



IoT-Enabled EV Charging Infrastructure for Sustainable Urban Mobility in India

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ABSTRACT

Rapid urbanization and motorization in India have intensified challenges related to air pollution, traffic congestion, and energy consumption. Electric vehicles are often touted as a greener option, but the charging stations we have are not always up to the task. By adopting Internet of Things (IoT) technology into EV charging could change things for the better, making urban transportation more sustainable. This study investigates the how uasge of Internet of Things (IoT)-integrated electric vehicle (EV) charging infrastructure in fostering sustainable urban mobility within the Indian context. This study uses secondary data for data analysis and government policies to evaluate progress, policy initiatives, and operational challenges. The study shows that the northern-eastern states are doing quite poorly, which shows that there are big differences across regions. As of December 16, 2025, India has more than 29,151 public charging stations up and running. This is an incredible rise of 1519.5% compared to statistics from 2022. But 20346 of these 29151 charging stations are sluggish charging stations.

1. Introduction

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1.1 Background of Study

India's urban landscape is evolving quickly. More than a third of the population in the country today live in cities, and by 2035, that number is expected to rise to about 40 percent. This rapid growth of cities, together with increasing income and poor public transportation, has caused a big rise in the number of people who own cars. The Indian government wants to set the sales target to 30% of all vehicles as electric vehicles by 2030. This includes 30% of individual automobiles, 70% of commercial vehicles, and 80% of two- and three-wheelers. This change is not just good for the environment, but it is also a big chance for the economy. It may lessen India's reliance on fossil fuels, generate jobs, and make India a world leader in making electric vehicles.

1.2 What the Internet of Things (IoT)

Traditionally electric vehicle (EV) charging stations have worked without any smart technology, interoperability, or linkages to metropolitan energy networks. Adding Internet of Things (IoT) technology to EV charging infrastructure is a big change from traditional charging systems to smart, connected ecosystems. IoT-enabled charging solutions let you keep an eye on things in real time, charge intelligently, plan maintenance, change prices, and analyze data.

Integrating IoT into the EV charging ecosystem solves a number of important problems

Real time Availability

locate available charging stations , check real time status

Grid Stability

AI-driven charging algorithms

Renewable Energy Intergration

integration between solar and wind power generation

1.3 Research Objectives

1. To analyze the current state and future growth of IoT-enabled EV charging infrastructure in Indian urban cities.
2. To analyze the government policies and impact on EV adoption and infrastructure development.

1.4 Significance of the Study

This study helps people to understand the new EV charging industry as a sustainable area. And as Indian cities slowly start to use smart city technologies, adding IoT-enabled charging infrastructure is an important part of urban planning and plans for long-term growth.

2. Literature Review

2.1 Sustainable Urban Mobility and Electric Vehicles

Sustainable urban mobility is a hot subject in current urban planning talks, especially in fast-growing nations like India. The plan involves transportation systems that are healthy for the environment, produce money, are open to everyone, and employ the latest technology. Electric cars are a big element of plans for long-term transportation because they might lower greenhouse gas emissions, clean up the air, and make us less dependent on fossil fuels that we have to buy from other countries. The Indian government initiated the National Electric Mobility Mission Plan (NEMMP) 2020. This plan lays out a whole plan for speeding up the use and manufacture of electric cars. Primary objectives of the plan include increasing national fuel security, environment friendly transportation options, and making India as a global electric vehicle manufacturing leader.

2.2 IoT and Smart Grid Technologies in EV Charging

The adoption of internet of things technology with electric vehicle charging infrastructure has been studied widely in the context of smart grid integration. Smart grid ev charging stations are intelligent and connected infrastructure that optimize consumption of electricity by enabling two way communication. IoT sensors provides help in real-time performance monitoring, user authentication, and seamless payment systems, by creating a smooth user experience while generating helpful operational data for system optimization. Vehicle-to-Grid (V2G) technology enables bidirectional energy flow between electric vehicles (EVs) and the power grid, allowing parked EVs to charge during low demand and discharge stored energy back to the grid during peak times.

2.3 Business Models in EV Charging Infrastructure

The infrastructure for charging electric vehicles needs business models that are stable and balance expenses, investments, and income. The researcher has found multiple concepts that work in India:

• Direct Ownership Model: Businesses buy and install EV chargers and run them and set prices on their own.
• Pay-Per-Use Model: this model is a usage-based pricing model where user pay the exact amount for the consumption.
• Subscription Model: consumer pay on weekly or monthly charges for unlimited charging or fixed criteria.
• Partnership Model: collaboration between established EV charging service providers and who install and manage. Like P3model or JV.
• Fleet Partnership Model: collaboration between CPO and OEM and commercial fleet owners. (Cabs, logistics, public transport).

2.4 Government Policy and Regulatory Framework

Government policy interventions have played a pivotal role in accelerating EV infrastructure development. The FAME (Faster Adoption and Manufacturing of Hybrid and Electric Vehicles) scheme, launched in phases beginning in 2015, FAME was the technical and financial springboard for India's electric mobility, offering direct buyer subsidies, technology development funding, pilot deployments, and support for charging infrastructure—all managed by the Ministry of Heavy Industries. Fame Promote manufacturing of Zero Emission Vehicles (ZEV) and hybrid vehicles domestically by supporting the manufacturing ecosystem. And contribute to the country's efforts for a low emission-intensive economy (as agreed in COP 21). Fame also Support reduction of vehicular emissions, especially in cities.

The PM Electric Drive Revolution in Innovative Vehicle Enhancement (PM E-DRIVE) scheme, allocates ₹2,000 crore for the installation of approx.72,000 public EV charging stations, offering high-percentage capital subsidies. Subsidies include up to 100% for equipment and infrastructure in government locations, and 70-80% for high-traffic public sites (commercial/highways). Public Locations & Highways: 80% subsidy for upstream infrastructure and 70% for EVSE. Target Infrastructure: The 2,000 crore, part of the wider ₹10,900 crore schemes, will install 22,100 fast chargers for 4-wheelers, 1,800 for buses, and 48,400 for 2/3-wheelers.

2.5 Challenges in EV Charging Infrastructure Deployment

Despite significant progress, several challenges impede the optimal deployment of EV charging infrastructure:

1. Infrastructure gap in comparison of growing population
2. Reflecting Uneven Geography distribution
3. Higher operational costs and low utilization rates
4. High Dependency on Energy Sources
5. Absence of standardized communication protocol between charging operators and grid operators.

3. Research Methodology

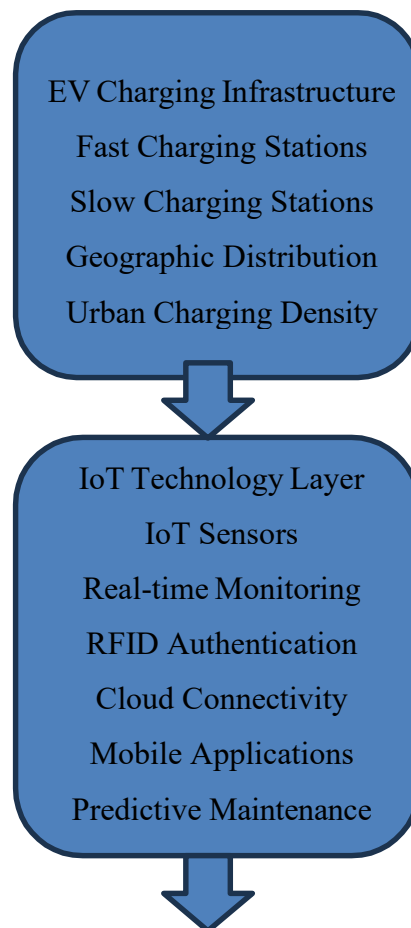
3.1 Research Design

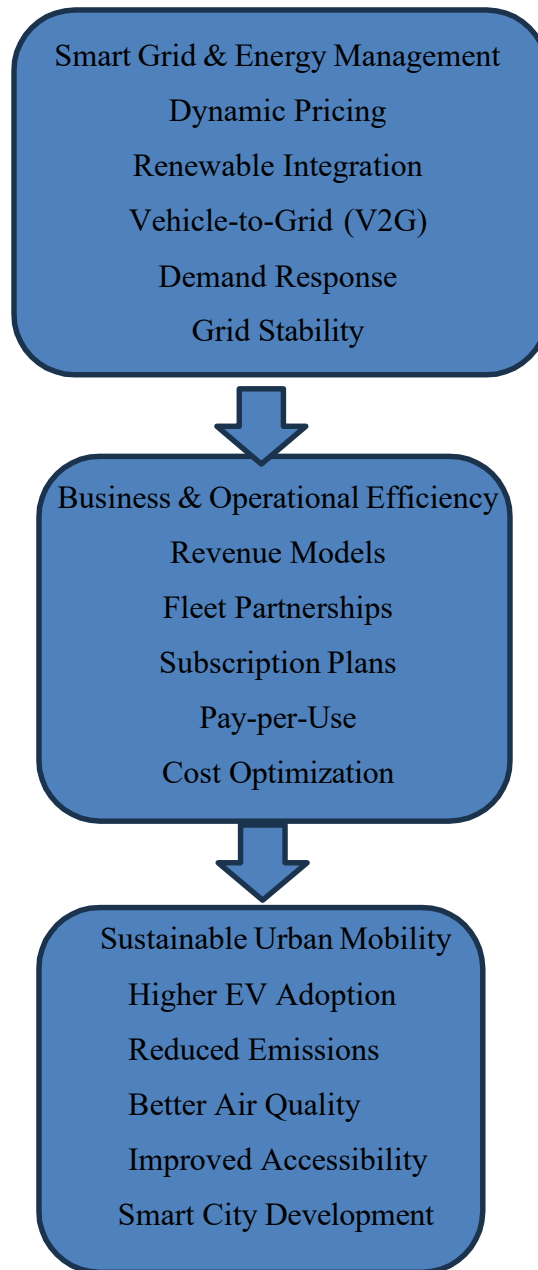
This study employs a descriptive and analytical research design unify secondary data from government publications, industry reports, academic literature. The research adopts multi-dimensional aspects of IoT-enabled EV charging infrastructure in urban India.

3.2 Analytical Framework

GOVERNMENT POLICIES

(FAME, PM E-DRIVE, State EV Policies, Smart Cities Mission, BIS Standards)





3.3 Research Gap

The adoption of electric vehicles (EV), development of charging infrastructure, smart grids and IoT enabled charging technologies have been well covered in the past studies. However, there are still numerous critical research gaps, especially for the Indian context. Previous research focusses mostly on the technical elements of IoT-enabled charging systems, battery management, communication protocols, and charging optimization algorithms. Some studies focus on the government programs such as the FAME scheme, PM E-Drive and the EV adoption trends. Limited study, however, has not comprehensively assessed the technological, infrastructural, business and regulatory features of IoT enabled EV charging infrastructure for sustainable urban transportation in India. This paper fills these research gaps by offering a complete review

of India's public EV charging infrastructure utilizing recent secondary data, official policy papers, and industry sources. The research combines infrastructure development, IoT capabilities, smart charging technologies, commercial models and legislative activities into a common analytical framework. It also examines patterns of regional distribution and highlights major operational problems that might impact India's transition to sustainable urban transportation.

3.4 Limitations

This study acknowledges several limitations:

- Dependence on secondary data sources may not present real picture of the Selected Sector.
- Research primarily focuses on urban area
- No focus on primary data collected from EV consumers and Charging Station operators.

4. Analysis and Findings

4.1 Infrastructure Growth Trajectory

Charging infrastructure of India has witnessed robust growth, from just 1,800 charging stations in 2022 to 12,146 charging stations in 2024. A phenomenal growth of 574.77% in just two years. By 16 December 2025, this network has further expanded to over 29151 public charging stations(out of these charging Stations 8805 stations supports fast charging and 20346 charging stations supports slow charging), representing again a phenomenal growth of 1519.5% as compared to 2022. This Robust growth shows how government policy, support and private sector investment boost the EV market and infrastructure.

4.1.2 Geographic Distribution and Urban Concentration

Infrastructure deployment exhibits significant geographic concentration. Karnataka, Maharashtra, Uttar Pradesh, Delhi & Tamil Nadu emerged as the top 5 states for EV charging Stations Tier-1 cities account for the majority of both EV registrations and charging station installations, creating a pattern where urban India leads EV adoption. Study further reveals that Karnataka has highest 20.91 percent share and Ladakh and Lakshadeep has lowest .003 percent share. Even there is huge difference in share ranks first and third that reflects there is still lot of developmental and functional work pending. Tamil Nadu State score 5th position but has highest number of Fast charging Stations. Charging stations to EV ratio is .012 in Uttar Pradesh that describe the difference is very high.

NO OF CHARGING STATIONS INSTALLED DATA

State / UT	Total Charging Stations	Fast Chargers	Slow Chargers
Karnataka	6096	751	5345
Maharashtra	4166	1205	2961
Uttar Pradesh	2316	540	1776
Delhi	1957	399	1558
Tamil Nadu	1780	926	854
Rajasthan	1515	523	992
Kerala	1389	553	836
Gujarat	1205	578	627
Madhya Pradesh	1146	353	793
Telangana	1062	548	514
Haryana	919	384	535
West Bengal	891	321	570
Andhra Pradesh	791	424	367
Punjab	698	225	473
Odisha	606	165	441
Bihar	518	172	346
Jharkhand	353	129	224
Chhattisgarh	347	124	223
Assam	345	96	249
Uttarakhand	221	84	137
Jammu And Kashmir	180	61	119
Goa	156	94	62
Himachal Pradesh	133	52	81
Meghalaya	62	21	41
Manipur	58	9	49
Tripura	55	4	51
Puducherry	46	28	18
Arunachal Pradesh	45	4	41

Nagaland	37	6	31
Dadra and Nagar Haveli and Daman and Diu	14	11	3
Mizoram	13	0	13
Chandigarh	13	11	2
Sikkim	12	3	9
Andaman And Nicobar Islands	4	1	3
Lakshadweep	1	0	1
Ladakh	1	0	1

STATE - WISE EV REGISTRATION DATA 2025

State	PLUG-IN EV	HYBRID	PURE EV	STRONG EV	HYBRID	TOTAL
UTTAR PRADESH	0		1,99,918	3		1,99,921
RAJASTHAN	0		79,395	0		79,395
KERALA	0		72,215	1		72,216
ODISHA	0		65,021	1		65,022
BIHAR	0		58,583	0		58,583
GUJARAT	0		56,704	5		56,709
DELHI	0		55,967	4		55,971
ANDHRA PRADESH	0		44,613	2		44,615
WEST BENGAL	0		41,552	0		41,552
KARNATAKA	0		1,37,237	10		1,37,247
ASSAM	0		35,328	0		35,328
CHHATTISGARH	0		34,773	2		34,775
PUNJAB	0		30,035	0		30,035
TAMIL NADU	0		1,19,781	4		1,19,785
HARYANA	0		19,337	1		19,338
JHARKHAND	0		17,305	0		17,305
UTTARAKHAND	0		11,956	0		11,956

MAHARASHTRA	0	2,05,601	8	2,05,609
JAMMU AND KASHMIR	0	5,450	0	5,450
GOA	0	5,318	0	5,318
MADHYA PRADESH	0	1,04,986	0	1,04,986
TRIPURA	0	4,937	0	4,937
PUDUCHERRY	0	3,763	0	3,763
CHANDIGARH	0	1,786	6	1,792
HIMACHAL PRADESH	0	893	0	893
MANIPUR	0	658	0	658
MEGHALAYA	0	247	0	247
MIZORAM	0	235	0	235
UT OF DNH AND DD	0	147	0	147
ANDAMAN & NICOBAR ISLAND	0	72	0	72
ARUNACHAL PRADESH	0	34	0	34
LAKSHADWEEP	0	17	0	17
NAGALAND	0	14	0	14
SIKKIM	0	2	0	2

4.1.3 IoT Integration Penetration

A transformative shift is underway in the technological sophistication of charging infrastructure. This represents a strategic pivot from basic charging hardware to intelligent systems capable of:

IoT Capability	Functional Benefits
Real-time Monitoring	Uses sensors to track performance, location & battery health (BMS).
User Authentication	Glitch free user identification through RFID cards, mobile apps, or vehicle-integrated authentication systems for enhanced security features.

Dynamic Payment Systems	Various payment modes (such as UPI, credit/debit cards, digital wallets).
Remote Diagnostics	Cloud-based platform to track and identify problems and resolve issues without physical site visits.
Load Management	Effective use of Artificial Intelligent to prevent local grid overload.

4.2 Technological Framework and Smart Grid Integration

With the help of artificial intelligence and IoT sensors smart charging systems boosts the stability of the grid and the use of power. IoT-enabled charging infrastructure makes easier to connect with renewable energy sources, which helps India reach its goals of increasing the use of electric vehicles and transitioning to sustainable energy. Smart charging stations can perform with with help of AI and IoT:

Price as per the renewable energy left on the grid.

Directly work with solar panels installed on commercial buildings, malls, and parking lots.

Allow energy storage devices to charge when there is too much renewable energy and discharge when demand is highest.

4.3 Business Models and Economic Viability

Charge Point Operators have developed diversified revenue models to enhance economic viability:

4.4 Policy Framework and Government Initiatives

4.4.1 PM E-Drive Scheme and Infrastructure Targets

The PM Electric Drive Revolution in Innovative Vehicle Enhancement (PM E-DRIVE) scheme represents the most ambitious government intervention to date. Launched with a ₹2,000 crore allocation specifically for charging infrastructure (part of a ₹10,900 crore total outlay), the scheme targets deployment of 72,000 Approx. public charging stations by 2027. Charging Stations will be placed at strategic locations along with 50 national highway corridors, in busy places including metro cities, toll plazas, railway stations, airports, gas stations, and state roads.

GOVERNMENT SCECHMES	NO OF CHARGING STATIONS INSTALLED
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FAME-1	479
FAME-2	9097

Location Targets

Urban: At least one station in a grid.

Highways: At least one station every 25 km on both sides of highways/roads.

Heavy Duty: Fast charging stations every 100 km on both sides of highways.

4.5 Urban Mobility Integration and Strategic Locations

4.5.1 Transit Hub Integration

In operational hours Metro stations, airports, and bus depots offer consistent high utilization due to continuous vehicle and passenger flow.

4.5.2 Commercial Real Estate Integration

Malls, shopping complexes, and commercial office buildings represent strategic charging locations.

4.6 Problems and Obstacles

4.6.1 Gap in infrastructure and speed of deployment

India's development rates are outstanding, but the country has a big infrastructure gap since participation is uneven between states. The country needs 1.32 million public charging stations to reach its goal of 30% EV adoption by 2030. This means that more than 400,000 stations need to be installed each year starting in 2026.

4.6.2 Limitations on Grid Capacity and Power Supply

Local electrical grids have to work very hard to provide fast-charging infrastructure. A single 150 kW DC fast charger uses as much electricity as about 50 homes, which might overload distribution transformers in places that were not built to handle such heavy loads.

4.6.3 Problems with Economic Viability and Profitability

CPOs have to deal with profitability problems because of low utilization rates in the early expansion period. Most vehicle types (excluding two- and three-wheelers) have less than 2% EV penetration right now. This means that charging stations in many places do not get enough use to cover their costs.

4.6.4 Education and Awareness for Consumers

Even if more people are aware of EVs, there are still big gaps in understanding among people who would choose to embrace them:

- Not knowing how long it takes to charge, which leads to unreasonable expectations
- Range anxiety continues even in places with good charging coverage because of gaps in information
- Worries about the expenses of charging and how power prices work Not sure how reliable and well-maintained charging stations are Fear about hazards to cyber security.

5. Recommendations

- Develop and publish a 10-year national charging infrastructure roadmap with clear deployment targets.
- Transition from pure capital subsidies to performance-based incentives
- Require technical and operational interoperability across all charging networks
- Introduce special time-of-use tariffs for EV charging that incentivize off-peak
- Incorporate EV charging infrastructure as a core component of smart city and sustainable urban mobility planning from initial design stages.
- Targeted policy interventions and regional based incentives to ensure balanced development.

6. Conclusion

This research has examined the multifaceted dimensions of charging infrastructure. And reveals Uttar Pradesh has largest population in India but ranked 3rd position in charging station rank and has a difference of 3780 no of charging stations (12.97% share difference) in comparison of rank 1 state. Participation of U.T's is significantly low and contributes very less. 17 states including U.T's has less than 1% share that shows state governments need to work hard on advanced electric vehicle charging infrastructure. Study further reveals northern-eastern states also performing very low highlighting substantial regional disparities. India's charging infrastructure has expanded dramatically, with over 29,151 public charging stations operational as of 16 December 2025, presenting phenomenal growth of 1519.5% as compared to 2022 data .but out of these 29151 charging stations 20346 stations are slow charging stations. Both government

(central and state) needs to do work on advancement of charging stations as well as do focus on installation of new charging stations. Current deployment rates shows we will miss the target by a huge margin even by performing well in comparison to previous years.

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