RESEARCH PAPER

Smart Car Emission Prediction System

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ABSTRACT
Transportation systems have grown rapidly throughout the world over the last decade, leading to an increase in the number of vehicle miles driven. The increase in vehicle uses results in more convenience and greater mobility. However, it also means greater environmental pollution because nearly all vehicles currently in use rely on internal combustion engines to produce power and emit pollutants such as CO2, CO, NOx, and particulate matter into the atmosphere.
The main objective of the study is to create a vehicle emission prediction system that will assess various parameters of vehicles and provide estimates of emissions releases from electric vehicle. Through the use of historical vehicle data and analyses of energy consumption and environmental conditions, the system produces estimates of emissions levels. Predictive and statistical models will be used in conjunction with data from machine learning algorithms to enhance the accuracy of emissions predictions. The resulting system will enable users to understand the environmental impacts of transportation systems and work towards providing innovative green solutions within the transportation industry.
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1.Introduction

The growth of transportation infrastructures has created a large increase in the volume of road vehicles around the globe. Although the presence of vehicles makes it easy to get from point A to point B, they produce a great deal of environmental pollution as well. Conventional combustion engine-powered vehicles also produce CO_2, CO, NOx, and particulate matter through their exhaust systems.

With the development of smart transportation technology and electric vehicles, the demand for emission predicting systems has increased substantially. Electric vehicles are typically thought to contribute positively to the environment due to their lack of tailpipe emissions during operation; however, indirect emissions may still be generated based on where the electricity to charge the vehicle comes from. Therefore, it is critical to understand and predict actual vehicle emissions for various vehicle types (electric vs gasoline), energy sources and driving conditions in order to evaluate their total impact on the environment. A comprehensive emission predicting system can therefore provide valuable information to help assess the impact of transportation systems on the environment.

These gasses have contributed to global climate change and other forms of air pollution as well as many health concerns. Given the growing nature of environmental issues, many governments and researchers have begun to search for technologies that will help reduce the emissions created by vehicles.

Alternative transportation options, such as electric vehicles (EV) and intelligent transport systems (ITS), are available today as alternatives to gas-powered vehicles. Even though an EV produces no direct emissions, there may be indirect emissions when electricity to charge the vehicle is generated from fossil fuel. Accurate predictions of emissions from the vehicle are therefore important when examining the environmental impact of a vehicle.

The Smart Car Emission Prediction System is designed to analyze vehicle-specific information to create a model and estimate the level of emissions from the vehicle. The system utilizes predictive models along with data analytics and machine learning to estimate emissions in various driving conditions

2.Literature Review

It is important to accurately predict the emissions produced by vehicles in order to assist in the development of public policy, the improvement of vehicle designs, and the supply of information to consumers. There have been numerous studies that utilize machine learning and deep learning methods for predicting CO_2 vehicle emissions. These studies have also recently used machine learning and deep learning methods to predict pollutant emissions from vehicles. The objective of this literature review is to collect the major studies pertaining to the prediction of the emission output from both electric and hybrid vehicles.

Holdway et al.(2010) evaluate the total indirect emissions (well-to-wheel) of electric vehicles; they perform these calculations across a total of three different countries (US, UK and France), after which they then compare their results to the hybrid electric vehicle and the conventional petrol vehicle. Their findings show that electric vehicles can reduce carbon dioxide emissions. However, they emphasize that the source of electricity (i.e., the source of the electricity that will be used to recharge electric vehicles) must be from cleaner sources of energy; for electric vehicles to be considered environmentally friendly; this means that electric vehicles will only be charged from either hydroelectric or nuclear power [1].

According to Zhang et al., the results of the study found that if there is a 1% increase in using hybrid vehicles instead of traditional gas or diesel vehicles, then this will result in a 0.17% reduction in CO2 emissions. [2].

Castillo et al This study examines how the use of hybrid electric vehicles can help Latin America for reducing conventional fuel consumption and emission of greenhouse gases and they conclude that hybrid vehicle can reduce the energy consumption and emissions significantly if the vehicle widely adopted and the government must formulate some policies to entice the people of Latin America to adopt the hybrid electric vehicle instead of conventional petrol or diesel vehicles [3].

Castillo et al examined the potential benefits of hybrid electric vehicle (HEV) technology for Latin America. HEVs are able to significantly reduce conventional fuel consumption as well as emissions of greenhouse gases when they are widely utilized, and HEV adoption would require governmental policy initiatives that provide incentives to (encourage) adoption in developing countries (specifically: Latin American countries). [3]

Meng et al developed a prediction model for global CO2 emissions using machine learning techniques. They utilized their model to predict levels of CO2 emissions in 2022 with a 91% accuracy rating, providing policymakers with evidence-based policies [4].

According to a study done by Huang, et al.,they calculated and compared fuel consumption and emissions between hybrid electric vehicles and both gasoline- and diesel-powered conventional motor vehicles. They determined that hybrid electric vehicles are more efficient, saving up to 25-49% in fuel use when compared with conventional vehicles; however, because of their relatively high carbon monoxide emissions compared with the particulate emissions from either type of conventional vehicle, they are not as effective for improving urban air quality compared with conventional vehicles. [5]

Wang and Zhang (2018) proposed a new prediction model called the Grey Bernoulli Model that can be used to predict CO_2 emissions in Shaanxi, China, in situations where data is limited. This is especially useful for modelling emissions during the early stages of both electric vehicles (EVs) and hybrid electric vehicles (HEVs), where there may not yet be enough actual data to support accurate predictions. Even when limited input data is available, the predictions generated using the information from the Grey Bernoulli Model demonstrated a sufficiently high level of accuracy. Additionally, Ahn et al.

(2022) demonstrated through the use of hybrid models, that predictive modelling methods using hybrid models consistently outperform predictive modelling methods that rely solely on either statistical or machine learning modelling techniques, thus supporting the use of hybrid models as integrated methodologies [9].

4. Electric Vehicle Methodological Foundations for Emission Quantification

4.1 Carbon Accounting Scopes (Electric Vehicle)

The methodology for calculating emissions from electric vehicles in India should consider the various phases of the vehicle's lifecycle (these are called the "operational phase", where the vehicle is actually in use and generating emissions, and the "manufacturing phase", where components of the electric vehicle are produced/assembled, and then shipped/stored before they are used), which corresponds to Scope definitions used by the global carbon accounting framework to categorize emission sources. The operational phase of the Electric vehicle would be classified as "Scope 1" emissions, which represent direct emissions created from the operation of a vehicle. In the case of battery-powered electric vehicles or (BEV) - Battery Electric Vehicle; the scope 1 emissions from the operation of BEV's are effectively zero due to the fact there are no emissions from the tailpipe of a BEV.

4.2 Key Data Components for Emission Calculation

The data components of emissions associated with electric vehicles include the carbon intensity of the grid, energy efficiency of the vehicle based on its specific driving environment, the technical losses within the electricity supply chain (where transmission and distribution occur), and the embodied carbon of the manufacturing of components used in vehicles. Carbon intensity is measured in kilograms of CO2 produced for every kWh of electricity generated through fossil fuels. Energy efficiency defines energy consumed to travel a distance in an electric vehicle. Technical losses are incurred when transmitting and distributing electricity from the power plant to the charging station. The embodied carbon represents the CO2 generated during the production (manufacturing) of components used in electric vehicles, such as batteries, motors, and structural materials.

5. Framework for Quantifying Lifecycle Greenhouse Gas Emissions of Electric Vehicles in the Indian Ecosystem

The transition toward electric mobility in India represents a multifaceted endeavor aimed at reconciling rapid economic growth with international climate commitments. As the world's most populous nation, India is a critical determinant of global energy-sector emissions trajectories.[1] While the transport sector has historically been a significant contributor to urban air pollution and national greenhouse gas (GHG) inventories, the shift to electric vehicles (EVs) is positioned as the primary mechanism for achieving the country's Net Zero 2070 target.[2] However, the assertion that electric vehicles are "zero-emission" is a simplification that ignores the upstream environmental costs associated with electricity generation, transmission, and manufacturing.[4] For researchers and project developers seeking to calculate the actual emissions of EVs in India, a robust, data-driven methodology is required—one that moves beyond tailpipe metrics to encompass a full lifecycle assessment (LCA) or a Well-to-Wheel (WTW) framework.[6]

5.1 Transition Towards Electric Mobility in India

The transition to electric mobility in India is a major step in balancing speedy economic growth with environmental sustainability. With over 1 billion people living in the country, India has a big effect on how people around the world use energy and how they produce greenhouse gases. In addition to damaging air quality in cities and contributing significantly to the emissions reporting done by countries, transportation contributes a lot to urban air pollution and greenhouse gas emissions. As a result, EVs are viewed as an important tool in helping India to lower its emissions and deliver on the country's long-term aspirations for climate change, including the goal of Net Zero by 2070.

5.2 Limitations of the "Zero-Emission" Concept

While EVs (electric vehicles) are commonly called zero-emission vehicles because they do not emit tailpipe gases, the term can be misleading. EVs can have various indirect emissions based on how the electricity to power them is generated and transported. The indirect emissions generated from producing electricity have a direct relationship with the number of emissions generated from transporting that energy to power an electric vehicle. If the electricity used to charge an EV comes from fossil-fuel-based power plants (like coal), the total amount of emissions produced from operating an EV can be relatively high.

5.3 Life Cycle Assessment (LCA) Methodology
Researchers commonly perform life cycle assessments (LCA) to assess the environmental effects produced by electric vehicles. LCA uses a systematic procedure to evaluate emissions produced across a vehicle's entire lifecycle, from material sourcing, battery production, vehicle assembly, electricity generation, operation, and end-of-service disposal.
The life cycle assessment (LCA) methodology has been used as a method of systematically evaluating emissions generated by the electric vehicle's entire lifecycle.

5.4 Well-to-Wheel (WTW) Emission Framework
Another well-known method for assessing emissions from a vehicle is through a well-to-wheel (WTW) approach. The WTW approach considers emissions produced during the generation, delivery, and use of energy to power the vehicle. WTW can be separated into two major components: well-to-tank (WTT) emissions result from energy generation and delivery and tank-to-wheel (TTW) emissions occur due to vehicle usage.

5.5 Significance of Evaluating Emissions Using Data

For researchers and policy makers the adoption of a sound data-driven methodology is critical for gaining an accurate estimate of emissions from electric vehicles in an Indian context. Through the use of life-cycle assessment combined with emission forecasting model's researchers will have a greater understanding of the impact electric mobility has on the environment, resulting in viable strategies to decrease greenhouse gas emissions from transportation. This type of framework will support the development of sustainable transportation policies, while also facilitating the adoption of cleaner energy technologies.

Practical Project Implementation: Step-by-Step
To complete a project calculating EV emissions in India, the following procedural steps should be followed, integrating the data clusters discussed above.

Step 1: Define the System Boundaries
Determine whether the project is a Tank-to-Wheel (TTW) analysis (tailpipe only), a Well-to-Wheel (WTW) analysis (fuel production + use), or a full Life Cycle Assessment (LCA) (manufacturing + use + disposal).[7] For professional standards, WTW is the minimum credible boundary for EVs.

Step 2: Select the Relevant Grid Emission Factor
Identify the geographical scope. If the project is national, use the CEA weighted average for the current year (0.710 kgCO_2/kWh).[13] If the project involves new charging infrastructure, use the Combined Margin (0.757 kgCO_2/kWh) as it reflects the displaced generation.[12]

Step 3: Gather Vehicle Consumption Data
Obtain real-world efficiency data rather than just ARAI figures. Use the benchmarks for Tata, MG, and Mahindra vehicles provided in recent range tests.[14] Adjust for seasonal variations; for instance, account for a 15% increase in energy consumption during Indian summers due to HVAC load.[15]

Step 4: Apply Loss Factors
Incorporate a 15% loss for T&D [10] and a 10-15% loss for charging efficiency depending on the charger type.[23] A total loss factor of 25% is a standard conservative estimate for the energy journey from the plant to the battery.

Step 5: Quantify Manufacturing Emissions (for LCA)
Use battery capacity (kWh) and apply an emission factor based on chemistry (e.g., 100 kgCO_2/kWh for NMC or 80 kgCO_2/kWh for LFP).[37] Add the vehicle body footprint (e.g., 5-7 tones of CO_2 for a passenger car) based on material intensities.[29]

Step 6: Perform Comparative Modeling
Compare these results against the baseline ICE vehicles using the WRI India-specific road transport emission factors (e.g., 0.150 kgCO_2/kWh for a petrol sedan).[3]

The Evolution of the Indian Electricity Grid Emission Factor

The most significant variable in the emission calculation for an Indian EV is the carbon intensity of the national power grid. India's grid is historically reliant on coal, which accounts for over half of the country's CO_2 output.[1] However, a striking shift has occurred in the first half of 2025, where power sector emissions fell by 1% year-on-year—only the second such drop in nearly half a century.[1] This indicates a decoupling of electricity generation from carbon output, driven by a record 25.1 GW of non-fossil capacity additions in just six months.[1]

For accurate calculation, project developers must utilize the datasets provided by the Central Electricity Authority (CEA). The CEA maintains a CO_2 Baseline Database that tracks the weighted average emission factor across all grid-connected power stations.[11] The following table summarizes the foundational grid metrics for the 2023-24 fiscal year, which serve as the baseline for current operational emission assessments.

Grid Parameter	Definition and Application	Value (FY 2023-24) (tCO_2 /MWh)
Weighted Average	The mean emission of all stations, weighted by net generation; used for general carbon footprinting.	0.727
Simple Operating Margin (OM)	The emission factor of plants excluding must-run sources like renewables and nuclear; used to model the impact of new load.	0.962
Build Margin (BM)	The average emission of the most recent 20% of capacity additions; reflects the technology of the future.	0.552
Combined Margin (CM)	A 50:50 weighted average of OM and BM; standard for CDM and project-level mitigation analysis.	0.757

Vehicle Model	Battery Size (kWh)	Real-World Range (km)	Real-World Efficiency (km/kWh)
MG Comet EV	17.3	193	11.17
Tata Tiago EV (24kWh)	24.0	187	7.77
Tata Nexon EV (45kWh)	45.0	350	7.79
MG Windsor EV	38.0	308	8.10
MG ZS EV	50.3	339	6.70

The weighted average emission factor has shown a decadal decline from 0.774 tCO_2/MWh in 2013-14 to approximately 0.710 tCO_2/MWh in 2024-25.[13] This downward trend is essential for longitudinal studies, as an EV purchased today will operate on a grid that becomes progressively cleaner over its ten-to-fifteen-year lifespan.[5]

Energy Efficiency Benchmarks Across Vehicle Segments

The second requirement for completing an emission calculation is determining the energy consumption rate of the vehicle, expressed in kilowatt-hours per kilometer (kWh/km). In India, this data is often reported in the inverse or as watt-hours per kilometer.[14] It is critical to distinguish between the certified range provided by the Automotive Research Association of India (ARAI) or the Modified Indian Driving Cycle (MIDC) and real-world efficiency, which is often 25% to 30% lower due to traffic, weather, and the use of auxiliary systems like air conditioning.[14]

Passenger Four-Wheelers (4W)

In the passenger segment, efficiency varies significantly between ultra-compact models and premium SUVs. The MG Comet EV, for example, achieves a real-world efficiency of 11.17 km/kWh due to its light weight, whereas premium SUVs like the MG ZS EV or the Tata Nexon EV LR operate in the range of 6.7 to 7.8 km/kWh.[14]

Driving conditions play a pivotal role; EVs in India are generally more efficient in city traffic than on highways.[16] This is because low-speed urban driving allows for maximizing regenerative braking, whereas high-speed highway driving increases aerodynamic drag and continuous energy draw.[15]

Electric Two-Wheelers (2W) and Three-Wheelers (3W)

The two-wheeler segment is the largest driver of EV penetration in India.[17] These vehicles are highly efficient, typically consuming between 30 and 50 Wh/km.[15] For project calculations involving fleet electrification, such as gig-delivery or e-commerce fleets, these efficiency figures are foundational.[18]

Scooter Model	Battery Capacity (kWh)	Certified Range (km)	Owner-Reported Average Range (km)
Ola S1 Pro (Gen 2)	4.0	195	135.5
Ather 450X (3.7kWh)	3.7	150	112
TVS iQube S	3.04	100	75

Heavy Passenger Vehicles: Electric Buses

Electric buses (e-buses) offer the highest absolute emission reduction potential per vehicle. A traditional diesel bus in India consumes approximately 2.8 kWh/km of equivalent energy, whereas an electric bus averages 1.15 kWh/km.[20] The following efficiencies are representative of the leading models deployed by State Transport Undertakings (STUs) under schemes like FAME II and PM-eBus Sewa.[21]

Bus Model	Energy Consumption (kWh/km)	Estimated CO2 Savings per km (kg)
Olectra K7	0.95	~0.60
Olectra K9	1.10	~0.55
Tata Starbus EV	1.15	~0.50
Diesel Bus (Baseline)	2.80 (Eq)	1.50 (Tailpipe)

The Mathematical Framework for Operational Emissions

The operational emissions (E_{ops}) of an EV project in India are not merely the product of the grid emission factor and the vehicle efficiency. One must account for the upstream energy losses that occur between the power plant and the vehicle's battery. The general equation for calculating annual operational emissions is:

$$E_{ops} = \left(\frac{V_{con}}{\eta_{chg} \times} \right.$$

Where:

- V_{cons} is the vehicle's energy consumption in kWh/km (e.g., 0.13 kWh/km for a Nexon EV).[14]
- D_{ann} is the total annual distance traveled in kilometers.
- η_{chg} is the efficiency of the charging infrastructure (Level 1, Level 2, or DC Fast).[23]
- $L_{T\&D}$ is the Transmission and Distribution loss factor of the local grid.[10]
- EF_{grid} is the CEA-published grid emission factor in $kgCO_2$/KwH.[12]

Accounting for Transmission and Distribution (T&D) Losses

India's power sector has seen a robust transformation, with Aggregate Technical and Commercial (AT&C) losses reducing from 22.62% in 2013-14 to 15.04% in 2024-25.[10] For researchers, it is important to use the latest state-specific or national loss figures to avoid overestimating the carbon benefits of EVs. In Maharashtra, for example, some utilities report distribution losses as low as 4.99%, whereas other state-run DISCOMs may still exceed 18%.[24] High T&D losses mean that more electricity must be generated—and more CO_2 emitted—to deliver a single unit of energy to the vehicle's charging port.[5]

Charging Type	Nominal Voltage	Typical Efficiency Range	Primary Cause of Loss
Level 1 (Home)	230V AC	75% - 83.8%	Low current, long operation of onboard systems.[23]
Level 2 (Public AC)	230V/400V AC	89.4% - 95%	Higher current improves converter efficiency.[27]
DC Fast Charging	400V - 800V DC	85% - 92.6%	Battery thermal management and DC conversion.[23]

Charging Infrastructure Efficiency Losses

The process of transferring energy from the grid to the vehicle's battery involves significant losses, primarily as heat. These losses occur during the AC-to-DC conversion (for AC chargers) or through the high-current thermal management systems (for DC fast chargers).

The Break-Even Analysis: EV vs. ICE in India

A crucial output of any EV emission project is the "break-even point"—the mileage at which the EV's lower operational emissions compensate for its higher manufacturing emissions. This point is highly dependent on the grid mix.Under current conditions, where the Indian grid is ~70% coal-powered, an EV may take longer to reach environmental parity than in European markets. However, the analysis shows that even with a coal-heavy grid, EVs offer a 27% to 50% reduction in life-cycle emissions compared to petrol or diesel vehicles.

Segment	ICE Baseline Emissions	EV Lifecycle Emissions	% Reduction
Private Car	Petrol: ~150 g/km	~110 g/km	27%
Shared Car (Taxi)	Diesel: ~180 g/km	~90 g/km	50%
2W/3W	Fossil: ~50-130 g/km	~25-60 g/km	43% - 72%
Urban Bus	Diesel: ~1500 g/km	~900 g/km	40%

Lifetime Savings Projections

The transition to electric buses and shared mobility provides the fastest return on carbon investment. A shared electric car in India emits 50% less GHG over its lifecycle than a diesel equivalent, whereas a private electric car saves only about 27% because it travels fewer kilometers annually.[4] For commercial buses, the transition to EVs can save 460 tones of CO_2 over the vehicle's lifetime.[4]

Future Projections and Sensitivity Analysis

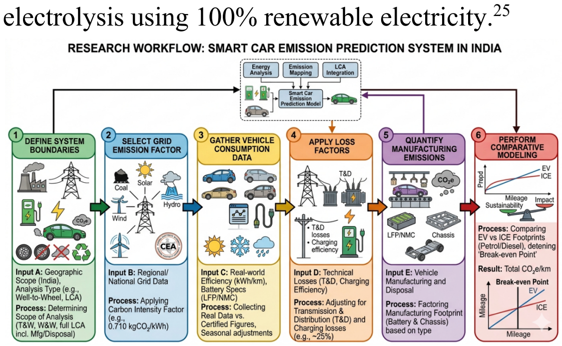
The emissions of an EV project are not static; they are a function of India's energy transition. The 2030 target of 500 GW of non-fossil capacity and the 2047 goal of energy independence will fundamentally change the calculation.[32]

Impact of a Greener Grid (2030 and 2047)

By 2030, the grid is projected to be 50% clean, with the emission factor expected to drop to 430.[5] By 2047, the grid could be 90% clean.[33] For an EV project, this means the operational emissions will follow a declining curve.

$$E_{total} = E_{mfg} + \sum_{t=1}^{n} \frac{E_{ops,t}}{(1+r)^t}$$

In this model, $E_{ops,t}$ decreases every year as EF_{grid} declines. Studies suggest that by 2030, BEVs and plug-in hybrids will show substantial improvements in WTW efficiency, with hydrogen-powered vehicles potentially achieving near-zero WTW emissions if hydrogen is produced via electrolysis using 100% renewable electricity.[25]



Results

The proposed system successfully predicts vehicle emission levels using vehicle and energy consumption data.

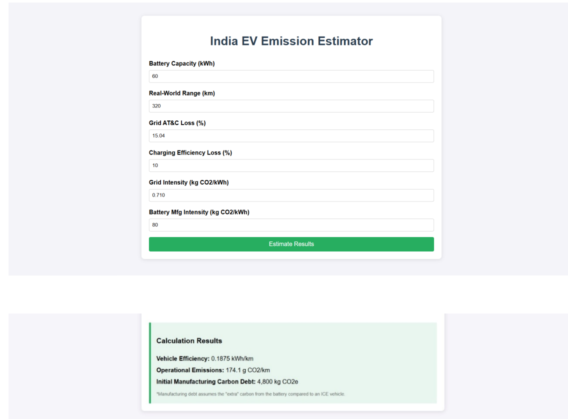


Fig. 9.2 Final Result

Conclusion And Future Scope

Completing a project on electric vehicle emissions in India reveals that while the current grid transition is in its infancy, the environmental benefits of EVs are already demonstrable. The reduction in grid emission intensity from 0.774 to 0.710 TCO_2/MWh over the last decade proves that the "dirty grid" argument is losing its validity.[13]

The key takeaway for any emission calculation is the necessity of a "dynamic baseline." An EV project's carbon savings will accelerate over time as the 500 GW renewable target is met.[32] For commercial and shared fleets, the transition is an immediate climate win, with life-cycle reductions exceeding 50%.[4] For private owners, the break-even mileage is steadily falling as battery manufacturing becomes more efficient and the grid greener.

Ultimately, the accuracy of EV emission calculations in India will continue to improve as new standards, such as the Electricity Distribution (Accounts and Additional Disclosure) Rules 2025, introduce uniform accounting and transparency across distribution utilities.[10] For the researcher, the path forward involves a rigorous application of CEA grid factors, real-world efficiency benchmarks, and localized manufacturing data to provide a transparent and actionable assessment of India's green mobility future.

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