 wheelers), cars(4wheelers) and totos (3 wheelers). The routes which are selected include AC31, AC12D and AC 4B. The bus depos like CSTC Bus Depo of Silpara, 3A Bus Stand, Jadavpur 8B Bus Stand. And Garia Toto stand and E-rikshaw stand of Thakurpukur. About 100 individuals including drivers, conductors, helpers, and vehicle owners have been surveyed through personal interviews to gather the required information. Ten random fuel stations have been selected to collect data regarding fuel stations. The owners, managers, and workers of the fuel stations have been interviewed with pre-formatted questionnaire.The results of the analysis show that Kolkata's green drive shows rising EV adoption, supported by FAME incentives but hindered by high costs.
Replacing diesel vehicles with EVs reduces major pollutants and offers carbon trading benefits.
EVs bring clear economic savings in daily and monthly energy costs compared to conventional fuels.Adoption remains income-dependent, with higher earners more willing, while affordability limits lower groups. EV adoption requires a dual approach: policy shifts toward mandates and localized supply chains, alongside research into advanced batteries, smart charging, and sustainable recycling to ensure long-term affordability and sustainability.This balance of regulation and innovation creates a clear roadmap for accelerating the transition to clean mobility

Keywords: Electric Vehicle, FAME, Energy consumption, environmental pollutants.

INTRODUCTION

The transport sector is one of the pillars of development for any county but the consumption of liquid fuel in transport sector has been increasing rapidly along with increase in population and industrialization. Gradually depleting sources of natural reserves, high fuel import, price hike of fuel, subsidization and increasing pollution level have create the need for renewable and environment friendly products. One of the ecofriendly discoveries is electric vehicles (EV). Electric Vehicles (EVs) and supporting technologies

and services represent new economic pathways in India to increase energy security (avoid oil imports), reduce carbon emissions (reduce greenhouse gas emissions) and improve air quality (better human health). EVs contribute significantly to SDG 7, which is focused on ensuring access to affordable, reliable, sustainable, and modern energy for all. By transitioning from fossil fuel-powered vehicles to EVs, we can significantly reduce reliance on non-renewable energy sources.

A study on electric vehicles (EVs) in Kolkata is grounded in the urgent need to address severe urban air pollution, improve public health, and transition towards sustainable urban mobility. The rationale for studying EVs in Kolkata lies in the confluence of environmental necessity, policy shifts, and the need for infrastructural adaptation.

The present study examines the possible impacts on economy and environment by the implementation of battery electric vehicles (BEVs) along with the conventional road transport system in metropolitans with a case study of selected routes of Kolkata.

Electric Vehicle Definition:

Battery Electric Vehicles (BEVs) Battery Electric Vehicles are complete electric vehicles that are powered by only electricity and do not include a petrol/diesel engine, fuel storage or exhaust pipe. They use electric motors and motor controllers for propulsion.

They do not have an internal combustion engine. They charge the battery through external charging outlet and hence also known as "Plug-in Electric Vehicles (PEVs)". There are various types of BEVs such as electric cars, buses, bikes, scooters, trucks and trains. They even include fewer parts than those used for those vehicles based on internal combustion engines. They even produce fewer noises compared to their counterparts.

Different type of Electric Vehicles:

- **Battery Electric Vehicles (BEVs):** This type of is completely powered by only electricity and do not include a petrol/diesel engine, they use electric motors and motor controllers for propulsion.
- **Hybrid electric Vehicle (HEVs):** This type of EV is a combination of internal combustion engine and electric propulsion systems.

The Government of India has taken some initiative several such as:

- The National Electric Mobility Mission Plan (NEMMP)
- FAME (Faster Adoption and manufacturing of hybrid and Electric Vehicles Scheme, launched in 2015.

STUDY OF LITERATURE

Palaniswamy Sivakumar, R S Sandhya Devi, Saravanan M and Anand M (2022) in their paper on Social**,** Economic and Environmental Impact of Electric Vehicles in India gave a general overview of the social, economic, and environmental impacts of electric vehicles (EVs) in India. Vashisth Renu and Gupta Jyoti (2021) in their paper on Consumer Perception Towards Electric Vehicle includes what are the various factors that affect the overall perception of a consumer towards an EV and whether or not those factors have a relationship with the perception towards the electric vehicle. Basu Rakhi in her article on Electric Bus Operation in Kolkata City discussed several questions about the challenges of EVs in Kolkata. Report of The Energy and Resources Institute (TERI) on "A Case Study of Kolkata" (2020) states that Kolkata, the city of joy has been passionately running tramway, an electrical mode of transport in the streets of the city since more than a century. Just like the trams, the city has introduced electric vehicles with an aim to decarbonize the transport sector and pioneers nationally in the operations of electric buses for public transport. The Kolkata Gazette (2021) published by Power Department of West Bengal states about various schemes, incentives allocation and policies related to EVs in Kolkata.Gobczyński Karol and Leroux Maxime (2011) in their paper on Socio-economic factors influencing the electric vehicle buying

process in Iceland proves that Iceland is an attractive place to start implementation of EV not only because of technical and environmental advantages, but also thanks to inclined population mindset. Simran Ahuja and Manisha Raj (2022) in their paper on Social and Economic Impact of Hybrid Electric Vehicles on Environment: An Indian Case Study examines the economic and social aspects that influence the hybrid electric car market in India. In a report of Impact by ESMAP 2021as published an article titled India: Transition to Electric Vehicles Puts Kolkata on The Road to Clean Transport. The study stated Decarbonizing transport is critical to achieving the world's climate change goals, as well as being a key component of a sustainable, livable, and energy-efficient city. Report on Implementation Plan for Electrification of Public Transportation in Kolkata (2017) by Shakti Sustainable Energy Foundation states that in India, transportation sector emissions are a significant contributor to the deteriorating air quality and human health in cities. With the rapid acceleration of the Indian automobile markets, battery powered electric vehicles (EVs) represent a promising pathway towards improving air-quality, energy security (avoiding oil imports) and economic opportunities. Pirmana Viktor, Alisjahbana Armida Salsiah, YusufArief Anshory, Hoekstra Rutger and Tukker Arnold (2023) published their paper on Economic and environmental impact of electric vehicles production in Indonesia the study concluded that electric vehicle production increases productivity, gross value-added, and job creation with a relatively small impact on the environment. Majumdar Deepanjan, Majhi Bijoy Kumar, Dutta Atanu, Mandal Ratan, Jash Tushar (2015) made a paper on Study on possible economic and environmental impacts of electric vehicle infrastructure in public road transport in Kolkata. The study has shown that the electric vehicle infrastructure may be implemented along with the conventional road transport system and it has the potential to be beneficiary from both economic and environmental aspects. Government of West Bengal Electric Vehicle Ecosystem Policy 2022 discusses about EV policy in West Bengal.

Research Gap

From the literature review it is seen that the areas needing further investigation include:

- **Environmental & Energy Gaps:**
  - **Grid Integration:** Research is required to ensure that charging uses renewable energy, reducing the overall carbon footprint.
  - **Sustainability Impact:** The long-term environmental consequences of battery disposal and recycling technologies need deeper investigation.
- **Consumer & Behavioral Gaps:**
  - **Range Anxiety:** The fear of running out of power remains a significant barrier to long-distance travel and adoption.
  - **Customer Knowledge Gap:** A lack of clear, accurate information causes misconceptions about battery life, resale value, and environmental impact.
  - **High Initial Cost:** Research into cost-effective manufacturing and market strategies to make EVs competitive with internal combustion engine (ICE) vehicles is needed.
- **Infrastructure & Policy Gaps:**
  - **Policy Support:** More research into effective government policies and infrastructure planning is required to support the transition, especially in developing nations.

Objective

The objectives of the present study were to examine:

- To study the growth trends of EV in Kolkata.
- To analyse the factors responsible for EV adoption in Kolkata
- To discuss the impact social, economic, and environmental impacts of electric vehicles (EVs)
- To highlight factors which acted as a hindrance for EV adoption

METHODOLOGY:

The methodology of the study has been divided into three steps

Pre field: This stage involves collection of different secondary data and maps. Questionnaire was prepared to collect primary data through survey.

Field Work – About 100 individuals including drivers, conductors, helpers, and vehicle owners have been surveyed through personal interviews to gather the required information. Ten random fuel stations have been selected to collect data regarding fuel stations. The owners, managers, and workers of the fuel stations have been interviewed with pre-formatted questionnaires This step involves visiting the study area to collect primary data by surveying.

Post Field – This included the analysis of data gathered with the help of maps and diagrams. The selection of formula or related methods and techniques of quantifications were made. Various cartographic techniques bar graphs, pie graphs, line graphs, scatter diagrams of the study area were prepared using Map info, a GIS software, analyzed and interpreted.

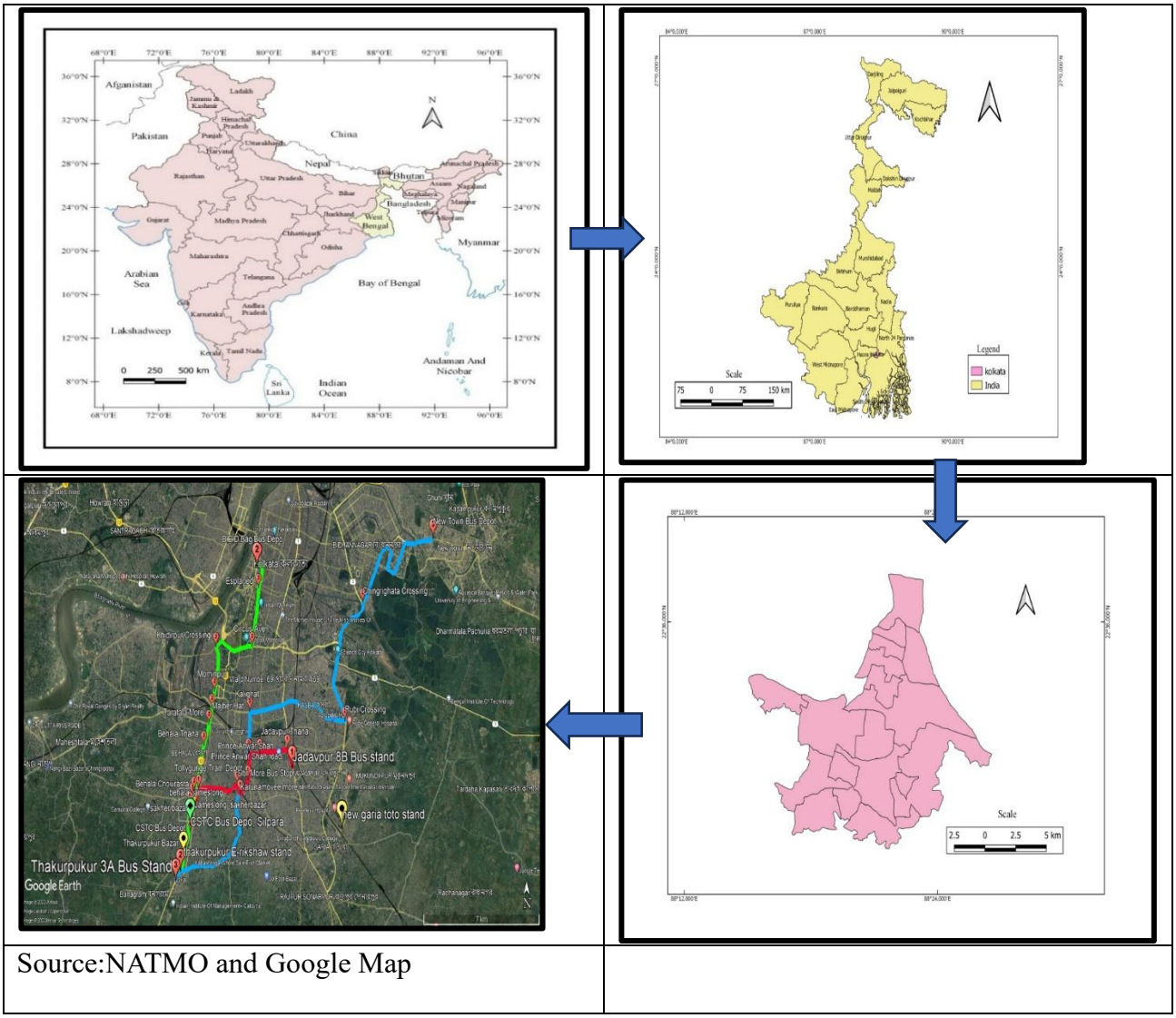
STUDY AREA

Kolkata has been chosen for the study, as it was the first city in India that introduced public transportation system running on electricity and represents a unique opportunity to leverage the electricity infrastructure for accelerated and cost-effective EV deployment

According to the World Health Organization Kolkata is also the twentieth most populated city in the world, and lists third among the Indian urban cities. Electrification of public transport will represent one of the most promising pathways to increased energy security and improved air quality in the city that retains Kolkata's spirit of electrification of public transportation.

The present study is conducted for different types of public transportation vehicles of Kolkata like - buses (6 wheelers), cars(4wheelers) and totos (3 wheelers). For Buses the chosen routs are Ac31, Ac12D and Ac 4B. The bus depos like CSTC Bus Depo of Silpara, 3A Bus Stand, Jadavpur 8B Bus Stand. And Garia Toto stand and E-rikshaw stand of Thakurpukur. (Fig No.2)

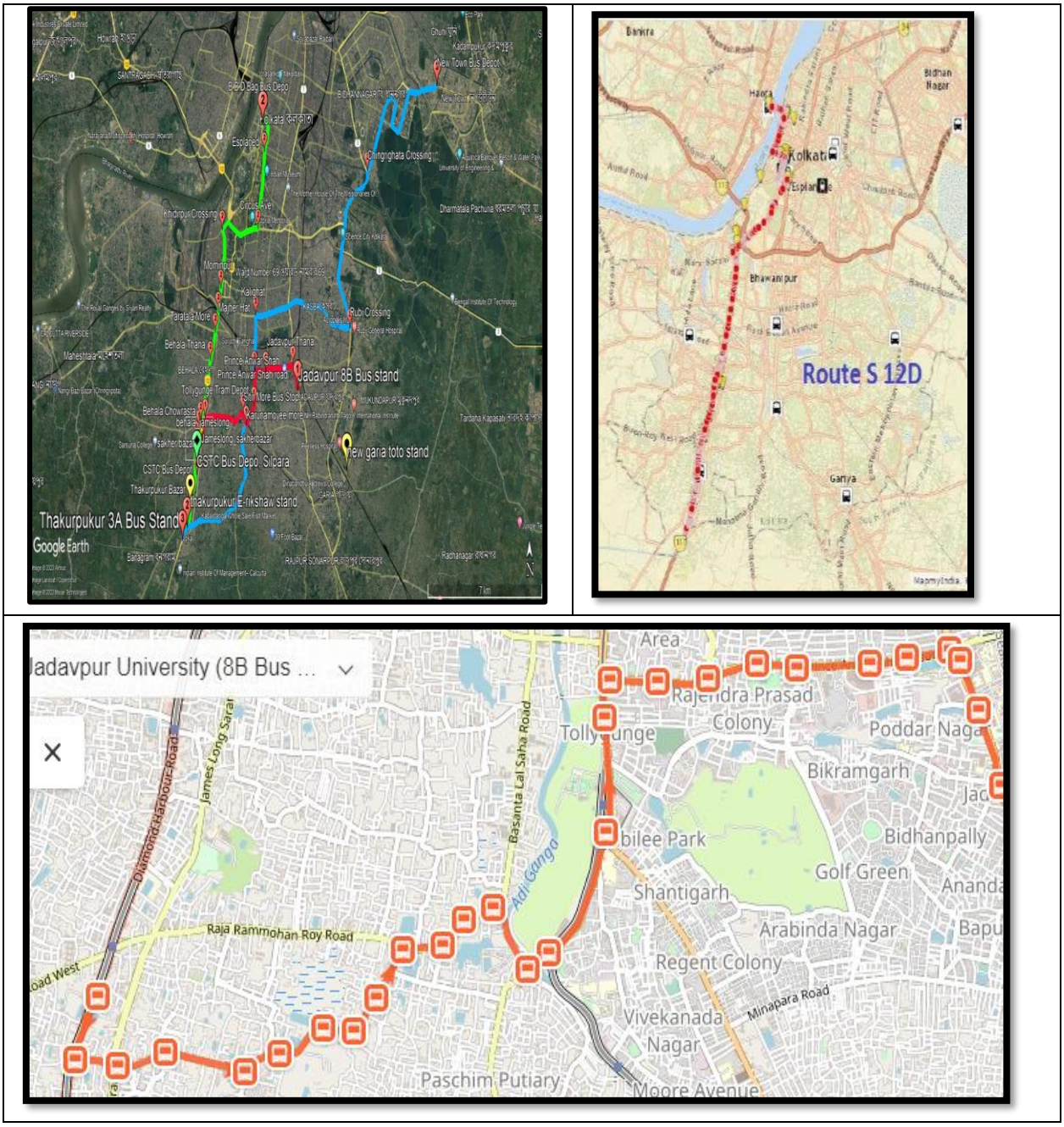
LOCATION MAP



Source:NATMO and Google Map

Fig No.1
Source: NATMO and Google Map

Some of the selected Routes



Source: NATMO and Google Map Fig No.2

DISCUSSION

Green Drive in Kolkata

- The Public Vehicles Department (PVD) reported **a sharp rise in the registration of battery-operated electric vehicles throughout 2022.**
- **Mostly in the personal vehicle category,** there were 837 such registrations throughout the year, up from 196 in 2021, 21 in 2019 and just 10 in 2018.
- Over the same period, 2,931 diesel vehicles - among the most polluting - were registered, again in the personal vehicle category, down from 4,498 in 2019 and 6,415 in 2018. (Fig No.3)

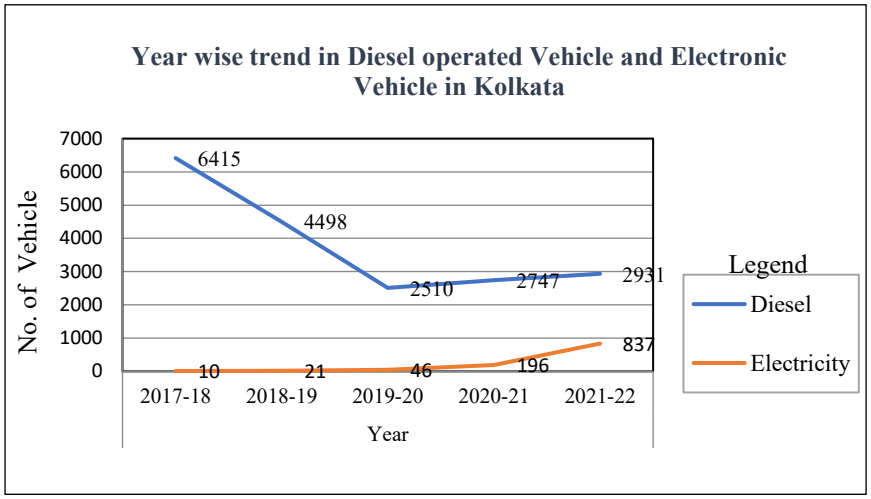


Fig No.3
Source: PVD Report

- Increasing shift towards cleaner fuels, such as CNG (compressed natural gas), petrol/CNG and petrol/hybrids.
- The city registered 20 CNG vehicles**, even though CNG refuelling stations are insignificant.**
- A number of people were going for **hybrids** because of the absence of charging infrastructure, said

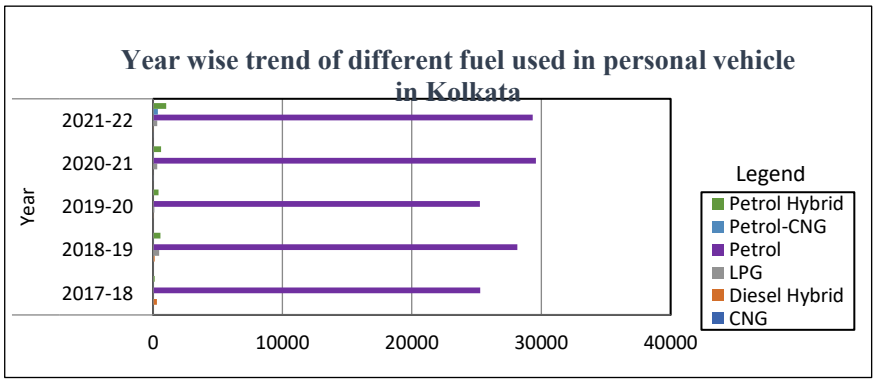


Fig No.4
Source: PVD Report

Faster Adoption and Manufacturing of Hybrid and Electric Vehicles (FAME) Scheme which was launched in April 2015 under the National Electric Mobility Mission, to encourage electric and hybrid vehicle purchase by providing financial support.

FAME II Scheme Components:
The phase II scheme of West Bengal for the Electronic Vehicle transportation, is titled as FAME II was implemented over a period of 3 years 1st April 2019. An overall outlay of Rs. 10,000 Crores.

- According to the Kolkata Gazette published by Power Department of West Bengal it can be seen that the **demand incentives were increased in terms of 2019-2020's allocation from 2021-2022.**
- The fund in **2019-2020 is 822 crores**, where it **increased as 4587 crores in 2021-2022 and 3187 crores in 2021-2022,** where the total fund requirement is 8596 crores.
- In charging station infrastructure, the total fund requirement is Rs.1000 crore but the allocation in 2021-2022 is Rs.300 crores.

- **Administrative infrastructure component has the less total fund**, which is Rs.38 crore and the allocations for every year is almost same, Rs.13 crores., so **the total allocation for FAME II is 9634 Crore.** (Fig No.5)

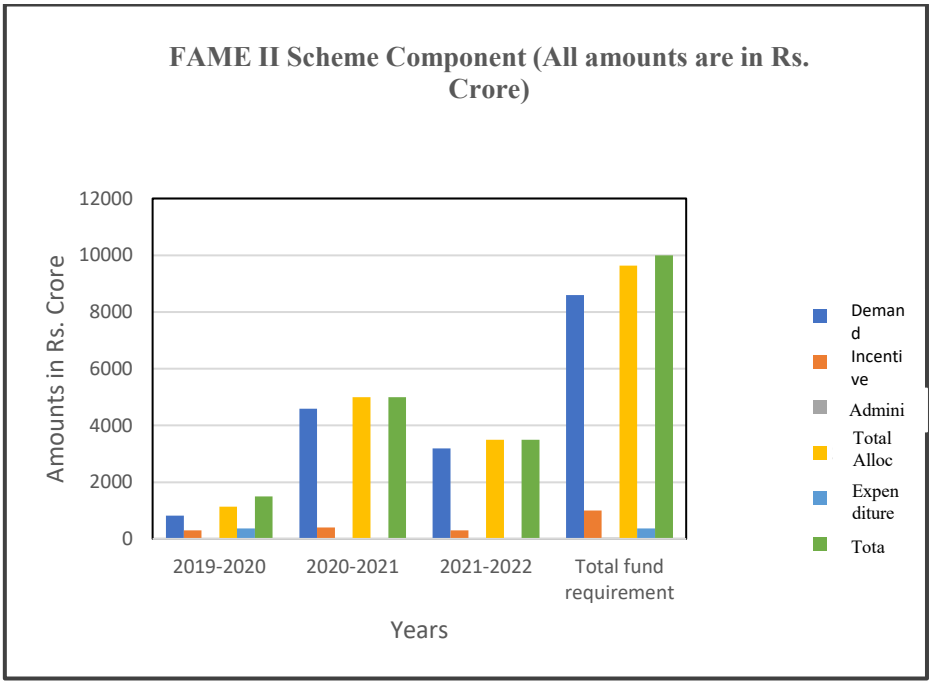


Fig No.5
Source: Kolkata Gazette

Maximum no of vehicles supported under Scheme:

- Here maximum no of vehicle seen for **Two-Wheeler** about 1,00,000.
- The number of three wheelers including **E-Rikshaw** also has huge number support which is about 5,00,000.
- E-Four-wheeler has 35,000 number of Vehicles support, 4W strong Hybrid Vehicle has 20,000 number of vehicle support.
- But the lowest allocation for the number of supports for **E- Buses** were seen, which is only 7,090. (Fig No.6)

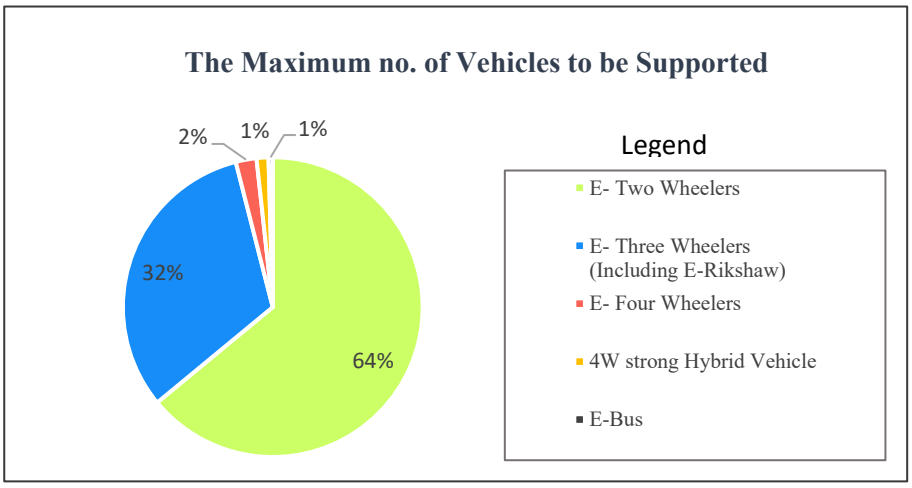


Fig No.6
Source: Kolkata Gazette

Total Approx incentives:
In Different Electronic Vehicle, the total incentive Allocations also fixed according to 1000/KWH for all vehicles and 20000/KWH for buses and trucks. **E-Two-wheeler has the allocations about Rs. 20,000, E-Three-Wheeler including E-Rikshaw has Rs. 50,000, E- Four-Wheeler has Rs. 1,50,000 and 4W strong Hybrid Vehicle has the allocation of 13,000. The highest incentive is for E-Buses which is 50,00,000**. (Fig No.7)

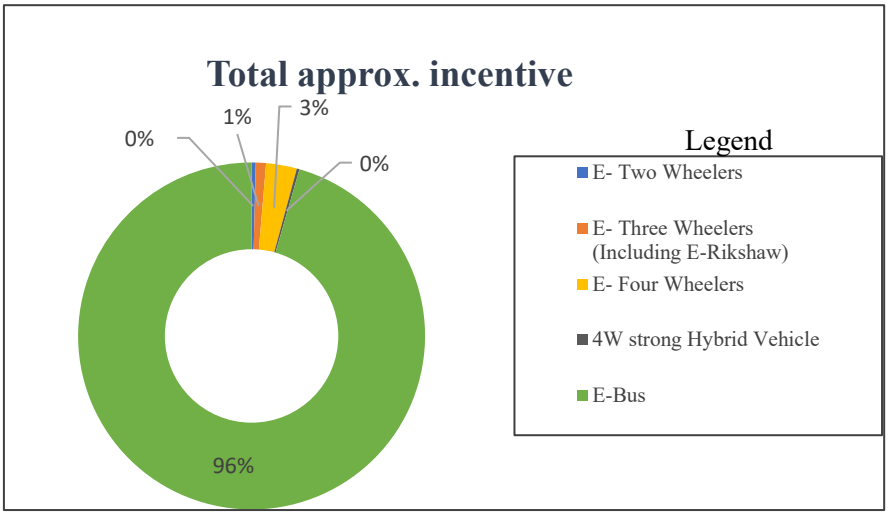


Fig No.7
Source: Kolkata Gazette

SOCIO-ECONOMIC FACTORS INFLUENCING THE ELECTRIC VEHICLE BUYING PROCESS
The aim of this study is the analysis of the socio-economic factors that would influence consumer buying process of electric vehicles in Kolkata. The purpose of the research is to detect the most crucial factors influencing the surveyed populations decisions for and against purchasing an electric vehicle, instead of car with internal combustion engine.

- **Reasons for Buying EV:**

Most of the people about 41% people was interested to buy an EV because of the lower electricity cost than the fuel cost, after that the energy Independency reason comes in second position which is about 26.12%, and environmental benefits comes in third position. There also some other reasons like trends, uniqueness, or innovation technological interest which all have least consideration in terms of buying an EV. (Fig No.8)

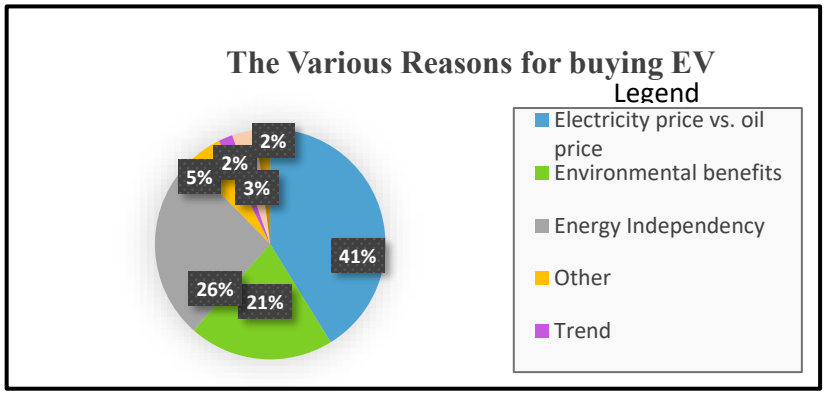


Fig No.8
Source: Primary data

The most Significant Advantage of EV:

There are some significant advantages of Electronic Vehicles, among them the most significant is Lower price of electricity which holds 40.30%, next the use of domestic recharge holds the second position about 24.49%and there after greenhouse reduction holds about 18.31%, noise reduction also second significant advantage which is 12.08%. the other advantages like convenience in urban transport and performance and durability advantages hold least value respectively. (Fig No.9)

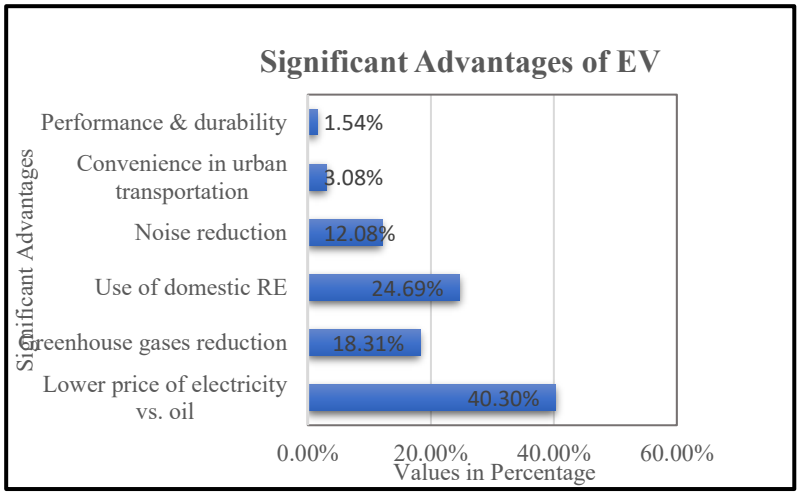


Fig No.9
Source: Primary data

Survey of impact of Age, Gender and level of education on perception of EV

- **Willingness of Replacing actual car by an EV vs. Age:**

In the age range of 18 to 25 which are the young generation are very much willing to replace their actual car (38.46%). In the Age group of 26 to 45, again more people are willing to replace than the not willing. And in last age group which is 46 to 65 years are majority of the people like 21.54% people in this category are not willing to replace their actual car. younger generation with good knowledge is more aware of environmental degradation, and aware of the benefits of EV in the Air Quality development in terms of air pollution. (Fig No.10)

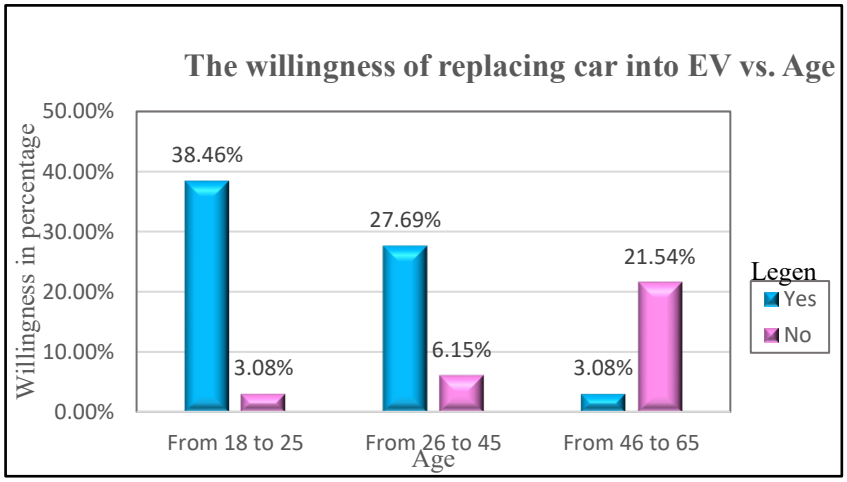


Fig No.10
Source: Primary data

- **Willingness of Replacing actual car by an EV vs. Level of Education:**

The educated people are willing to replace their actual car (20%). Post graduation and Graduation Education level group willing to replace their car into EV about 18.46% and 12.30% respectively. willingness of replacing seen in higher secondary age group (4.61%). least willingness seen in the group of literates to secondary level educational group, the more educated people are aware of environment health and technological advancement. (Fig No.11)

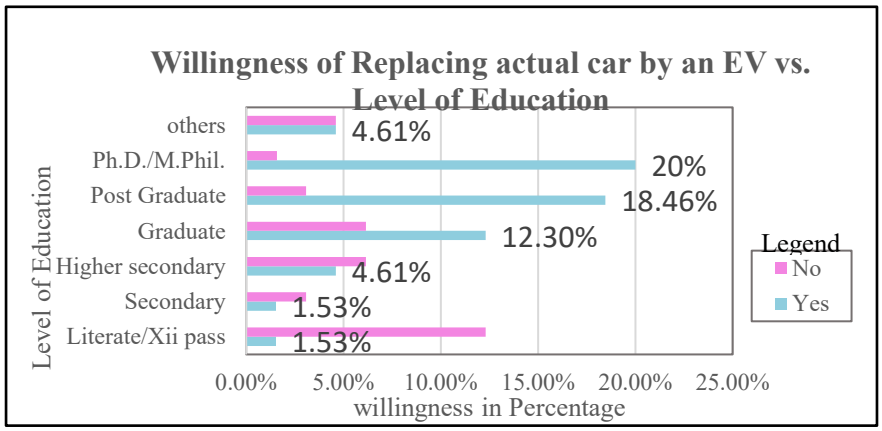


Fig No.11
Source: Primary data

- **The Most important barriers according to the use of EV car**:

Here the most important barrier according to the use of EV is seen Price Barrier and Range Barrier. People most of the time is not interested to buy an EV just because of its higher price, that's why it holds an excessive percentage (60%). On the other hand, range barrier is also another cause of lacking the use of EV. EVs are most of the time is not appropriate for long journey, because it needs high electric consumption according to its long-range journey, so here we can see 40% holds by price barrier. (Fig No.12)

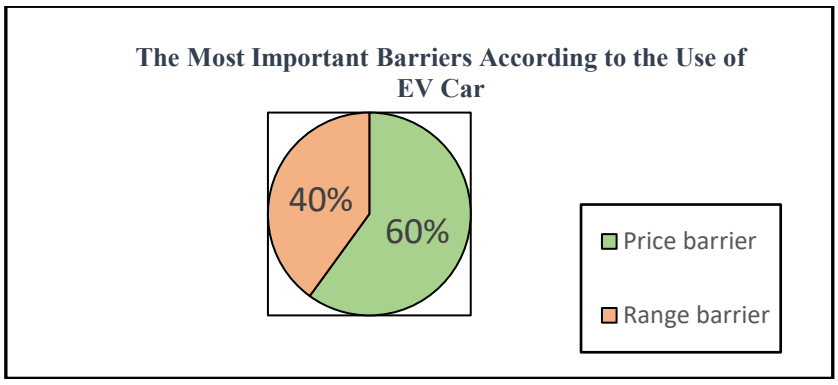


Fig No.12
Source: Primary data

Economic, Environmental and Social impact of Electric Vehicles (EVs)

The major impact has been observed in controlling the vehicular emission with a decrease in CO_2 level by 26.27 t per day, on replacement of only 2 % of the present public transport by suitable BEVs.

Pollutants emitted by buses and taxis in India:

- The major air pollutants released from an automobile are **CO_2, SO_2, N_2, CO, CH4, HC (hydrocarbon), and PM (particulate matter)**.

- In case of Kolkata, the road transport sector has an emission level of **129.54 t of CO_2**, **65.59 t of NO_2**, **51.02 t of HC**, and **10.13 t of PM** a day These pollutants have been formed mainly due to the combustion of the fuel used for vehicle propulsion (in this case, diesel).
- The combustion of 1 liter of diesel emits 2.71 kg of CO_2, 8.9 g of SO_2, and 2.9 g of NO_2. (Fig No.13)

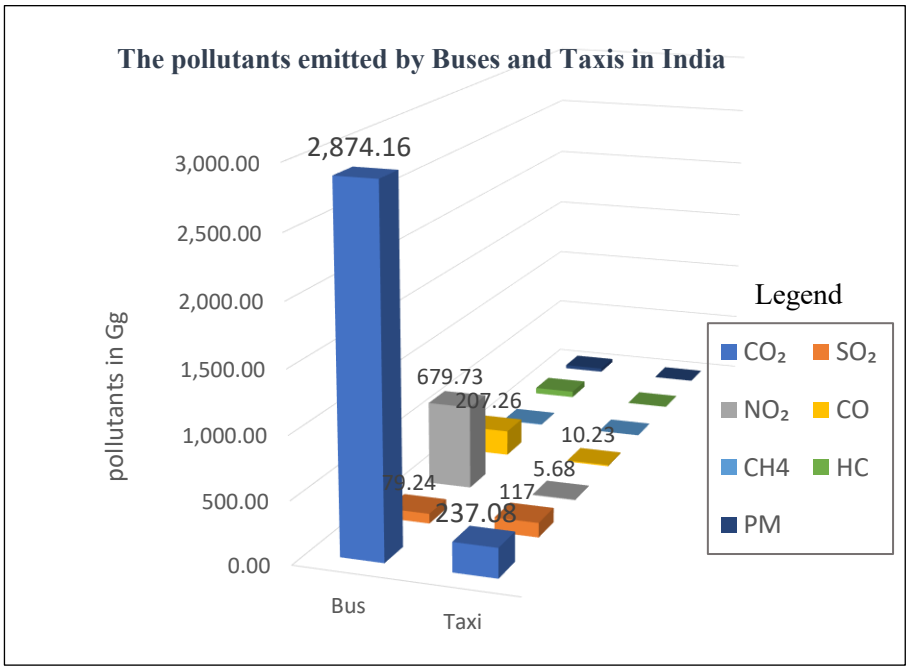


Fig No.13
Source: Secondary data from report of Deepanjan Majumdar ,2014

Reduction in emission of pollutants in Kolkata:
By replacing 2 % diesel-using vehicles by battery-operated electric vehicles in Kolkata, diesel consumption can be reduced by 11,654 l per day. Therefore, the quantity of CO_2 emission is reduced per day by 26.27 t, SO_2 by 0.972 t, and NO_2 by 0.209 t. (Fig No.14)

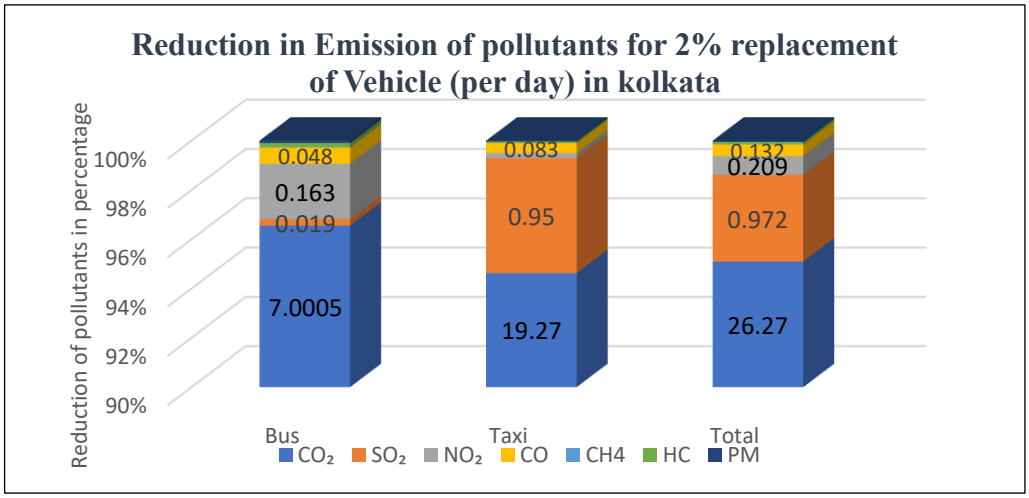
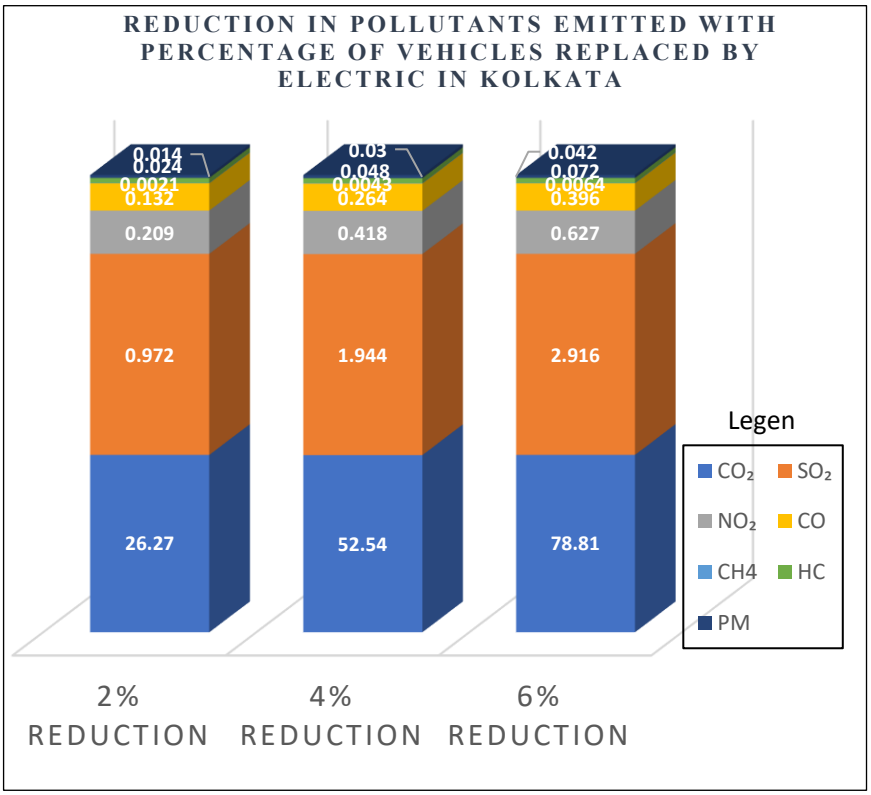


Fig No.14
Source: Secondary data from report of Deepanjan Majumdar ,2014

Reduction in pollutants emitted with percentage of vehicles replaced by electric vehicles in Kolkata: The emission of pollutants from the transport sector can be reduced further by replacing more vehicles using conventional fuel with battery-operated electric vehicles. This has been mainly due to the incomplete combustion of fossil fuels (diesel, petrol, LPG, etc.). Now, if the vehicles using conventional fuels can be replaced by battery-operated electric vehicles, the carbon-containing pollutants released into the atmosphere can be reduced. This can benefit in the context of carbon trading. If the amount of carbon emitted into the atmosphere can be reduced significantly the government can sell credits of CO_2 to countries which have exceeded their permissible carbon limits (as per the norms in the Kyoto Protocol), thereby gaining economic benefits. (Fig No.15)



Source: Secondary data from report of Deepanjan Majumdar ,2014 Fig No.15

ECONOMIC IMPACT

Fuel consumption and fuel cost for conventional fuel in Kolkata:

- As the **conventional bus** covered maximum average distance per day it consumed maximum Fuel (Diesel), cost of diesel is about **4625 INR** per day.
- **In taxi** consumed about 18 litre diesels in a day, cost of fuel is about **1665 INR.**
- The **Auto-Rikshaw** have less average consumption of fuel (LPG), so it has the less cost for energy consumption per day which is about **322.35 INR**. (Fig No.16)

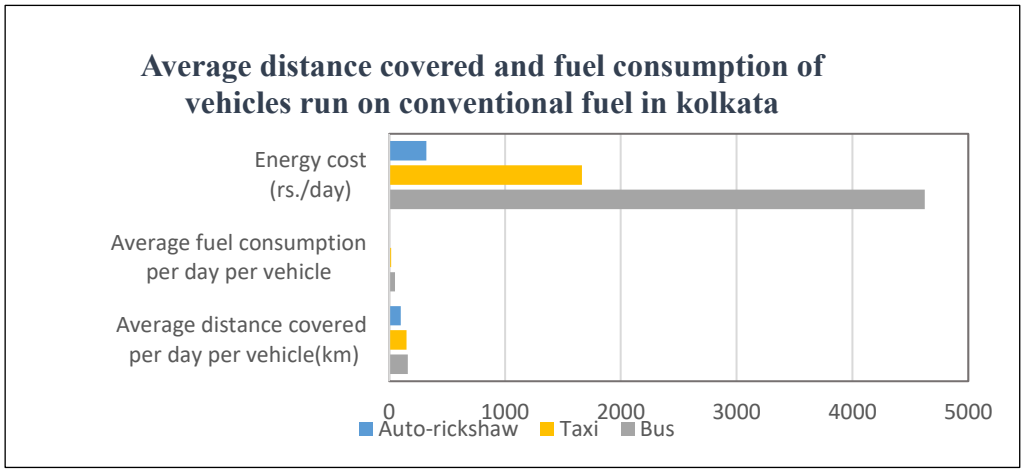


Fig No.16
Source: Secondary data from report of Deepanjan Majumdar ,2014

Energy consumed and energy cost for electric vehicles in Kolkata:

- As the E-bus covered maximum average distance, the daily cost of electricity is about **2240 INR per day**.
- In E-taxi we can see that the vehicle consumed about 36 KWH energy in a day, cost of energy is about **504INR.**
- The toto-Rikshaw have the less cost for energy consumption per day which is about **84 INR.** (Fig No.17)

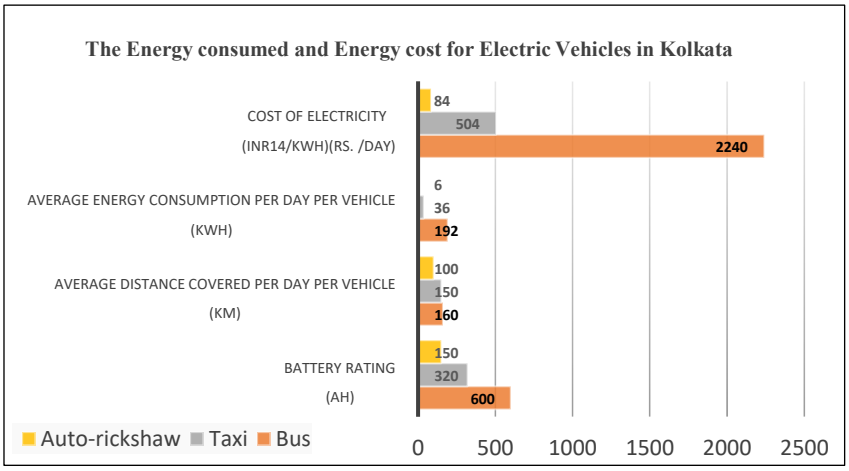


Fig No.17
Source: Secondary data from report of Deepanjan Majumdar ,2014

Cost comparison to run electric vehicles charged from different sources of electricity:

- Different sources of charging electric vehicles, such as, **Conventional Grid, Solar PV Tech, Solar bmg Hybrid.**
- The lowest cost can be seen from conventional grid. which is cost only Rs. 7.95/kWh.
- The second position is the solar bmg hybrid, which cost rs.10/kWh.
- Comparatively costly source is Solar PV tech which is Rs. 12.77/kWh. (Fig No.18)

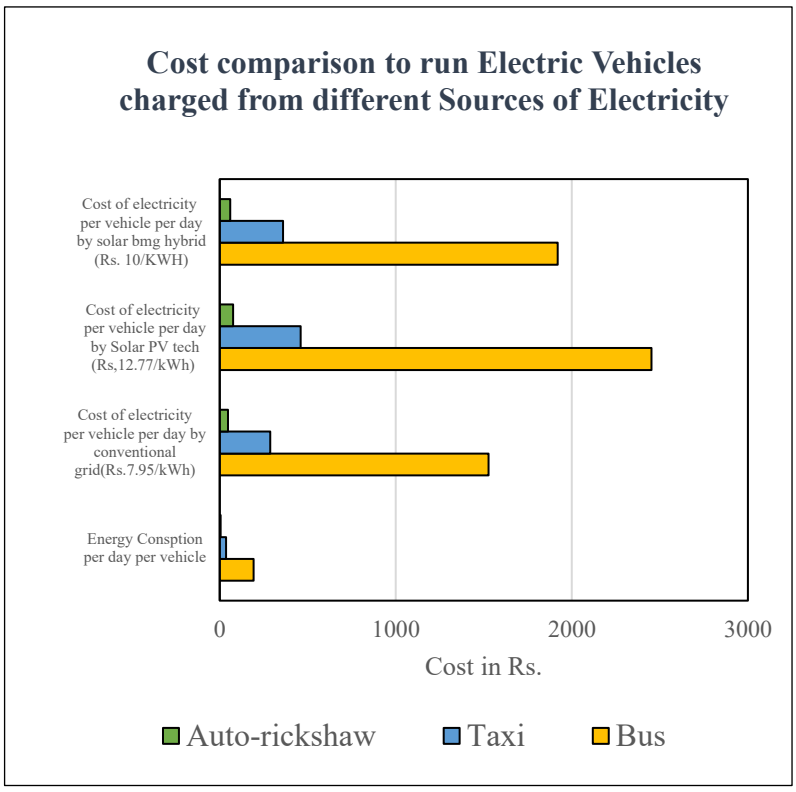


Fig No.18
Source: Secondary data from report of Deepanjan Majumdar ,2014

Monthly Electricity cost of Different EV:

- 67200 INR is the monthly cost for charging E-Bus.
- 15120 INR is the monthly cost for E-Taxi,2520 INR is the monthly cost of electronic toto. (Fig No.19)

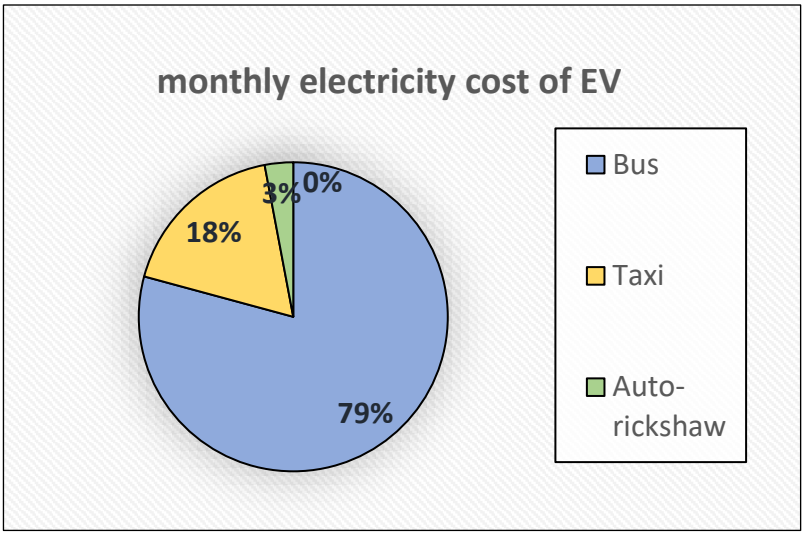


Fig No.19
Source: Secondary data from report of Deepanjan Majumdar ,2014

SOCIAL IMPACT

The implementation of the electric buses program in Kolkata has had a great impact on all aspects related to public mobility. The reliability of electric bus operation has seen to be improved up to 98% despite several initial challenges. Moreover, overwhelming responses have been received from the e-bus riders (a survey was conducted through social networking) in terms of comfort and reliability in each trip

Factors which acted as a hindrance for EV adoption

Factors of hindrance for EV adoption:

- The most significant factor is higher price of EV. about 47.69% people considered it as a main hindrance.
- About 29.3% people thinks that EV's driving time range is not as good as conventional Vehicles driving range.
- 15.38% people don't trust the technology. (Fig No.20)

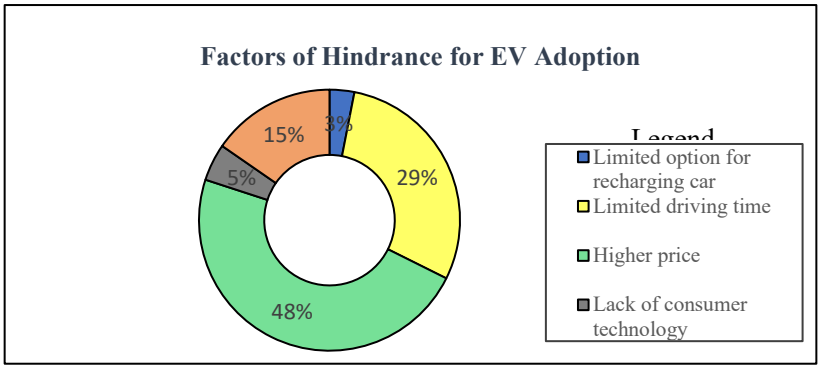


Fig No.20
Source: Primary data

Minimum ownership cost comparison – Conventional car vs electric car:

The diesel cost for conventional car is on an average of **Rs. 4.5 lakh**. But on the other hand, the minimum purchasing cost of an electric car per is comparatively high, which is **Rs. 12.49 lakh**. So, it is clear that purchasing cost is the one of the main hindrances. (Fig No.21)

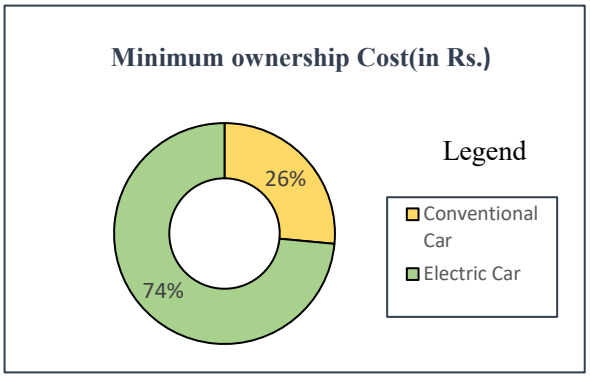
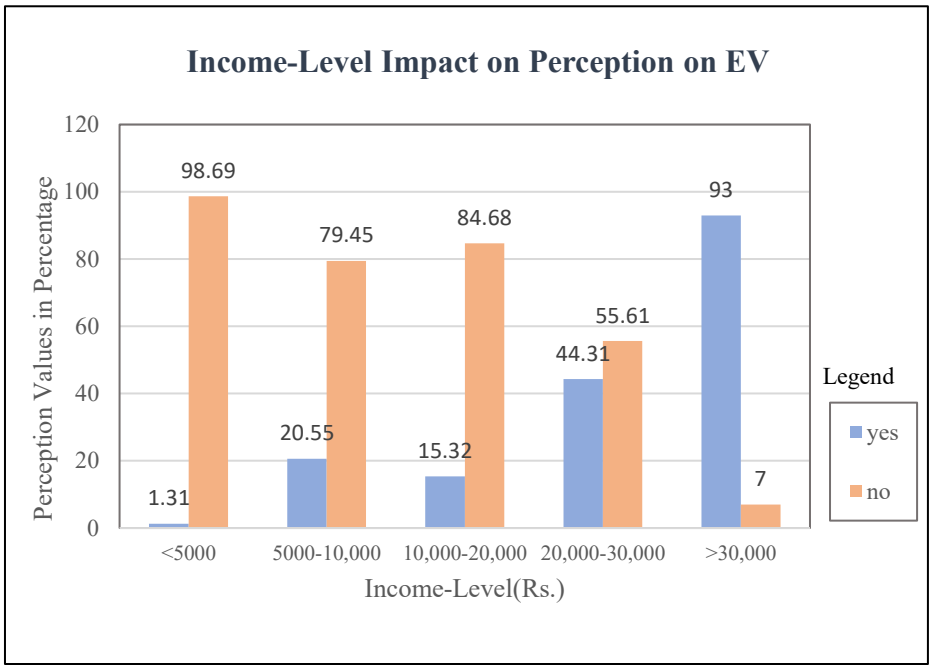


Fig No.21
Source: Primary data

Income-Level impact on perception on EV:

- People of higher income-level only significantly interested of buying EV, which holds 93% for the more than 30000 monthly income level group people.

- In 20000-30000 income level group 44.31% people willing to buy EV but 55.61% people still not interested for it. In next income level group, we see that 84.68% people say no to EV, as they are belonging to middle class or lover middle class income group, so they can't afford it.
- In Rs.5000-10,000 income level group, are interested to buy EV, mainly Toto but most of the people are not prepare for EV. And the lowest income group is not interested to buy any, so it holds 98.69% for not willing to buy EV. (Fig No.22)



Source: Primary data

RESULTS

Trend of Green Drive in Kolkata

- Kolkata saw a sharp rise in electric vehicle registrations in 2022, reaching 837 compared to just 196 in 2021.
- Diesel vehicle registrations fell significantly, from over 6,000 in 2018 to 2,931 in 2022.
- Citizens are shifting towards cleaner fuels like CNG and hybrids, though charging infrastructure remains limited.
- The FAME scheme, launched in 2015, continues to encourage adoption of electric and hybrid vehicles through financial support.
- FAME II in West Bengal (2019–22) allocated ₹9,634 crore, mainly boosting demand incentives but underfunding charging infrastructure.
- The scheme supports the highest number of three-wheelers (5,00,000) and the lowest number of E-buses (7,090).
- The scheme offers the highest incentive for E-Buses (₹50,00,000) and the lowest for 4W strong hybrids (₹13,000).
- Most people choose EVs mainly for lower electricity cost (41%), followed by energy independence (26.12%) and environmental benefits.
- The most significant advantage of EVs is lower electricity cost (40.30%), followed by domestic recharging, greenhouse gas reduction, and noise reduction.
- Younger people (18–25) show the highest willingness to replace cars with EVs, while older groups (46–65) are less inclined.

- Higher education levels show greater willingness to replace cars with EVs, especially among postgraduates (20%).
- The main barriers to EV adoption are **high price (60%)** and limited driving range (40%).

Environmental Impact

- The major impact has been observed in controlling the vehicular emission with a decrease in CO_2 level by 26.27 t per day, on replacement of only 2 % of the present public transport by suitable BEVs.
- Buses and taxis in India, especially in Kolkata, emit major pollutants like **CO_2, NO_2, HC, and PM** primarily from diesel combustion.
- Replacing 2% of diesel vehicles in Kolkata with EVs reduces daily emissions by 26.27 t CO_2, 0.972 t SO_2, and 0.209 t NO_2.
- Replacing more conventional fuel vehicles in Kolkata with EVs can significantly cut carbon emissions and even generate economic benefits through carbon trading under the Kyoto Protocol.

Economic Impact

- In Kolkata, daily fuel costs are highest for buses (₹4,625), followed by taxis (₹1,665), with auto-rickshaws lowest at ₹322.35.
- n Kolkata, daily electricity costs for EVs are ₹2,240 for e-buses, ₹504 for e-taxis, and ₹84 for e-rickshaws, showing clear savings compared to conventional fuel vehicles.
- Among EV charging sources in Kolkata, the **conventional grid is cheapest (₹7.95/kWh)**, followed by **solar bmg hybrid (₹10/kWh)**, while **solar PV tech is costliest (₹12.77/kWh)**.
- In Kolkata, the monthly electricity cost for EVs is ₹67,200 for e-buses, ₹15,120 for e-taxis, and ₹2,520 for e-rickshaws.

Sociological impact

- The main hindrances to EV adoption are **high price (47.69%)**, limited driving range (29.3%), and lack of trust in the technology (15.38%).
- The minimum ownership cost is a major hindrance, as a conventional diesel car averages **₹4.5 lakh**, while an electric car costs at least **₹12.49 lakh**.
- Interest in EV adoption in Kolkata is strongly linked to income, with 93% of higher-income groups (>₹30,000/month) willing to buy EVs, while middle and lower-income groups show limited interest due to affordability issues.

CONCLUSION

The study has shown that the electric vehicle infrastructure may be implemented along with the conventional road transport system and it has the potential to be beneficiary from both economic and environmental aspects. The reduction in the amount of diesel and LPG consumption per day by replacing 2% of the present passenger road transportation mode shows the feasibility of implementing parallel electric vehicle infrastructure. There is a major reduction in emission of pollutants from transport sector if we can come down in favor of this alternative. This system has the benefits of:
(i) reducing the consumption of conventional energy sources,
(ii) commercializing the use of renewable energy in a larger context,
(iii) reducing the ever-increasing problem of environmental pollution,
(iv) reducing the financial burden by checking the quantity of crude oil imports,
(vi) a nonconventional energy source because of which a considerable
amount of foreign exchange can be saved making a positive impact and
(vii) earning financial benefits through carbon trading according to protocol of Kyoto.

RECOMMENDATIONS AND SUGGESTIVE MEASURES

Based on current industry trends and policy reviews, the following measures are recommended to accelerate EV adoption:

- **Shift from Subsidies to Mandates:** Governments should transition from providing upfront consumer subsidies to implementing stringent regulations, such as Production-Linked Incentives (PLI) and mandating ZEV (Zero Emission Vehicle) production, to drive long-term sustainability.
- **Infrastructure Saturation over Expansion:** Rather than spreading infrastructure thinly, a "saturation program" should be adopted, focusing on fully electrifying public transport (buses, 3-wheelers) in specific cities before scaling.
- **Battery Leasing and "Battery Passports":** Nurturing a battery leasing industry and implementing "battery passports" (tracking battery health and composition) can drastically reduce the high initial purchase cost of EVs.
- **Rationalize GST/Taxation:** Aligning policies to ensure that GST on EV services (like charging) is as low as the EV purchase tax (5% GST) is necessary to boost economic viability.
- **Strengthen Local Supply Chain:** To reduce dependence on imported raw materials (lithium, cobalt, rare-earth magnets), policy support should focus on localizing cell manufacturing and battery recycling to achieve cost competitiveness.

Future research efforts are concentrated on solving the physical limitations of current battery technology and integrating EVs with smart grids.

- **Next-Generation Battery Chemistry:**
  - **Solid-State & Sodium-ion Batteries:** Developing alternatives to conventional Li-ion that offer higher safety, lower costs, and better energy density, aiming for 375Wh/kg.
  - **Cobalt-free Cathodes:** Research into LiMnFePO4 and Na-ion applications using local bio-waste for anodes to ensure material independence.
- **Advanced Battery Management Systems (BMS):**
  - **AI and Digital Twins:** Using AI for real-time battery diagnostics, predicting the State of Health (SoH), and optimizing thermal management to extend battery lifespan.
  - **Cell-to-Pack Technology:** Eliminating intermediate modules to reduce weight and increase the active material volume.
- **Charging Infrastructure & Power Electronics:**
  - **Wireless/Dynamic Charging:** Research into road-embedded charging pads that charge the vehicle while in motion, which could lead to smaller, lighter batteries.
  - **Wide-Bandgap Semiconductors (SiC/GaN):** Integrating Silicon Carbide (SiC) and Gallium Nitride (GaN) to make chargers smaller, more efficient, and able to handle 800V architectures.
  - **Vehicle-to-Grid (V2G) Systems:** Enhancing bidirectional charging technology to allow EVs to act as distributed energy storage units, providing ancillary services to the power grid.
- **Circular Economy and Recycling:**
  - **Sustainable Recycling Methods:** Developing efficient, non-polluting (wet and dry) methods for retrieving precious metals from old batteries.

REFERENCES:

1. Basu Rakhi, Electric Bus Operation in Kolkata City
2. Basu Rakhi. (2017) Transport Specialist & Task Team Leader Kolkata Urban Integration Transport Project implementation Plan for Electrification of Public Transportation in Kolkata October2017, Initiated by Sakti Sustainable Energy Foundation October 26, 2017
3. Census Of India 2001, 2011
4. Electric Vehicle Ecosystem Policy 2022, Government of West Bengal

5. Gobczyński Karol and Leroux Maxime (2011), Socio-Economic Factors Influencing the Electric Vehicle Buying Process In Iceland, Halmstad University
6. Government Of West Bengal, Electric Vehicle Ecosystem Policy 2022
7. India: Transition To Electric Vehicles Puts Kolkata on the Road to Clean Transport, Impact Issue 22, Kolkata (2017), Shakti Sustainable Energy Foundation
8. Majumdar D.Andmajhib. K.Anddutta A.Andmandal Rand Jasht. (2014) Study on Possible Economic and Environmental Impacts of Electric Vehicle Infrastructure in Public Road Transportin Kolkata ,21 October 2014
9. Majumdar Deepanjan, Majhi Bijoy Kumar, Dutta Atanu, Mandal Ratan, Jash Tushar (2015), Study on Possible Economic and Environmental Impacts of Electric Vehicle Infrastructure in Public Road Transport in Kolkata, Clean Technological Environment Policy
10. N G Das, Statistical Method Volume 1, M Das and Co.
11. N G Das, Statistical Method Volume 2, M Das and Co
12. Palaniswamy Sivakumar, R S Sandhya Devi, Saravanan M And Anand M (2022), Social**, Economic and Environmental Impact of Electric Vehicles in India,** Journal of Environmental Science and Management 25-1: 64-68
13. Pirmana Viktor, Alisjahbana Armida Salsiah, Yusufarief Anshory, Hoekstra Rutger and Tukker Arnold (2023), Economic and Environmental Impact of Electric Vehicles Productionin Indonesia, Clean Technologies and Environmental Policy
14. Report Of the Energy and Resources Institute (TERI), "A Case Study of Kolkata"
15. Report On Implementation Plan for Electrification of Public Transportation in Kolkata,2017, Shakti Sustainable Energy Foundation
16. Simran Ahuja And Manisha Raj (2022), Social and Economic Impact of Hybrid Electric Vehicles on Environment: An Indian Case Study, International Journal of Creative Research Thoughts (IJCRT)
17. Statistical Hand Book of Kolkata
18. The Kolkata Gazette (2021), Power Department of West Bengal
19. Vashisth Renu And Gupta Jyoti (2021), Consumer Perception Towards Electricvehicle, Journal of Contemporary Issues in Business and Government Vol. 27, No. 06
20. Vashisthrenu And Gupta Jyoti. (2021) Consumer Perception Towards Electric Vehiclevol. 27, No.06, 2021

Websites:

21. Https://Www.Statista.Com/Statistics/1298486/India-Total-Cost-Of-Ownership-Per-Km-Of-Small-Commercial-Vehicle-By-Fuel-Type/
22. Https://Wbtc.Co.In/Wbtc-Inaugurates-20-Electric-Buses/
23. Https://Www.Teriin.Org/Casestudies/Integrating-Electric-Buses-Public-Transport-Kolkatas-Success-Story
24. Https://M.Indiamart.Com/City/Kolkata/Electric-Vehicle-Battery.Html
25. Https://M.Timesofindia.Com/City/Kolkata/195-E-Vehicles-Registered-In-Kolkata-Last-Yr-But-Sales-Figure-May-Be-35k/Amp_Articleshow/89231727.Cms
26. Https://Www.Zigwheels.Com/Newcars/Electric-Cars