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Impact of Electric Vehicles on Traffic and Emissions

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ABSTRACT

In order to estimate carbon-emission specific road networks while taking electric cars (EVs) into account, this study develops a method. Oil-fueled vehicles (OFVs) prioritise minimising trip time, while EVs additionally take battery charge state and charging station locations into account when choosing a route. A mixed equilibrium traffic assignment model is used to determine the traffic volume for each link in the network. The three factors of traffic volume, average speed, and road type are then used to generate a carbon-emission estimating technique. Two networks are used in a case study. Due to EVs' propensity to select routes with charging stations, it has been discovered that the road network's travel time has increased by 27%. Perceived risk, safe electricity quantity, and anticipated charging electricity all influence EV route choices. EVs can lower carbon dioxide emissions, but they cannot lower road network energy usage. Furthermore, it was shown that the placement of charging stations significantly affects traffic flow. The overall trip time, total carbon emissions, and balance of charging station utilisation metrics in the transportation network have all comparatively decreased once charging station locations were optimised. These include a 0.2% reduction in total journey time, a 1.85% reduction in total carbon emissions, and a 0.95% reduction in the balance of charging station use. The study is useful for forecasting traffic flow and carbon emissions, as well as for building road networks and deciding where to put charging heaps. In India, electric vehicles (EVs) have been a game-changer for lowering greenhouse gas emissions, particularly carbon dioxide (CO_2). India's transport sector contributes significantly to the country's CO2 emissions, mostly because of its heavy reliance on fossil fuels. Making the switch to electric vehicles (EVs) that run on renewable energy presents a viable way to lessen environmental effects. By analysing existing emission levels, legislation, and the expected consequences of widespread EV integration, this research investigates the possible influence of EV adoption on CO2 emissions reduction in India. To hasten the deployment of EVs, the Indian government has launched a number of programs, including the Faster Adoption and Manufacturing of Hybrid and Electric Vehicles (FAME) project. By 2030, India hopes to significantly reduce emissions associated with transport through tax breaks, regulatory incentives, and the construction of charging infrastructure. By contrasting EVs with conventional internal combustion engine (ICE) vehicles, this study evaluates the direct and indirect effects of EVs on pollution reductions in India. The results highlight how important it is to match the growth of EVs with the increase of sustainable energy.

Keywords: Transportation, internal combustion engines, electric vehicles, and carbon dioxide emissions.

INTRODUCTION

Transportation is the main source of carbon emissions, and several nations have implemented carbon reduction regulations in response to global warming. The United States' "Long-Term Strategy Pathways to Net-Zero Greenhouse Gas Emissions by 2050," China's "The Action Plan for Peak Carbon Dioxide Emissions by 2030," and the United Kingdom's "Clean Growth Strategy" are a few examples. Reducing carbon emissions requires encouraging travellers to select eco-friendly means of transportation. It is anticipated that electric cars (EVs) will lower air pollution and carbon emissions, which will prompt significant development of related transportation infrastructure. Oil-fueled cars (OFVs) and electric vehicles (EVs) will coexist in a mixed traffic flow during the transition until EVs eventually completely replace OFVs.

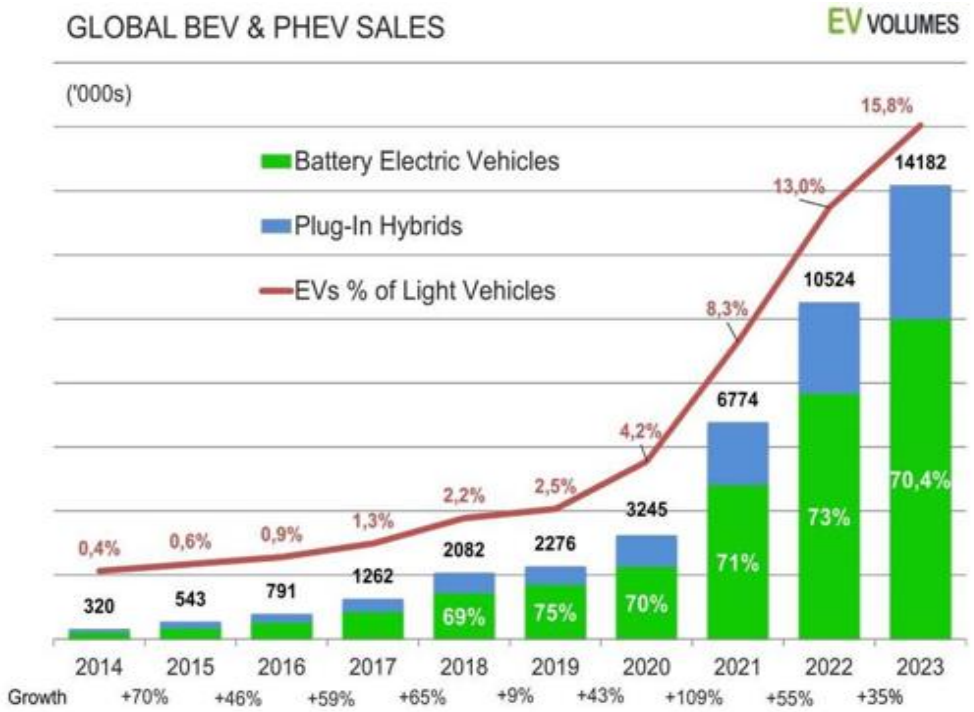
Additionally, there are several issues with EVs that must be resolved: First, there aren't many charging stations, therefore it's important to figure out how to make the most of them; Second, EVs can only go a short distance, which makes drivers nervous. Lastly, EV users' driving habits differ from those of OFVs, which may have new effects on the road network. As a result, academics are actively researching subjects like energy use, charging behaviour, and EV path selection.

Almost 25% of all energy-related emissions globally come from the transportation sector, making it one of the biggest contributors to carbon dioxide (CO_2) emissions. Reducing transportation-related emissions has become a global concern as climate change worsens and its effects become more apparent. With the potential to drastically cut carbon emissions and diminish reliance on fossil fuels, the emergence of electric vehicles (EVs) signifies a revolutionary change in this industry. Because they run on electricity instead of petrol or diesel, electric vehicles are frequently promoted as a greener option to traditional internal combustion engine (ICE) vehicles. This distinction is crucial because using fossil fuels in conventional cars emits a significant quantity of CO2, which is a major contributor to air pollution and global warming. EVs, on the other hand, have no direct tailpipe emissions and, depending on the energy sources utilised to generate power, provide a mechanism to potentially reduce emissions.

Global Scenario of Electric Vehicles

As nations strive to cut greenhouse gas emissions, fight air pollution, and switch to more environmentally friendly modes of transportation, the worldwide landscape for electric vehicles (EVs) is changing quickly. Key trends and advancements are influencing the future of electric mobility worldwide, even though the rate and type of EV adoption differ by country.

- **Global EV Sales Growth:** The International Energy Agency (IEA) reports that there were more than 10 million electric vehicles on the road worldwide in 2020, and EV sales have been rising annually. EVs made for almost 14% of all automobile sales worldwide in 2023. By 2030, estimates indicate that EVs may account for nearly 30% of all vehicle sales worldwide.
- **Transition to Complete Electrification:** Big automakers are establishing aggressive goals to transition to electrification. Businesses including Toyota, Hyundai, Ford, BMW, General Motors, and Volkswagen are making significant investments in EV manufacturing. A number of companies, such as General Motors and Volvo, have declared their intention to transition entirely to electric vehicles by 2035 or 2040.
- **China:** With more than half of all EV sales worldwide, China is the largest EV market in the world. The nation has actively encouraged EV adoption through infrastructure expenditures, local manufacture, and incentives. The Chinese government wants to become carbon neutral by 2060 and have 25% of all cars in the nation be electric by 2025.
- **Europe**: Norway, Germany, the UK, France, and the Netherlands are among the main nations in Europe, which is another significant market for EVs. For instance, Norway plans to phase out the sale of new cars with internal combustion engines (ICEs) by 2025.
- **Tax credits and subsidies:** To promote EV purchases, many nations provide financial advantages to consumers. For instance, depending on the type and manufacturer, tax credits of up to $7,500 are available in the United States for the purchase of a new electric vehicle. China offers incentives for manufacturers to make electric vehicles domestically and subsidies to EV buyers. At the national level, the European Union provides a number of incentives; Germany, for example, grants up to €9,000 for the purchase of a new electric vehicle.



Source: www.ev-volumes.com/country/total-world-plug-in-vehicle-volumes/

Sales of electric vehicles increased by almost 35% in 2023 compared to the year before. There were 14.2 million new Battery Electric Vehicles (BEVs) and Plug-in Hybrids (PHEVs) sold, of which 10 million were fully electric BEVs and 4.2 million were PHEVs.

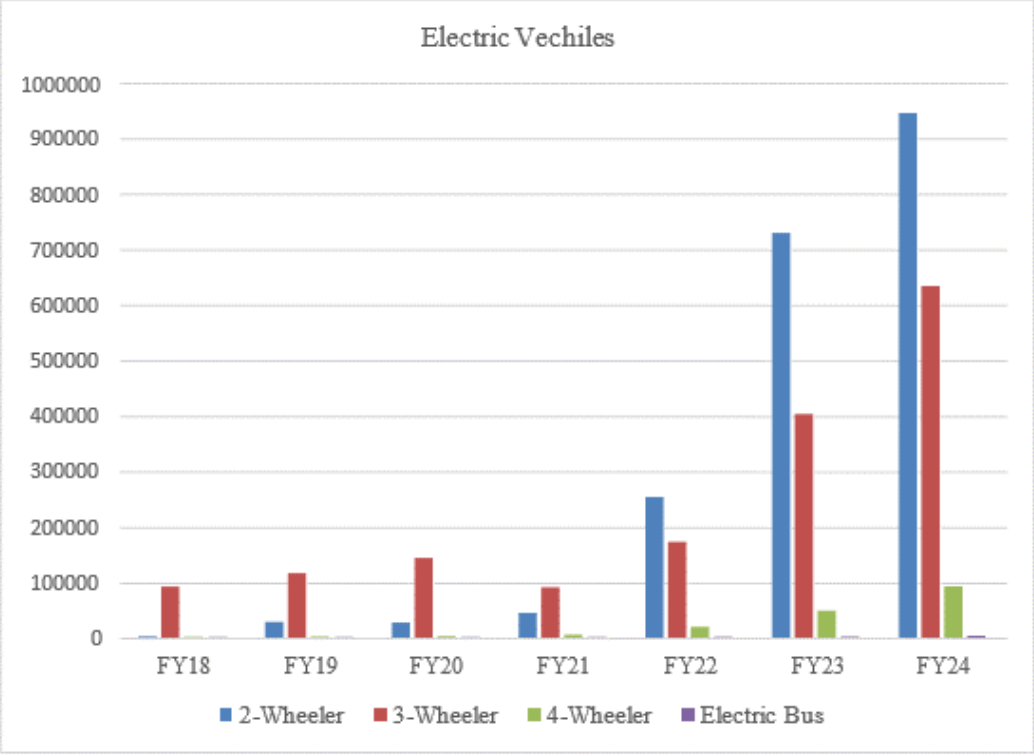
Indian Scenario Electric Vehicles

India is now the third-largest car market in the world in terms of sales, surpassing both Germany and Japan. Legislators and manufacturers are being asked to collaborate in order to shift customer preferences toward more environmentally friendly products. With numerous jobs and 7.1% of the nation's GDP, the automobile sector is essential to India's economy. The Economic Survey 2023 predicts that India's domestic electric car market will grow at a compound annual growth rate (CAGR) of 49% between 2022 and 2030, reaching 10 million annual sales by then. Additionally, it is projected that the electric vehicle industry would provide roughly 50 million direct and indirect jobs by 2030.

With a number of incentives and legislative frameworks designed to lower carbon emissions and promote sustainable mobility, the Indian government has taken a number of actions to promote the use of electric vehicles:

- **Faster Adoption and Manufacturing of Hybrid and Electric Vehicles**, or FAME India Scheme: This program, which was introduced in stages (FAME I in 2015 and FAME II in 2019), provides financial incentives for buying electric cars, building infrastructure for charging them, and producing batteries and electric cars. In order to encourage electric mobility in India, the government set out ₹10,000 crore (~1.3 billion) under FAME II, providing subsidies for electric buses, two-wheelers, three-wheelers, and four-wheelers.
- **PLI Program for EVs and Batteries**: To encourage domestic production of innovative batteries and electric vehicles, the government launched the Production-Linked Incentive (PLI) program. In order to create a more sustainable local EV ecosystem, this attempts to lessen India's reliance on imported EV parts and batteries.
- **State-Level Policies:** A number of Indian states, such as Delhi, Maharashtra, Tamil Nadu, and Uttar Pradesh, have implemented state-specific EV policies that provide extra benefits such exemptions from road taxes, lower registration costs, and subsidies for EV purchases. For instance, Delhi's EV policy provides a direct subsidy of ₹1.5 lakh for electric automobiles and ₹30,000 for two-wheelers.

Total Electric Vehicles Sales



Sr No	Year	2-Wheeler	3-Wheeler	4-Wheeler	Electric Bus	Total
1	FY18	2005	91970	1204	19	95198
2	FY19	28007	116031	1885	66	145989
3	FY20	26834	143051	2377	434	172696
4	FY21	44803	90898	5154	373	141228

5	FY22	252641	172543	18622	1194	445000
6	FY23	728054	401882	47499	1984	1179419
7	FY24	944126	632485	90432	3693	1670736

Source - https://www.smev.in/statistics

The total sales of electric vehicles in 2024 were over 16.7 lakhs, a 70.5% increase over 2023. Sales were approximately 11.7 lakhs in 2023, a 37.7% increase over 2022, and 4.45 lakhs in 2022, a 31.7% increase over 2021.

Importance of usage of Electric Vehicles

- **Reduction of Greenhouse Gas Emissions:** One of the main benefits of electric vehicles is their ability to reduce greenhouse gas (GHG) emissions. Cars with internal combustion engines (ICE), which run on petrol and diesel, are primarily responsible for transportation-related emissions worldwide. EVs, on the other hand, produce very little to no pollution from their exhaust. EVs frequently have a lower carbon footprint, even when power generation is taken into account.
- **Better Air Quality:** Particulate matter, nitrogen oxides (NOx), and volatile organic compounds (VOCs) are among the air pollutants and smog-causing substances that EVs do not discharge due to their zero exhaust emissions. This is particularly important in urban areas where air quality can have a significant influence on public health. Reducing car emissions can help avoid respiratory problems, heart disease, and other ailments linked to air pollution.
- **Noise Pollution Reduction:** Electric cars are much quieter than conventional ones. Particularly in cities where traffic noise can be distracting and harmful to one's health and wellbeing, engine noise reduction helps reduce overall sound pollution.
- **Reduced Reliance on Fossil Fuels:** EVs can reduce reliance on fossil fuels, such as petroleum. This is particularly important in light of global efforts to reduce reliance on oil and reduce geopolitical conflicts related to energy. Since EVs need electricity to run, they can be powered by renewable energy sources like solar, wind, and hydroelectric power, resulting in a more reliable and sustainable energy system.
- **Long-Term Cost Savings:** Although an EV's initial cost may be more than that of a conventional car, its ongoing expenses are frequently lower. EVs are less expensive to maintain because they have fewer moving parts, don't require oil changes, and frequently have fewer mechanical issues. Additionally, powering an EV with electricity is usually less expensive than using petrol or diesel for a conventional vehicle. Buyers may eventually pay less for EVs as a result of these savings.
- **Climate Change Mitigation:** Given the urgent need to address climate change, reducing transport emissions is an essential part of the answer. Electric vehicles that run on clean energy help reduce the transportation sector's carbon footprint, which is one of the main contributors to global warming.
- **Energy Security:** By diversifying energy sources and moving away from fossil fuels, electric vehicles contribute to greater energy security. Many countries rely heavily on imported oil, which is susceptible to price fluctuations and geopolitical risks. EVs make energy supply chains more localised and stable, especially when combined with renewable energy.

Negative Effect of Carbon Emission

- **Global Warming:** One of the main greenhouse gases, CO2, traps heat in the Earth's atmosphere, raising global temperatures generally. The effects of this phenomena, which is referred to as global warming, are extensive.
- **Extreme Weather Events:** As temperatures rise, extreme weather events like storms, droughts, floods, and wildfires occur more frequently and with greater intensity. These occurrences cause infrastructure damage, ecological disruption, and fatalities.
- **Melting Polar Ice and Rising Sea Levels:** As temperatures rise, polar ice caps and glaciers melt, which raises sea levels. Millions of people may be displaced globally, low-lying areas may flood, and coastal erosion may result.
- **Health Effects:** Although atmospheric amounts of CO2 are not immediately detrimental, activities that release CO2, such burning fossil fuels, frequently release additional pollutants like particulate matter (PM), nitrogen oxides (NOx), and sulphur dioxide (SO2). These contaminants are linked to heart disease, pulmonary issues, and early mortality.
- **Changing Growing Conditions:** As a result of climate change brought on by carbon emissions, rainfall patterns may change, resulting in flooding in some areas and droughts in others. Food security and agricultural productivity are impacted, particularly in vulnerable areas.
- **Infrastructure Damage:** Rising sea levels and extreme weather can harm buildings, roads, and energy systems, resulting in high repair and reconstruction costs.
- **Loss of Agricultural Productivity:** Climate-related reductions in agricultural productivity can raise food costs, jeopardise global food security, and limit the resources available to underprivileged groups.

- **Disruption of Ecosystem functions:** Pollination, soil fertility, water purification, and climate regulation are just a few of the vital functions that ecosystems offer. Climate change brought on by carbon emissions may jeopardise these services, affecting human populations that rely on them for existence.

Global economy, biodiversity, public health, and the environment are all negatively impacted by carbon emissions. In order to lessen these effects and move toward a more sustainable future, carbon emissions must be addressed.

One of the best ways to lower carbon emissions in the transportation industry, which is one of the main sources of greenhouse gas emissions worldwide, is to employ electric vehicles. We can greatly reduce direct and indirect carbon emissions, enhance air quality, and contribute to climate change mitigation by switching from petrol and diesel-powered vehicles to electric vehicles. Adoption of EVs must, however, coincide with efforts to address environmental and social concerns related to battery production as well as a cleaner, more sustainable electricity grid in order to optimise these advantages.

Carbon Dioxide Emission Calculator

Reductions in CO2 emissions over the course of a two-wheeler vehicle's lifetime If a car travels 25 kilometres a day on average, then

Sr No	Year	CO2 emissions reductions during the lifecycle of the vehicle (Tonnes)	NO of Vehicles	CO2 Emission Reduction (Tonnes)
1	FY18	1.67	2005	3348.35
2	FY19	1.67	28007	46771.69
3	FY20	1.67	26834	44812.78
4	FY21	1.67	44803	74821.01
5	FY22	1.67	252641	421910.47
6	FY23	1.67	728054	1215850.18
7	FY24	1.67	944126	1576690.42

Source - https://e-amrit.niti.gov.in/co2-calculator decreases in CO2 emissions over the three-wheeler vehicle's lifetime If a car travels 40 kilometres a day on average, then

Sr No	Year	O2 emissions reductions during the lifecycle of the vehicle (Tonnes)	NO of Vehicles	CO2 Emission Reduction (Tonnes)
1	FY18	9.72	91970	893948.4
2	FY19	9.72	116031	1127821.32
3	FY20	9.72	143051	1390455.72
4	FY21	9.72	90898	883528.56
5	FY22	9.72	172543	1677117.96
6	FY23	9.72	401882	3906293.04
7	FY24	9.72	632485	6147754.2

Source - https://e-amrit.niti.gov.in/co2-calculator decreases in CO2 emissions over the four-wheeler vehicle's lifetime If a car travels 50 kilometres a day on average, then

Sr No	Year	CO2 emissions reductions during the lifecycle of the vehicle (Tonnes)	NO of Vehicles	Emission Reduction (Tonnes)
1	FY18	12.03	1204	14484.12
2	FY19	12.03	1885	22676.55
3	FY20	12.03	2377	28595.31
4	FY21	12.03	5154	62002.62
5	FY22	12.03	18622	224022.66
6	FY23	12.03	47499	571412.97
7	FY24	12.03	90432	1087896.96

Source - https://e-amrit.niti.gov.in/co2-calculator

Findings

India's overall CO2 emissions reductions between FY18 and FY24:

Sr. No	Vehicles Category	CO2 Emission Reduction (Tonnes)
1	2-Wheeler	3384204.9
2	3-Wheeler	16026919.2
3	4-Wheeler	2011091.19
	Total	**21422215.29**

Using electric vehicles (EVs) to reduce 21,422,215 tonnes of carbon dioxide (CO_2) emissions would have major positive effects on the environment, human health, and the economy. The benefits of such a reduction are broken down as follows:

- **Decrease in Global Warming:** One greenhouse gas (GHG) that causes the Earth's atmosphere to warm is CO2. This would help decrease the rate of global warming and make it simpler to reach international climate targets, such those outlined in the Paris Agreement, by cutting emissions by 21.42 million tonnes of CO2.
- **Carbon Budget:** Each tonne of CO2 released contributes to the global carbon budget, which is the highest amount of CO2 the earth can release before warming dangerously. Reducing 21.42 million tonnes helps prevent irreversible climate damage by keeping the rise in world temperatures well below 2°C.
- **Health Benefits:** Heart attacks, bronchitis, asthma, and other respiratory and cardiovascular conditions are associated with air pollution. Reducing hazardous emissions enhances public health, which may result in fewer hospital admissions and chronic illness instances. According to a World Health Organization (WHO) research, air pollution causes more than 7 million deaths worldwide annually.
- **Reduced Fossil Fuel Consumption:** Using EVs reduces CO2 emissions by 21.42 million tonnes, indicating a decrease in the use of fossil fuels, especially petrol and diesel. This lessens a nation's reliance on imported oil, which is expensive for many countries.
- **Decarbonising the Transportation Sector:** Approximately 25–30% of the world's CO2 emissions come from the transportation sector, which is one of the biggest contributors to carbon emissions. This is a significant step in decarbonising transportation, which is necessary to reach global climate targets, as emissions have been reduced by 21.42 million tonnes.

CONCLUSION

In order to evaluate the effect of EVs on traffic assignment, the study creates a mixed equilibrium model that takes travellers' beginning battery level, perceived time deviation, and risk perception into account. In order to estimate CO2 emissions in the network, a carbon emission model is also constructed based on traffic assignment. Sensitivity studies for road type, safe remaining electricity, desired charging electricity, and risk perception are performed in two test cases to examine the effects of EV features on the network. The results show that because EVs prefer routes with charging stations, they will lengthen the overall travel time on the road network. The road network's journey time has grown by 27%. Vehicle routing decisions are influenced by the charging state's location and the user's sense of risk. The overall journey time, total carbon emissions, and balance of charging station utilisation all fell by 0.2%, 1.85%, and 0.95%, respectively, when we relocated a charging station. Additionally, the kind of road and average speed have a significant impact on carbon emissions. Mixed network charge times are 113.83% longer than those of main roads, although they are 21.96% and 17.29% shorter than those of subsidiary and branch roads, respectively.

The majority of current research focuses on static road networks, which are frequently virtual rather than actual networks. Future studies could use real-world data to investigate traffic assignment and billing strategies in dynamic traffic flow networks. Additionally, a hybrid stochastic user equilibrium model might be used for additional research, taking into account users' uncertainty regarding trip duration. Simultaneously, the analysis of charging station optimisation may enhance road traffic efficiency and reduce future psychological "charging anxiety" among EV customers. Adopting electric cars (EVs) would reduce 21.42 million tonnes of CO2, which would have numerous positive effects on the environment, the economy, and human health. reducing the effects of climate change and supporting international efforts to achieve carbon neutrality. Reducing healthcare expenses, lowering health risks, and improving air quality. promoting energy security, reducing dependency on fossil fuels, and generating new employment in the green economy. fostering technological innovation, boosting the use of renewable energy sources, and increasing energy efficiency in order to promote sustainability.

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