INTEGRATING DYNAMIC WIRELESS CHARGING WITH URBAN ELECTRIC VEHICLE TRANSIT IN INDIA: OPPORTUNITIES AND CONSTRAINTS

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ABSTRACT
Transition to low-carbon road transport is essential for India's net-zero and energy security objectives, with Electric Vehicles (EVs) aided by national initiatives such as FAME II and PM E-DRIVE being central to this transformation. Nonetheless, issues including local supply chain localization, funding constraints, battery limitations, and limited charging points continue to be a concern. Dynamic Wireless Power Transfer (DWPT), which is an extension of Inductive Power Transfer (IPT), enables EVs to replenish their batteries while in motion along coils integrated into roads, which offers a seamless and high-efficiency power provision that could decrease battery size, lower charging time, and increase fleet availability, especially along electric bus corridors and Bus Rapid Transit Systems (BRTS). Integration of Renewable Energy Sources (RES) with electric public transport can also enhance environmental and economic benefits, while Public-Private Partnerships (PPPs) will play a key role in creating sustainable charging networks as well as green technologies. However, implementation of DWPT is hindered by high installation costs, infrastructure preparedness, management of power grids, electromagnetic safety, and standardization. Thus, in order to ensure scalable and sustainable EV mobility in India, tech leaps in charging technology, renewables integration, and enabling policy steps are crucial.

Keywords: : Inductive Power Transfer (IPT), Dynamic Wireless Power Transfer (DWPT), Electric Vehicles (EVs), Static vs Dynamic Charging, Efficiency Parameters and Design Considerations, FAME-II Scheme, PM E-DRIVE Program, National Electric Mobility Mission Plan (NEMMP), Public–Private Partnerships (PPPs), Electric Bus Deployment, Charging Infrastructure, Renewable Energy Integration, Policy and Regulatory Framework, Standardization Challenges, Smart City Inclusion, Energy Security, Sustainable Public Transport, Battery Limitations, Electromagnetic Safety, and Bus Rapid Transit Systems (BRTS).

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I Introduction

Inductive Power Transfer (IPT) moves energy without wires using magnetic fields, skipping physical plugs - this tech helps charge next-gen electric cars more smoothly. Instead of cords, it links separate coils to send power safely while parked or even driving. Breakthroughs in electronics from the University of Auckland in the late '80s made this possible. While today it's good for fixed spots and quick top-ups, tomorrow could bring road-powered charging on the go. By cutting out traditional cables, IPT gives drivers a simpler way to stay charged up.

The global move from gas-powered transport grows stronger as people worry more about clean energy and nature's health. Yet cars that plug in face issues since their power packs tend to be bulky, pricey, and wear out fast. As engineers focus on smarter setups, cutting down energy waste, materials, spending, and delays feels urgent now. Across India, going electric isn't just good for air quality - it's backed by rules too, thanks to big pushes such as FAME-II, NEMMP, and the PM e-Bus Sewa rollout. All these plans give rewards, boost local production, push innovation efforts while building strong charging networks. Programs such as NEMMP, FAME, or PM E-DRIVE continue driving electric vehicle use alongside infrastructure growth.

India's electric vehicle scene is taking shape but faces hurdles - funding gaps, too few charging points, or weak local production of batteries and electronic parts. Officials are stepping in, setting rules and safety steps to strengthen the system. Even though big costs and missing support structures slow things down, steady government action, cash from businesses, along with new tech breakthroughs, are pushing the country closer to eco-friendly transit options, where wireless charging through magnetic fields leads the shift

II Literature

2. Dynamic wireless charging

2.1.1 Inductive Power Transfer (IPT)

A wireless system sends energy without cables by using magnetic fields created between two coils - one powered, one receiving. This idea's gotten way better lately, now popping up in gadgets, medical devices inside bodies, robots, even cars that charge while parked. There are mainly two kinds: one relies on close-range magnetism, another boosts efficiency through tuned signals. The first type runs faster than old-school transformers - think 20 thousand to a million cycles per second - and handles heavy loads when coils sit just millimeters or centimeters apart. On the flip side, the upgraded version pushes frequencies much higher, say 5 to 20 million cycles each second, making it ideal for weaker needs across gaps wider than the coil itself. [1]

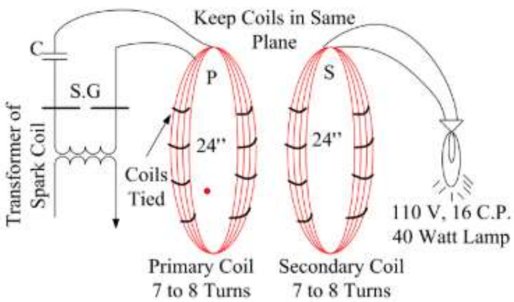

Fig-1. H. Winfield Sector's Tesla apparatus and experiments were published in Practical Electrics in November 1921.[1]

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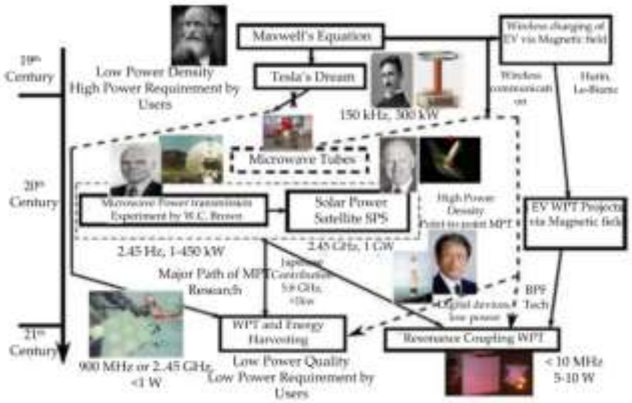

Fig-2. History of WPT technology.[1]

2.1.2 Compensation Topologies

Compensation setups help match the receiver (Rx) and transmitter (Tx) coils so energy moves better without wires. Instead of "and," different links like "while" or "with" keep things flowing smoothly across four main types: Series-Series (SS), Parallel-Series (PS), Series-Parallel (SP), plus Parallel-Parallel (PP). The SS type uses a cap in line on both Tx and Rx ends - works well for efficiency and boosting voltage, yet stumbles when the load shifts. On the flip side, SP runs a series cap on Tx while tossing a parallel one on Rx, giving steady voltage no matter the load thanks to Zero-Phase Angle (ZPA) - great for heavy-duty jobs. Meanwhile, PS flips it: parallel up front, series at the back. Then there's PP, where each side gets a parallel cap instead. The PS and PP setups handle empty loads better than SS or SP when the transmitter runs without a receiver. Besides that, mixed designs such as Double-Sided LCC - which works well for electric vehicle charging - and LCC-S, which suits smaller power needs better than SS - are gaining attention thanks to smoother operation and adaptability[2].

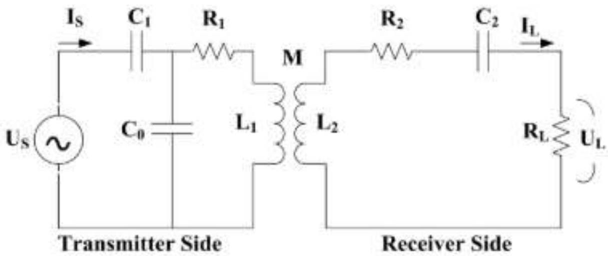

Fig-3. Equivalent circuit of SP/S compensated ICWPT system[2]

2.1.3 Coil Design Aspects

Coil shape plays a big role in how well an inductively coupled wireless power system works - especially when charging electric cars - since it affects how much movement the setup can handle and how the magnetic field flows. Various designs have popped up for vehicles: round ones, flux pipe types, double D layouts, double D with quadrature setups, plus bipolar versions. Round coils don’t rely on orientation and fit best in static charging spots - but they struggle if things shift even slightly out of place. Double D styles are directional and create a side-to-side magnetic push; they tolerate small shifts along one axis better, yet there are dead zones where power drops sharply. Advanced variations like DDQ or bipolar models build on the double D idea by handling misalignment across both axes, making them ideal for moving or partially mobile car charging while keeping energy flow steadier despite position changes. [2]

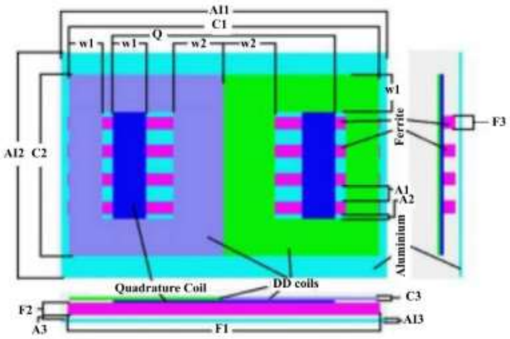

Fig-4.DDQ pads[2]

2.1.4 Performance Parameters

The way a coil is shaped really affects how well an inductively coupled wireless power system works - especially when charging electric cars - because it changes how forgiving the setup is to positioning errors and guides the flow of magnetic energy. Different designs have popped up for vehicles: round ones, flux channel types, double D layouts, double D with quadrature setups, plus bipolar versions. Round coils don't favor any orientation and are best suited for parked charging sessions, though they struggle if things aren't perfectly lined up. The double D type uses directional alignment to create a sideways magnetic field, handling shifts along one axis better - but there are spots where power delivery drops off hard. Advanced variants like double D with quadrature or bipolar models build on that base by tolerating bigger offsets both ways, which helps keep power steady while driving through charge zones, so shifting car position doesn't wreck efficiency. [3]

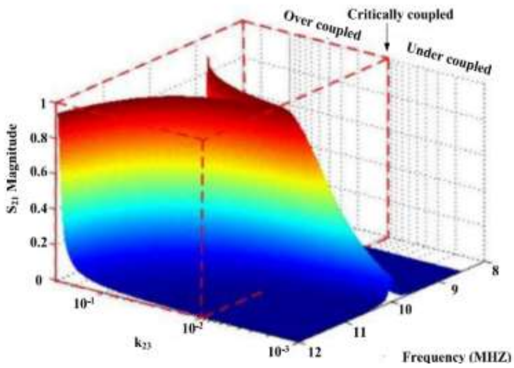

Fig-5. S21 magnitude for the simplified circuit model as a function of frequency and transmitter-to-receiver coupling[3]

2.2 Static Vs Dynamic Wireless Charging

2.2.1 Static Wireless Charging

The car charges on its own when sitting still at a set spot. These pads use iron-based stuff to guide the energy flow, along with aluminum layers that block unwanted magnetic leaks, so power goes where needed. This setup makes charging easier - people won't need to remember plugging in - and cuts risks like exposed wires, tampering, or sparks. Built-in wireless systems are getting close to full development and now reach over 90% efficiency[4]

2.2.2 Dynamic Wireless Charging (DWPT)

Makes electricity flow while the car moves on a dedicated path equipped with IPT tech. Main aim? Keep sections of busy roads or key highway stretches energized nonstop. This lets cars carry much smaller built-in batteries, cutting upfront EV prices and easing worries about running out of charge. Instead of fixed coils, there's a long buried wire or split power segments hidden below ground.

Takes on the challenge of keeping a single coil contained. Figuring out how to set up smart positioning signals for the receiver matters - so coils power up or down at the right time.[4]

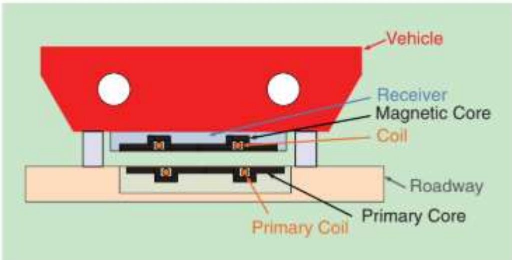

Fig-6.An illustrating of the dynamic charging concept[4]

One-coil setup (long path): easy handling, fewer parts needed. But it’s got downsides - weak link strength between coils, energy leaks where they don’t connect, plus heavy coil resistance. Split-coil layout fixes those one-coil limits. Catch? You’ve gotta work out complex tracking so you can turn each piece on or off at the right moment. Fairly decent performance tops out around 70% with one coil setup 28 - though that number drops compared to fixed systems due to more off-center positioning29. Split, fine-tuned coils could get close to 90% effectiveness.[4]

2.2.3 Infrastructure Coverage and Safety

DWPT looks doable based on sim results. To hit a 300-mile range with 30 kW sent to the car, IPT must cover this stretch[4]

	Insight	Impala	Explorer
	UDDS		
Coverage (%)	0.46	0.91	1
	HWFET		
Coverage (%)	17	27.3	43.8
	HW-MTN		
Coverage (%)	17.2	35.4	64.3

TABEL.1 IPT Coverage Needed for 300-miRange (30 kW Supplied to Vehicle)[4].

The results show that just 1% of city roads equipped for power transfer - using the UDDS pattern - lets nearly every kind of car hit the 300-mile goal without needing a large battery. Shown here (adapted from) are speed over time plus total distance covered during charging windows for three models: Explorer, Impala, and Insight under the same driving schedule. The marked paths, highlighted in black, point out which road sections an automated solver picked as ideal spots to set up wireless charging lanes.

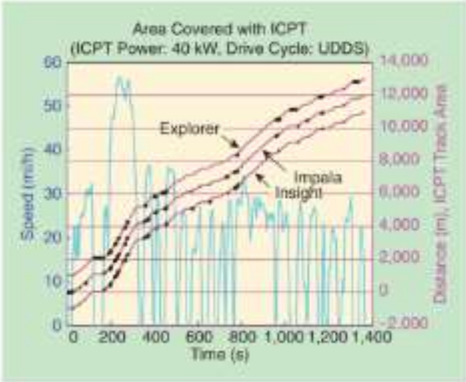

Fig-7 The area covered with IPT-optimization for different cars,[4]

2.2.4 Health and Safety

Wireless charger designs will need to meet agreed standards on magnetic emissions, including those of the International Commission on Non-Ionizing Radiation Protection (ICNIRP)[4]For exposure in the 3–100 kHz frequency band, the general public maximum exposure limit is 27 µT. will need to include a solid foreign-object identification system to switch off the power automatically if an obstacle is introduced into the magnetic link, which could be hazardous.[4]

2.3. Efficiency parameters & design consideration

A mobile app or smart device working offline - say, AR on phones or self-flying drones - needs a neural network that’s accurate without draining battery, yet still runs fast enough to react instantly[5]. Factories and production units guzzle power, so switching to low-energy tech helps save money and reduces harm to nature. But getting there isn’t easy because setup prices are steep and current tools have limits.[6] Picking the right green solution means juggling trade-offs between price, power use, and ecological footprint - it's never just one thing. To make sense of options, experts use MCDA, mixing techniques such as AHP, TOPSIS, or SAW for clearer rankings.[7] What matters most when comparing choices? Power draw, expense, and damage to the environment[6]. Some factors boost value ("Benefits"), others add burden ("Costs") - sorting through both reveals which path works best (called Process Routes)[8].

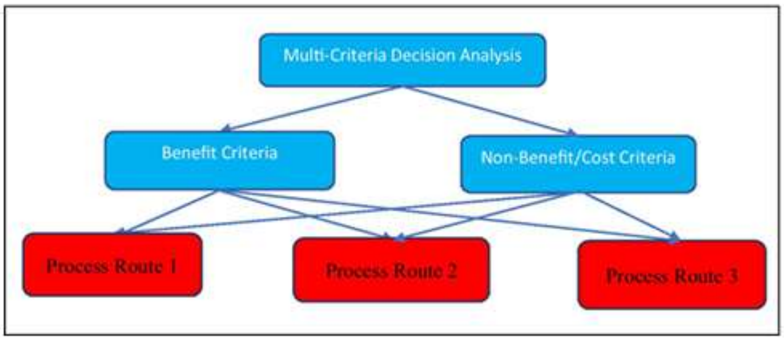

Fig-8. Schematic Diagram of the Multi-Criteria Decision Analysis Flow in Evaluating Energy-Efficient Manufacturing Solutions(Source:researchgate.net)[8]

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2.3.1 Implementation and Results (Efficiency Parameters)

Some energy-saving tech got installed plus checked during half a year. Used high-end heat transfer units along with leftover heat capture setups.[6]

Industrial Sector	Energy Consumption Before (kWh)	Energy Consumption After (kWh)	Energy Savings (%)
Chemical Production	500000	375000	25
Metal Processing	600000	480000	20
Food Manufacturing	300000	255000	15

Table 2. Energy Consumption Data for Different Industrial Sectors Before and After Implementation

One out of four units less energy used[9]. Switched to top-performing heaters along with improved insulating techniques. Energy use dropped by a fifth. Got money back fastest - just 24 months to break even. Overall expenses went down from one-tenth up to three-tenths. Putting funds into these fixes proved smart, earning full returns anywhere from two to half a decade[6].

2.3.2 Core Efficiency Parameters and Trade offs

The biggest issue? Balancing accuracy, speed during inference, along with power used per query. Researchers suggest a fresh scaled measure - accuracy divided by joules - to help pick better models. That number shows how much electricity it takes to gain one step in precision. When deep neural nets get bigger, tiny accuracy gains demand way more energy than before. When it comes to accuracy per joule, tiny models - built for basic gadgets - beat big ones by a wide margin, sometimes even tenfold. Apps focused on saving power ought to pick a model that’s super frugal with energy, settling for decent precision instead of chasing the highest score[10].

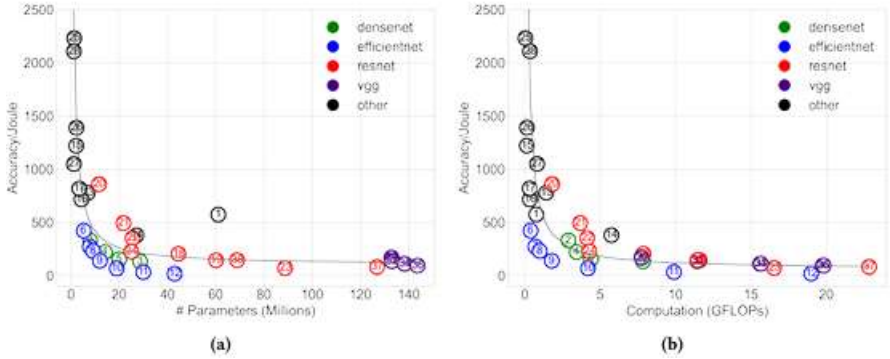

Fig-9: Effect of model characteristics on Accuracy Per Joule[10]

2.3.3 System-Level Design Considerations (Dvfs)

The energy use can drop more when tweaking setup settings - like adjusting voltage and speed on the built-in GPU. Inference gets slower as GPU speed goes down. When GPU frequency drops, power used also falls at about the same rate. Cutting GPU speed reduces power in a straight line, yet delays grow faster than expected. That means apps that don’t need strict timing can save a lot on energy.[10]

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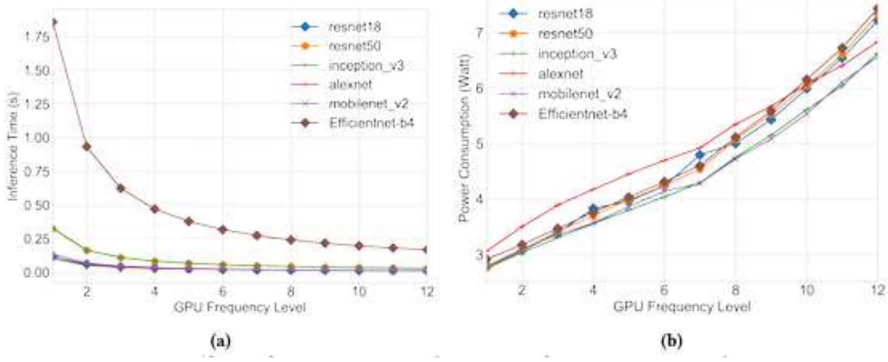

Fig-9: Effect of Frequency Scaling on Inference Time and Energy[10]

2.3.4 The Recommendation Algorithm

It's built to tackle the tough choice of picking the best model and speed, especially since how accuracy, delay, and power use connect isn't straightforward - so solving it perfectly takes way too long. While some methods try shortcuts, they often miss better options hiding in the mix; because small changes can lead to big differences, guessing won't cut it here.

To figure out how well it runs, the method relies on a math-based setup built around two main formulas - each shaping the next step in its logic

Inference Time : $Tm(F)=am\ F+bm$

where and depend on the model, while stands for how fast it runs.

Energy per Request : $Em(F)=PF\times Tm(F)$

here stands for how much energy is used at that frequency.

The aim of the method is to keep checking step by step - beginning with the most accurate setup - for a good match between model and frequency that hits peak performance without breaking the app's time or power limits.[10]

2.4. EV Transit System in India

2.4.1 Status of Electric Bus Deployment Under FAME-II

The first FAME II plan kicked off in April 2019 with a budget of ₹10,000 crore.[11]

Components of FAME II and corresponding fund allocation

Component	Earmarked funds (₹ crore)	Share of total earmarked funds
Demand incentives	8,596	85.96%
Public charging infrastructure	1,000	10.00%
Administrative expenditures, including publicity, information, communication, and education activities	38	0.38%
Committed expenditures of FAME I	366	3.66%
Total	**10,000**	**100%**

Table-2 Compound Of FAME and Corresponding Fund Allocation[11]

This first split sent money to Demand Incentives (₹8,596 crore, that's 85.96%) while directing the rest to Public Charging Infrastructure (₹1,000 crore, about 10.00%). After changes rolled out in February 2024, the total budget jumped to ₹11,500 crore.[11] Electric buses got ₹3,209 crore under the updated plan - that's 28% of all designated money. Meanwhile, public charging infrastructure received ₹839 crore, which is less than the original ₹1,000 crore set aside.[11]

Component	Earmarked funds (in ₹ crore)	Share of total earmarked funds
Electric two-wheelers	5,311	46%
Electric three-wheelers	987	9%
Electric four-wheelers	750	7%
Total for subsidies	**7,048**	**61%**
Electric buses	3,209	28%
Public charging infrastructure	839	7%
Grants for creation of capital assets	**4,048**	**35%**
Others	404	4%
Total	**11,500**	**100%**

Table-3 Components of FAME II and corresponding fund allocation after February 2024 updates[11].

2.4.2 Charging Infrastructure For Bus Deployment

Even though the FAME II plan approved many charging spots, this report zeroes in on bigger vehicles like buses - aimed at cutting idle time and boosting daily performance. Charging buses at one point can take hours with a regular unit, but drops to roughly 40 minutes if you use a quick DC option. Swapping batteries instead? That's done in just 3 to 6 minutes, slashing stoppage periods while possibly lifting earnings. Setting up heavy-duty power points means combining different types of chargers. With buses heading back to their home spots - usually found at depots or key logistics centers - to cover extra mileage demands and ease concerns about running out of charge on busy routes.[11]

2.4.3 FAME II Targets and Budget

The FAME II program acted as India's main funding tool to boost electric transport. Running for five years, it got a ₹100 billion allocation. Around 7,000 e-buses and hybrids were targeted under this push. By July 2022, about 532 charging spots had been built nationwide[444]. Another 2,877 stations were lined up - aiming for one every 3 km in urban areas, or every 25 km along highways.[12]

2.4.4 Operational Status and Early Success

Electric buses now run across several cities in India - Delhi, Bengaluru, along with Kolkata. BMTC in Bangalore saw big wins using e-buses, leading the way when it comes to cutting down fuel use and CO_2 output. The plan targets 30% of vehicles going electric nationwide by 2030.[12] Instead of focusing on personal cars, funding support should go toward company-owned fleets and city transport since they slash emissions faster while being used more often, making up for pricier beginnings thanks to lower running costs.[12]

2.4.5 Deployment Policy and Financial Strategy

The FAME initiatives mostly worked well to boost electric vehicle use. Still, staying effective over time means changing priorities slightly[13]. Instead of just handing out cash rewards, FAME II poured money into building charge spots while supporting uptake[11]. Meanwhile, the Indian government lowered GST rates - EVs went from 12% down to 5%, and charging gear dropped from 18% to match that same lower rate[12]. A big money move plus careful steps stay key to building a solid charging setup for every kind of electric vehicle. The government could use mixed funding paths - think public-private teamwork, eco-bonds, or fresh methods - to pull in private cash while lowering potential downsides[14,15].

2.5. The Role of Public-Private Partnerships (PPPs) in Road Infrastructure Projects

A Public-Private Partnership (PPP) serves as a common way to build, upkeep, and run road projects - providing a fresh approach compared to standard government-run methods. What fuels its growing use is how well PPPs perform when stacked against conventional public systems[16].

2.5.1 Core Objectives and Rationale for PPP Adoption

The core purpose of PPPs mixes funding with growth, targeting major shortfalls in infrastructure. Instead of hiking taxes or borrowing right away, governments use these partnerships to get essential roads and services built. That helps ease pressure on tight public budgets. By using PPPs, officials aim to close the widening gap between rising need for transport networks and the slow, flawed results from standard government contracting. Long-term deals link government and private companies to run public services, covering areas like power, healthcare, or schools - not just transit. When roads are built this way, they become key to growth and how people stay connected across regions.[16]

2.5.2 Primary Research Themes and Functional Roles

The study spanning three decades (1993–2022) points to four key ways PPPs function in road development - using different models, blending public and private efforts, handling funding shifts, while also shaping infrastructure growth through shared responsibilities

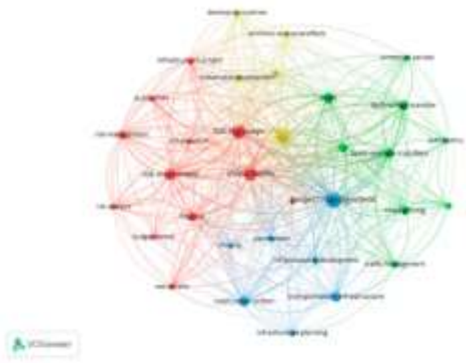

Fig-10 Keyword network on PPPs in road infrastructure projects. [16]

This idea's getting the most attention from researchers right now. Cash flow matters - funding talks pop up everywhere, showing how PPPs help pull private money into public work. Instead of just one side taking hits, splitting dangers like cash shortfalls or weak demand boosts odds of winning; both government and business need to share that load. To sweeten the deal, officials often toss in safety nets so companies feel safer putting money down. In poorer nations, they lean on Build-Own-Run setups to handle expenses while earning back costs over time. When it comes to roads, setting fair user fees keeps things running smooth - how you collect shapes who benefits and how much. The length of the concession time matters a lot - poor setup might cause expensive fixes later or even contract cancellation. With PPPs, ongoing project control shifts to private companies instead.[16].

Keyword	Occurrences	Total Link Strength
Infrastructural development	20	57
Infrastructure planning	19	34
Life cycle	12	26
Maintenance	17	45
Project management	99	339
Road construction	44	104
Transportation infrastructure	41	95

Table-4. Keywords in the privatization of transport infrastructure services topic.[16]

Private firms teaming up with governments don't offer fast solutions - rather, they face challenges throughout a project's life, handling maintenance and rule compliance alike.[16] Recently, focus has grown around lasting effects, linking such efforts to worldwide green goals.[19] Each plan must weigh people’s needs against environmental safety and budget logic.[20] Slowly, their role will evolve to support eco-friendly practices in construction and daily use - like clean techniques, recycled materials, or efficient layouts reducing emissions.[16].

2.5.3 Thematic Evolution of Research

In road-based public-private partnerships, a sharp rise started from 2008 onward - this spike came after the worldwide economic crash that year forced officials to explore fresh ways to fund projects[16]. Leading Topics: At first, most studies focused on Engineering; however, lately its role’s shrunk, making space for fields like Business, Management & Accounting along with Economics, Econometrics and Financial Studies.

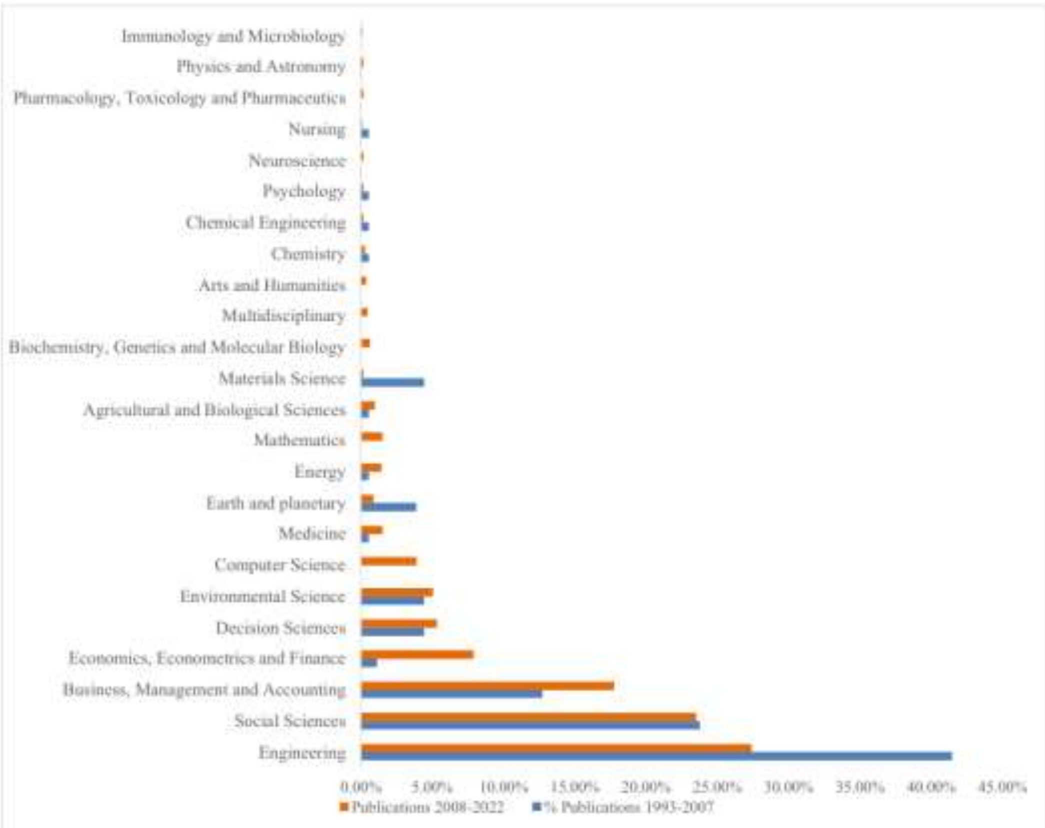

Fig-11.Evolution of the areas of research

Folks are mixing different areas now, so ideas such as long-term sustainability pop up alongside time-limited permits - meanwhile budget tracking's gaining attention too [16].

2.6. Urban infrastructure in India

2.6.1 Fundamental Infrastructure Challenges

The sluggish shift to electric transport in India stems largely from messy and unplanned city layouts. Because roads are in bad shape, traffic flows unpredictably, making it tough to map out where chargers should go. On top of that, weak electricity networks complicate things further - placing stations wrong can spike uneven energy use, hurting grid balance while wasting power and lowering supply quality. So picking spots means checking how steady, safe, and strong the local power system really is. One big problem? Cities were built without ever thinking about spreading EV chargers around. So, finding good spots to charge cars matters a lot in cities. Even with efforts by governments and groups, switching from gas-powered cars to electric ones isn't moving fast - mainly because teams don't sync up well and rewards aren't clear enough[21].

Key player	Role
Ministry of Power	Coordinate with Electricity Distribution Company for creating charging infrastructure and propose guidelines for setting up of charging stations.
Department of Heavy Industry	Fund the pilot projects of charging station development.
Ministry of Urban Development	Manage 'Smart Cities Mission' and provide sustainable charging infrastructure for intra-city traffic.
The National Institution for transforming India Aayog (NITI Aayog)	Draft policies for charging infrastructure placement and pricing scheme in charging stations.
Distribution company	Provide necessary connections for establishing charging stations.

Table-5 : Key players in charging infrastructure planning in India based on Mancini et al. (2020)[21]

2.6.2 Strategic Placement and Planning Methodologies

The Ministry of Power put out rules back in 2018 about building charging spots. Big cities need chargers first, then state capitals along with Union Territory hubs come next. Each public charger setup has got to have liquid-cooled cords, solid groundwork, its own transformer, besides 33/11 kV wiring. To handle traffic plus grid flow together, computer simulations play a key role. A mix of Genetic Algorithm and Particle Swarm Optimization helped pick where stations go and how big they should be - cutting costs while keeping voltage stable and power steady. A grid approach got used by splitting the whole city into 1×1 km squares[14]. Each square received a ranking through a total score built from adjusted pros and cons - highlighting likely spots for EV charging points [21]. A plan came up for setting things in place in Delhi, shaped by how traffic moves, where vehicles park, and timing patterns. For the first round of rollouts, spots like official buildings - say, North and South Block - state-run firms such as GAIL or NTPC, along with key transit and business centers were picked[21]

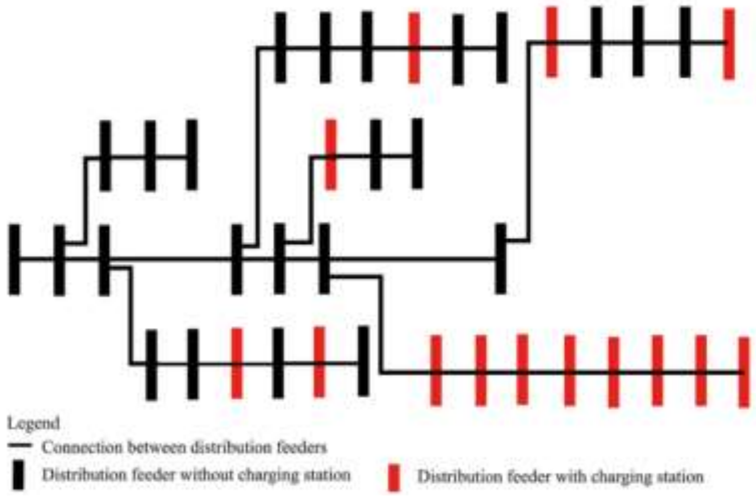

Fig- 12. Locations of EV charging stations in the distribution system of Prayagraj City (Awasthi et al., 2017)[21]

2.6.3 Future Integration: Vehicle to Grid (V2G)

The way cities in India handle power might change thanks to V2G - even if it's still early days. Instead of just taking energy, electric cars can send it back when demand spikes, working like mini power stations or flexible tools for managing use. This idea fits into the bigger push toward local grids, cleaner energy, smart tech, open markets, and public control - often called the 5Ds. A test run in Guwahati used fuzzy logic systems to check how well this works; results showed some ability to ease strain during busy times. Still, real-world rollout faces issues: hackers could exploit new access points, rules don't let EVs help balance loads yet, car makers and power firms aren't teaming up, and people worry heavy use might wear out batteries faster [21].

2.7. Policy and Regulatory Framework

The updated rules say electricity rates at EV charging spots shouldn't go beyond 15% above the usual power delivery cost. Several regions - like Delhi along with Andhra Pradesh - have rolled out unique pricing for electric vehicles. Putting up public charge points doesn't need a license; anyone can do it as long as they follow tech norms. On standard types, BIS backs CCS-2 plus CHAdeMO for use across India. To speed things up, authorities offer cash help - around ₹30,000 for e-scooters or bikes, while car buyers get about ₹1.5 lakh. The government's tweaking rules to remove taxes and registration costs for electric vehicles used off roads. Right now, the plan counts on teamwork between public agencies and private firms to boost how many people switch to EVs, help local manufacturing grow, while building more places to charge them[22].

2.7.1 National EV policy & charging guidelines

India's move to boost electric transport relies on two main programs, both tackling rising pollution and unstable spending on imported oil[23]. Launched back in 2013, the National Electric Mobility Mission Plan (NEMMP) 2020 wanted to cut reliance on foreign fuel while pushing greener auto growth. Its efforts centered on four things - building buyer interest, setting up charging stations, advancing tech, plus testing small-scale trials. It expected transport-related CO_2 levels to drop by around one-tenth[24]. By 2015, FAME came along under this umbrella, offering cash benefits to people buying new electric vehicles. Focused on boosting demand through rewards, small-scale trials,

Industrial Engineering Journal
ISSN: 0970-2555
Volume : 54, Issue 11, No.1, November : 2025

and setting up charge points - backed by a sanctioned fund of Rs. 795 crores. Even though it helped kickstart EV use, just 41% of the allocated money got spent[23]. Starting off with Rs. 10,000 crore in funding, FAME II changed how subsidies worked by tying them to battery capacity, giving a flat Rs. 10,000 for every kWh stored. Under this plan, support for lead-acid cells was dropped altogether, putting all attention on modern types like Lithium-ion or similar tech. Officials want around three out of ten vehicles across India running on electricity by 2030[23].

2.7.2 Charging Infrastructure Status And Guidelines

The FAME II initiative wanted to place around 2,877 EV chargers nationwide, aiming for one unit per 3 km inside urban areas and a station every 25 km along national roads[25]. By July 2022, roughly 4.75 lakh electric cars had been bought under the FAME program since it began in April 2015. When checked against fuel pumps, most regions show way fewer public charge points - Delhi being the only real exception. Because public setups remain limited, analysts expect household charging to become dominant, possibly covering close to 70% of usage by 2030[23].

States	PCS	Retail Outlets of gas and Petroleum	States	PCS	Retail Outlets of gas and Petroleum
Maharashtra	88	5419	Uttar Pradesh	108	6616
Karnataka	58	3836	Andhra Pradesh	4	3004
Madhya Pradesh	27	3269	Delhi	322	393
Kerala	57	2009	West Bengal	22	2244
Telengana	65	2228	Tamil Nadu	94	4702
Gujarat	27	3384	Haryana	55	2536

Source: Ministry of Power, Government of India, 2021

Table-6: Comparison between Number of PCS and Retail Outlets of Petroleum

NITI Aayog got tasked with leading the EV policy plan, working alongside five government departments - Heavy Industry, Public Enterprise, Roads and Transport, Power, along with Housing and Urban Affairs. After Karnataka rolled out its EV and Energy Storage Policy back in 2017, several other states started shaping their own versions - Delhi, Kerala, Maharashtra included - offering extra perks on top of the central FAME scheme [23].

2.7.3 Financial and Fiscal Incentives

NITI Aayog got tasked with leading the EV policy plan, working alongside five government departments - Heavy Industry, Public Enterprise, Roads and Transport, Power, along with Housing and Urban Affairs. After Karnataka rolled out its EV and Energy Storage Policy back in 2017, several other states started shaping their own versions - Delhi, Kerala, Maharashtra included - offering extra perks on top of the central FAME scheme [23].

2.8. Gaps in standards for DWPT

2.8.1 Wireless Charging Standards (General)

Wireless power transfer - also called inductive charging - is grouped with plug-in charging and switchable batteries as one way to recharge devices.[26]

Industrial Engineering Journal
ISSN: 0970-2555
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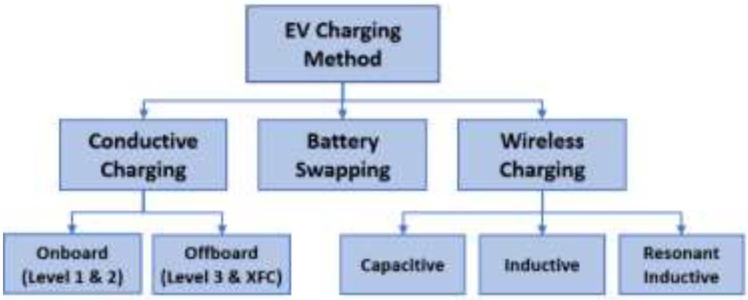

Fig- 13. Electric vehicle charging methods[26]

Without wires, energy moves through shifting magnetic fields - from outlet to car's battery. This method splits into three kinds: one based on capacitance, another on induction, while the third leans on tuned induction[27,28]. Rules about such systems pop up now and then, like SAE J1772 or IEC 61980

Specification	Level 1	Level 2	Level 3	Extreme Fast Charging (XFC)
Charging Power	1.44 kW - 1.9 kW	3.1 kW – 19.2 kW	20 kW – 350 kW	>350 kW
Charger Type	Onboard - Slow charging	Onboard - Semi-fast charging	Offboard - Fast charging	Offboard – Ultra-fast charging
Charge Location	Residential	Private and commercial	Commercial	Commercial
Charging time	200 km: +/- 20 hours	200 km: +/- 5 hours	80% of 200 km: +/- 30 min	Approximately 5 min with high energy density
Power Supply	120/230 Vac, 12 A – 16 A, Single phase	208/240 Vac, 12A - 80A, Single phase/Split phase	208/240 Vac & 300-800Vdc, 250-500A Three phase	1000Vdc and above, 400A and higher Polyphase
Supply Interface and Protection Type	Convenience outlet (Breaker in cable)	Dedicated EV supply equipment (Breaker in the cable and pilot function)	Dedicated EV supply equipment (communication & event monitoring between EV and charging station)	Dedicated EV supply equipment (communication & event monitoring between EV and charging station)
Standards	SAE J1772, IEC 62196-2, IEC 61851-22/23, GB/T 20234-2		IEC 61851-23/24 IEC 62196-3	IEC 62196 SAE J2836/2 & J2847/2

TABLE-7. Comparison of different electric vehicle charging

DC fast chargers work outside the car, so they've gotta match plug types like CCS Combo 1, CCS Combo 2, or CHAdeMO. Because these units push out heavy power, safety rules get way more intense when setting them up. Instead of just making things run, those rules help everything fit together safely with the electrical system. Groups like SAE, IEC, and ISO lead the charge on creating guidelines that keep electric vehicles working smoothly across markets - without chaos or confusion.[26].

2.8. Potential Inclusion in Smart City Programs

2.8.1 Technological Integration and Smart Standards

Working alongside power companies and grid managers - known as DSOs - matters a lot when building infrastructure that's smooth, secure, and affordable. Since DSOs know best where the grid can handle more load, particularly for rapid charging, their insight is vital. To speed things up, clearer access to info on grid capacity makes a big difference. Instead of keeping data locked down, cities ought to push for open rules around charging tech and systems that support intelligent energy use. That means bringing in communication methods like. Open Charge Point Protocol, also known as OCPP, or ISO 15118 - Oslo makes it mandatory for any station getting government money to use OCPP along with open payment systems[29]. In Amsterdam, energy providers like Nuon and Vattenfall run smart

Industrial Engineering Journal
ISSN: 0970-2555
Volume : 54, Issue 11, No.1, November : 2025

charging initiatives at public spots, pushing users to charge when the grid isn't under pressure[30]. To get started, planners need solid info on how people actually charge their cars, what kinds of electric vehicles are out there (full battery ones versus plug-in hybrids), where those cars are parked based on home setups, plus a breakdown of current chargers available by model. This information helps urban areas figure out what kind of charging setup works best for them. To attract private funding, towns must create rules that push for frequent use of chargers. Using electric cabs, delivery vans, or ride-services creates steady demand - this gives charge-point operators confidence in returns[29]. Local strategies ought to plan ahead for zones where only clean vehicles are allowed[31]. Officials might boost usage by setting aside spots just for EVs or cutting parking costs when drivers go electric[32]. Cities might boost private funding by simplifying permit steps - like what's happening in Stockholm - with site approvals ready ahead of time. That tackles red tape slowdowns, which usually turn off investors.[33]

III Challenges

- Putting in transmitter coils means steep setup expenses, while upgrading current roads adds to the burden.
- Many city streets aren't set up for wireless charging lanes, meaning big rebuilds must happen instead.
- Constant wireless power might shift how much demand hits the grid, which could mess with its balance and cause delivery hiccups.
- EMF safety needs checking so that magnetic fields stay under the levels allowed by ICNIRP rules.
- Right now, there's no one-size-fits-all setup for DWPT tech, so rolling it out widely or getting devices to work together stays tricky.
- Movement between the road's wire loop and the car's pickup part makes energy move less effectively.
- The setup needs accurate sensing plus timing to turn on coils just if a car's around, which makes things trickier.
- A major rollout needs tight teamwork between officials, power providers, urban designers, along with business allies.

IV Conclusion

The use of moving wireless charging for city buses and cars could change how people travel in India. Even though more electric vehicles are hitting roads thanks to programs like FAME-II, PM e-Bus Sewa, and the national mobility plan, problems remain - charging spots aren't everywhere, plugging in takes too long, and big batteries add weight and cost. Instead of waiting at stations, this tech charges vehicles as they drive, so batteries can be smaller, service breaks shorter, and bus fleets run smoother, especially along busy routes like BRT lines or city-wide electric bus services.

Still, rolling out DWPT on a wide scale runs into big hurdles - expensive setup fees, challenges balancing power demand, missing tech standards, worries about electromagnetic exposure, along with tight teamwork needed among electricity providers, city designers, and transit agencies. To help fund the build-out and spread risks, cooperation between government and private firms will matter a lot; meanwhile, connected urban platforms could assist in blending green energy sources and intelligent grid tools into electric vehicle routes.

Achieving lasting, expandable EV travel using DWPT across India means mixing smart tech upgrades with helpful rules, funding perks, or joint strategies. Tackle these hurdles right - DWPT could boost energy safety, cut CO2 output, while speeding up the shift to cleaner, smoother city transport ready for what's next.

Full Forms

- **EV** - Electric Vehicle
- **IPT** - Inductive Power Transfer
- **DWPT** -Dynamic Wireless Power Transfer
- **RES** - Renewable Energy Sources
- **PPP**- Public–Private Partnership
- **BRTS**- Bus Rapid Transit System
- **FAME-II -** Faster Adoption and Manufacturing of Hybrid and Electric Vehicles – Phase II
- **PM e-Bus Sewa / PM E-DRIVE -** Prime Minister Electric Bus Service Scheme
- **NEMMP -** National Electric Mobility Mission Plan
- **V2G**- Vehicle-to-Grid
- **ICNIRP** - International Commission on Non-Ionizing Radiation Protection
- **OCPP** - Open Charge Point Protocol
- **CCS -** Combined Charging System
- **GST**- Goods and Services Tax

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