SOLUTION TO THE CHICKEN-EGG DILEMMA OF ELECTRIC MOBILITY FOR INDIAN CITIES: A ROADMAP TO CLEAN ENERGY

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Resume

Since the electrical vehicles (EVs) are infrastructure-dependent technology, their penetration faces the problem of lacking recharging infrastructure. Thus, there is a dilemma of chicken-egg in the penetration of EVs and their charging infrastructure for the decision-makers. The article examines the e-mobility scenario of 3 Indian cities to understand issues and challenges in implementing EVs. The study suggests a co-diffusion strategy for the EVs and charging infrastructure. Firstly, the priority EV segment has been decided based on the transport mode preference. Then, suitability of charging facilities according to the segment of the EVs has been presented by analyzing the turnover rate and time spent at several places. The study recommends policies on the upfront cost of EVs, charging infrastructure, awareness generation and others, while leveraging the existing government schemes like Atmanirbhar Bharat and FAME-II.

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1 Introduction

Historically, efforts have been made to introduce electric mobility, which is successful only in some niche markets. However, over the last decade, a collection of circumstances like climate change, advances in renewable energy, rapid urbanization, the digital revolution, advances in battery technology and energy security have joined together to create an opening for electric mobility to enter into the mass market [1]. E-mobility is a cleaner mobility option to improve air quality by reducing carbon emissions and minimizing dependency on fossil fuels. In short, they are improving the quality of life locally. A comparison of life cycle greenhouse gas (GHG) emissions by internal combustion engine vehicles (ICEV) and electric vehicles (EV) shows that the EVs have a huge potential of reducing emissions [2]. The maximum air pollution takes place during the use phase of a vehicle. Though, in the case of EVs, the pollution is due to upstream emissions, which usually occur far from the place where vehicles are being used. Pollution caused due to manufacturing and recycling process is also away from the city. Since the tailpipe emission of an EV is zero [3], the impact of EVs in cities is zero. The pollutants released during the life cycle emission of vehicles can be trapped. Then, the carbon dioxide can be separated and transported for storage, which can be used for many purposes. This process of trapping the CO_2 is called carbon capture. In the case of fossil fuel vehicles, emissions occur in dispersed form and carbon capturing from vehicles is pretty impossible as even if the emissions are trapped, storing them in the vehicle and transporting them to the processing plant is way out of the league. In the EVs, these dispersed emissions are shifted to a concentrated emission source (electricity generation plants), from where the capturing can be done, thus increasing the efficiency of the process. Once captured, concentrated CO_2 can be transported to places where it can be used as an input-for example, cured in concrete or as a feedstock to make synthetic jet fuel-or simply stored underground [4]. During the "Janta Curfew" in India, amidst COVID-19, which was imposed on 22nd March 2020, leading to reduction in the number of on-road vehicles, resulting in a reduction of nitrogen oxide levels up to 51% and carbon dioxide levels up to 32%, as compared to 21st March [5]. However, experts say that these reduced emission levels are temporary due to lockdown. This saving in GHG emissions could be made permanent if vehicles on roads convert to EVs.

There is a need to increase the market share of EVs to decrease the emission of GHGs from the transportation segment. However, since EVs are infrastructure-dependent technology, their penetration faces a lack of recharging infrastructure [6]. There is a dilemma of whether to install charging infrastructure before deploying enough EVs or reverse. This dilemma is named the chicken-egg dilemma. In this paper, an attempt has been made to address this problem. The objectives of this study were (1) to determine obstacles to penetration of e-mobility from the literature review, (2) to identify the issues and challenges in e-mobility in Indian cities, (3) to plan a strategy for the diffusion of EVs and charging infrastructure in the Indian market, (4) to suggest policies that can address the barriers in the implementation of the e-mobility.

To solve this dilemma, a co-diffusion strategy has been suggested by this study for Indian cities, which suggests the deployment of EVs as per the preference of a mode of travel in a city. Meanwhile, the target for installing charging infrastructure is set as per the deployment strategy of EVs in a city. In addition, an approach has been made to understand the current e-mobility scenario of the Indian cities and identify issues and challenges. For this, three cities, viz Lucknow, Indore and Mumbai, that have got subsidies under the FAME-I scheme were visited and interviews of drivers of EVs and operators of charging infrastructure have been conducted.

The paper is structured as follows. Section 2 briefly describes the study methodology. In Section 3, a literature review of the obstacles to adopting electric vehicles worldwide is discussed. Section 4 describes the e-mobility scenario in India and reflects on the issues and challenges in the Indian cities. Section 5 gives a strategy for co-diffusion of EVs and charging infrastructure. Lastly, Section 6 concludes with policy recommendations for a way forward.

2 Study methodology

In the present study, at first, a detailed literature review has been conducted to understand the barriers to e-mobility adoption. According to which, major barriers to e-mobility include lack of charging infrastructure, interoperability issues, etc. In addition, existing scenario of e-mobility in India is studied, after which, 3 cities, i.e. Mumbai, Lucknow and Indore are finalised for case study. For all the three short listed cities e-mobility scenario in terms of infrastructure availability, fleet size, usage of infrastructure, vehicle category, etc. is studied in detail, after which strategies for co-diffusion of EVs and charging infrastructure is developed. At the end, the study is concluded with suggestions of policy measures, which can be integrated with existing schemes and initiative by government of India.

3 Literature review

Through an extensive literature review, several factors have been identified that act as barriers to e-mobility adoption worldwide. Among these, charging related issues and, in general, shortage of charging points appear to be the major barrier that need to be addressed to increase the adoption of EVs [7-11]. There is a limited availability of EV charging stations for journey within the city in some cities, but what if a trip was planned to a suburban area and then there would be lack of charging stations. Insufficient charging infrastructure creates charging point anxiety in the EV users, i.e., fear of not finding a charging point when needed. This anxiety is increased by lack of standardization of charging infrastructure, as there is fear of not finding the charger type compatible with the EV [12]. Apart from infrastructural barriers, the EVs have many downsides due to wide changes in their characteristics compared to conventional fossil fuel vehicles. The introduction of EVs in the transport fleet requires a wide change in the mindset of the consumers. There lies negative perception in the minds of consumers regarding EVs due to their high upfront cost, the shortrange of travel, long charging time, low top speed and uncertainty of new technology [13].

The major argument regarding e-mobility is spinning around the chicken-egg problem worldwide, that what should be deployed first? The charging infrastructure and eco-system for EVs or the EVs themselves [6]. Every alternate fuel vehicle (AFV) faces an obstacle of the lack of refuelling facility during an initial market diffusion. There is a vicious circle for EVs; if vehicles' sale is small, it leads to a disadvantage as saving in costs due to large production cannot be achieved. In addition, potential firms would not invest in recharging infrastructure. Therefore, due to the unclear growth scenario and small EV demand, economic risks lie in EV industry [14].

4 E-mobility scenario in India

In India, the real momentum in the sale of EVs came with phase-I of a scheme entitled „Faster Adoption and Manufacturing of (Hybrid and) Electric vehicles" or FAME-India scheme, which was sanctioned under the National Electric Mobility Mission Plan 2020 (NEMMP). According to the Annual Report, 2018-19 by the Ministry of Heavy Industries and Public Enterprises, about 0.278 million hybrid and EVs were supported by demand incentives amounting to US$ 41.7 million (approximately). This has resulted in a total fuel saving of 45.57 million litres and a CO_2 emission reduction of 0.1136 million tonnes. In addition, 465 buses were sanctioned to various cities/states under this scheme. Overall outcomes, in terms of fuel-saving and CO_2 emission reduction, are significantly below the target for FAME phase-I. According to Electric Vehicles Sales

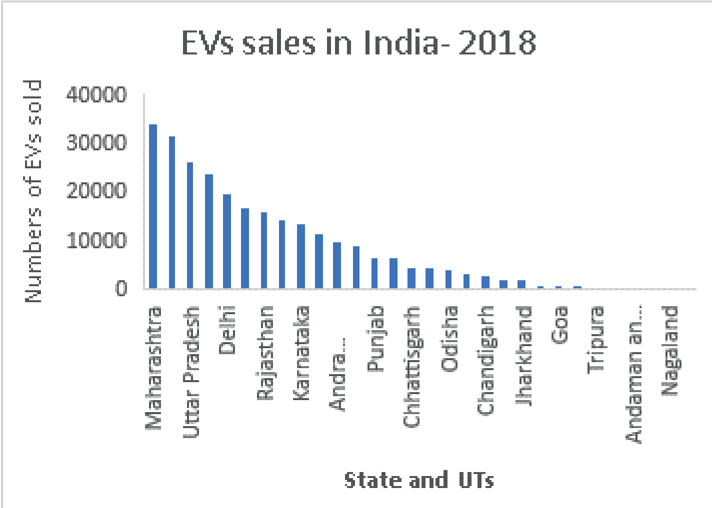


Figure 1 *State wise EVs sales in India 2018*

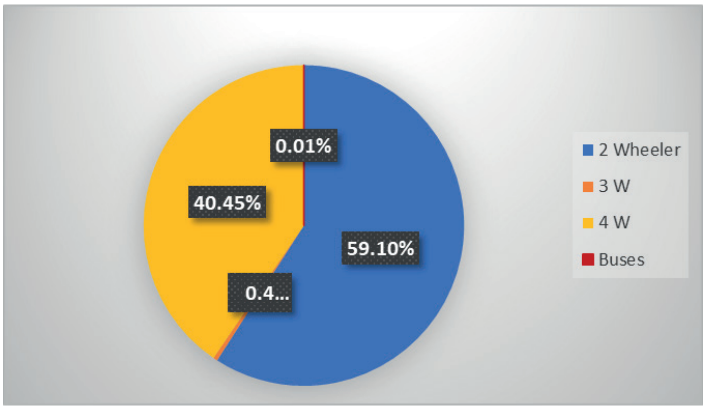


Figure 2 *Share of each type of vehicles in EV sale 2018*

Report in India 2018, Maharashtra and Gujarat stand top in the sale of EVs, whereas Meghalaya stands at the bottom, as shown in Figure 1. Further, as it can be seen from Figure 2 that the EV sales market is dominated by the two-wheelers having 59.10 % of sales, followed by four-wheelers with 40.45 % of sales and the least share of buses is observed. For FY2019, EV sales in India were 0.13 million which increased to 0.16 million for FY2020 [15].

In the second half of December 2017, the Central Government has provided Rs. 437 crore subsidies to 11 cities under the FAME-I scheme in India for launching 390 electric buses, 370 taxis and 720 three-wheelers. The cities include Delhi, Ahmedabad, Bangalore, Jaipur, Mumbai, Lucknow, Hyderabad, Indore and Kolkata, plus two cities - Jammu and Guwahati under a special category. The nine big cities on the list are given subsidies for 40 buses each, while Jammu and Guwahati for 15 buses each. Subsidy for taxis is given to Ahmedabad for 20 taxis, Bangalore for 100 taxis, Indore for 50 taxis and Kolkata for 200 taxis, based on their demand. Bangalore has been given subsidy for 500 three-wheelers, Indore for 200 and Ahmedabad for 20. Out of these eleven cities, three cities i.e. Lucknow, Indore and Mumbai have been visited as the case study to understand the practical setup of EVs in Indian cities. Lucknow, Indore and Mumbai were visited in November 2019, December 2019 and March 2020, respectively. The profile of these cities has been discussed in this section. As described in this section, EV drivers' and expert interview surveys have been conducted in these cities.

4.1 Profile of the cities visited

Lucknow is a city in northern India and is the capital of the state of Uttar Pradesh. The city covers an area of 349 sq. km. and has a population of 2.82 million, according to the census 2011. Since the population is greater than 1 million, the city belongs to the category of million-plus cities of **Class-I**. The city bus service in Lucknow is operated by "Lucknow City Transport Services Limited" (LCTSL). Currently, the fleet consists of 300 buses, out of which 40 are electric and the rest run on compressed natural gas (CNG). Apart from e-buses, e-rickshaws are also used in the city as a para-transit mode. The city had 17 thousand registered e-rickshaws till December 2018. The UP cabinet approved the

Table 1 Passenger modal share of road transport for Lucknow, Indore and Mumbai, Census 2011

Mode of travel	Modal Share (%)		
	Lucknow	Indore	Mumbai
On foot	22	26	45
Bicycle	26	26	2
2-W	34	32	8
4-W	6	5	9
Tempo/Autorickshaw/Taxi	8	3	6
Bus	4	8	30
Total	100	100	100

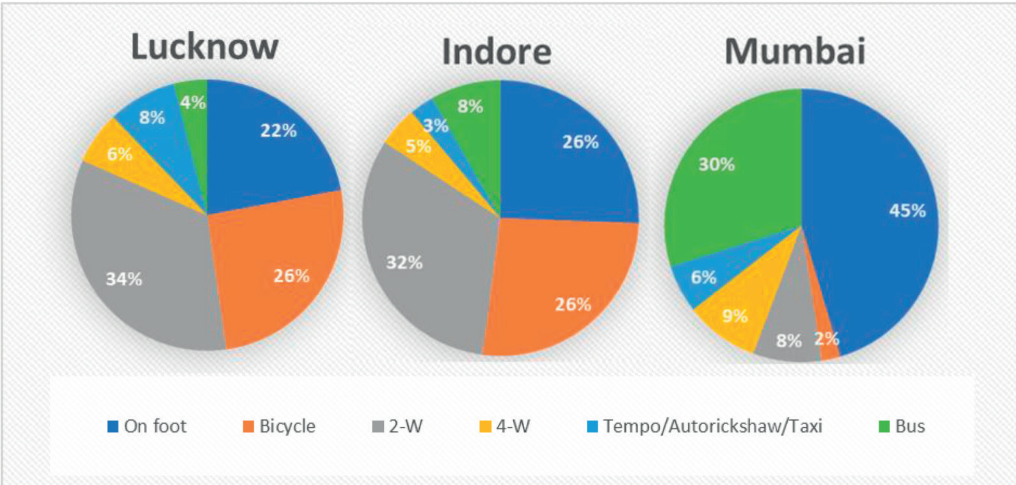


***Figure 3** Passenger modal shares of road transport for Lucknow, Indore and Mumbai, Census 2011*

scheme to distribute 27 thousand of e-rickshaws for free in Uttar Pradesh in 2015. The average trip length of the city is about 5 km.

Indore is a city in west-central India. It is a **Class-I** city in the Madhya Pradesh state of India, with a **million-plus** population. As of the census of 2011, the population of the city is 2.39 million and it covers an area of 530 sq. km. The city bus is run by "Atal Indore City Transport Services Limited" or AICTSL, which is currently operating 312 CNG buses and 40 e-buses. Along with e-buses, e-rickshaws have also been plying in the city. Under the E-Sawari project of the Madhya Pradesh government, 100 e-rickshaws driven by women were launched in Indore.

Mumbai is a densely populated city on India's west coast. The total area of Mumbai is 603.4 sq. km. As per the census of 2011, the city accommodates a population of 18.41 million. It is the biggest city in India in terms of population. Since the population is greater than 10 million, it comes under the **megacities** of **Class-I.** Most city buses in Mumbai are operated by the Brihanmumbai Electricity Supply and Transport Undertaking (BEST) and Navi Mumbai Municipal Transport (NMMT). Total number of buses under these operators are around 3,800. The fleet comprises of diesel, CNG, hybrid and electric buses.

The passenger modal share of road transport for these three cities has been shown in Table 1 and Figure 3.

In million-plus categories of Class-I cities, i.e., in Lucknow and Indore, the modal share by passengers is dominated by motorized 2-wheelers, including mopeds, scooters and motorcycles, followed by the non-motorized transport modes. In megacity Mumbai, the highest percentage is walking, followed by bus mode (30 %).

4.2 The E-bus scenario

The E-buses have been plying in all three cities. Essential parameters of e-buses have been summarized in Table 2, based on interaction with their drivers.

From Table 2 it can be observed that the range achieved on the road by e-buses is about half of the range claimed. In Lucknow, the Daily distance travelled by each driver is around 220-230 km, with one round trip length of about 70-80 km. After one round trip, the bus is kept for charging, which takes about 2-2.5 hours to get fully charged. While the first bus is charging, the driver takes another bus for the next trip and so on. Therefore,

Table 2 *E-bus parameters for Lucknow, Indore and Mumbai*

Parameter	Lucknow, LCTSL	Indore, AICTSL	Mumbai, BEST	Mumbai, NMMT
No. of buses	40	40	10	30
Model	Tata Ultra	Tata Ultra	Olectra-BYD eBuzz K7	JBM Solaris
Running from	February 2019	November 2019	September 2019	October 2019
Claimed range	150	150	200	225
Range achieved	80	80	110	120
Total daily distance (km)	150	135	80	90-100
Round trip length (km)	70-80	20-25	20-25	-
Charger type	DC fast charger	DC fast charger	AC slow charger	DC fast charger
Connector type	-	-	IEC 62196 Type 2	CCS 1.0
No. of chargers (Dual type)	12	6 (7 under construction)	10	2 (4 under construction)
Charging time (hrs)	2-2.5	2-2.5	3	1-1.5
Regenerative braking	No	No	Yes	Yes

Figure 4 *Informal charging of e- rickshaw*

each driver rides two buses in a day to complete 3 round trips. Thus, around 150 km distance is travelled by each bus daily.

In Indore, the round-trip length by e-bus is shorter compared to Lucknow. The AICTSL plans to increase the trip length after installing charging stations in the middle of the routes for opportunity charging.

In Mumbai, ten buses were procured by BEST and 30 by NMMT. The buses procured by both the state transport undertakings (STUs) have the feature of regenerative braking, i.e., in these buses, electrical energy is stored every time the brake is applied. Though regenerative breaking is there, the total daily distance covered by e-buses in Mumbai is less than in Lucknow and Indore.

For charging these buses, most of the STUs were using fast chargers, except for BEST in Mumbai, where both plugs of a charger were inserted at the same time in a bus for charging, reducing the total time taken by the slow charger and making it equivalent to the time taken by fast chargers. The adverse effects of fast charging on a battery can be avoided by using the slow chargers.

4.3 E-rickshaw scenario

E-rickshaws have been plying on Lucknow and Indore roads as para-transit mode. Lucknow city had 17 thousand registered e-rickshaws till December 2018. The UP cabinet approved the scheme to distribute 27 thousand of e-rickshaws for free in Uttar Pradesh in 2015. As per the guidelines, e-rickshaws are given the permit to operate only on feeder routes and within a colony. They are supposed to connect an arterial route with the main road and not ply on main roads as a measure to provide last-mile connectivity. Therefore, e-rickshaws were banned on many routes by the transport department and traffic police joint exercise. Some informal charging of rickshaws was observed during the survey, as shown in Figure 4.

Under the E-Sawari project of the Madhya Pradesh government, 100 e-rickshaws were launched in Indore by the CM on 7th December 2019, as shown in Figure 5. The Government gives a subsidy of 50 % of the initial cost of the rickshaw and the rest is to be paid in instalments by the drivers themselves. Females operated these

Figure 5 *E-rickshaws for women in Indore, source: AICTSL*

Figure 6 *Informal E-rickshaws stand near Rajwada, Indore*

Table 3 *E-rickshaw parameters for Lucknow and Indore*

Parameter	Lucknow	Indore
Running from	More than five years	Five years
Initial cost (in thousand US$)	1.4-2.1	1.4-2.7
Range achieved	60-80	70-90
Total daily distance (km)	70-100	70-100
Charging location	Home and depot	Home
Charging time (hrs)	2-12 (depending upon model)	2-6 (depending upon model)
No. of times charged	Half once a day and full at night	Half once a day and full at night
Driven by	Men	Both men and women
Average driving speed (km/h)	18-20	20-25
Top driving speed (km/h)	25-30	30-40

rickshaws. The rickshaws had a facility for digital payment, GPS tracking (by Chalo), radio-FM (sponsored by My FM) and free Wi-Fi sponsored by Jio.

There was no dedicated parking space for e-rickshaws in the city and the E-rickshaw sharing system was there, so vehicles had to wait on roads to collect passengers, as shown in Figure 6. Due to this, the roads were getting jammed and there was a restriction on many roads to park the rickshaws. Drivers sometimes face a shortage of charging in the middle of a trip. In this case, drivers had to drag the vehicle to the charging location.

Important parameters of e-rickshaws for Lucknow and Indore have been summarized in Table 3.

Not much difference is observed in the parameters of e-rickshaw between the two cities. The initial costs of an e-rickshaw were higher in Indore. In addition, e-rickshaws in Indore were better in terms of range achieved, charging time and top speed. This implies that the model of e-rickshaws was better in Indore than in Lucknow.

4.4 Charging points for personal vehicles

4.4.1 Workplace charging at Indore

The Government had also provided 16 electric cars to their employees at smart city cell until December 2019 and planned to provide 50 more cars. The model is Tata

Figure 7 *E-cars charging station at Smart City Cell, Indore*

Figure 8 *Different EV charging points at Vikhroli sub-station*

Tigor EV, claiming a range of 142 km per charge. Seven slow chargers and four fast chargers were installed within the Smart City Cell, Nehru Park, Indore. The employees had started using e-cars. The daily travel distance is about 40-60 km. They usually charge the cars at the office during day time, as shown in Figure 7 and at home during the night time if required. They get a travel range of about 100 km. It takes 4-6 hours for slow chargers and 2-3 hours for fast chargers to fully charge the car.

4.4.2 Tata Power Co. Ltd., car charging point, Mumbai

Tata Power established its first public EV charging station in Mumbai at Firoz shah nagar, Vikhroli having diverse charging standards and specifications. These chargers have been used free of cost for about two years. Its working has been kept on halt for a few weeks as the company was developing a payment method now for charging their EVs. The company has also developed a Tata Power EV Charging mobile app. It provides EV users with the facilities like locating charging stations on an aerial map, reserving a charging slot, getting updates on charging, recommendations on suitable time of day to use and paying charges online.

Since there were many types of chargers and connectors, as shown in Figures 8 and 9, it provides an opportunity for many EV owners to meet the standard for their vehicles. Still, there might be a situation where one type of charger is in very much demand and others might remain idle for a long time.

4.4.3 Magenta Power charging point, Mumbai

Magenta Power is in the business of providing green energy solutions. Its business unit, ChargeGrid, was setup to focus solely on providing the EV eco-system services based on the user's demand. The office was located near Alpha Garden, Sector-14, Kopar Khairane, Mumbai. Three slow charging points were installed outside the office. The chargers were mounted on the wall, as shown in Figure 10, having IEC (refer to Figure 11) and domestic connector types. About 5-6 EVs arrive in a day for charging, including cars and scooters. The vehicles were charged for about 4 hours. The payment was made via the app "ChargeGrid". The rate was Rs. 30 per unit. With the help of this app, the users can search the nearby charging stations and get the real-time availability of chargers before reaching the charging point.

Figure 9 *Different types of connectors at Vikhroli sub-station*

Figure 10 *Charging Station at Magenta Power office, Navi Mumbai*

Figure 11 *IEC 60309 connector*

Figure 12 *Personal charging point in a housing society*

A private charging point has been installed in a housing society in Vashi, Navi Mumbai, by Magenta Power, for a resident owning an EV, as shown in Figure 12. It has provided a charging point facility at Turbhe, Palava and other places in Mumbai on demand. Magenta Power has also setup fast chargers at Mumbai-Pune Expressway and is working on other such projects. The cost of a fast-charging point is very high compared to a slow charger. The huge difference is that the setup of a slow charger is small and can be mounted on a wall. In contrast, fast charger has a large setup, similar to or bigger than the size of a petrol pump setup and also because a proper foundation is required. In addition, the material, cables, connector, etc., in the case of fast charger, is expensive as it requires more power.

4.4.4. BEST car charging station, Mumbai

To support the Government's clean energy initiative, BEST has set up a fast charger for charging the car and other vehicles at Worli Shivaji Nagar bus depot, as shown in Figure 13. The connector has Bharat DC-001 standard (refer to Figure 14). The depot has a single charger with one charging plug; therefore, one vehicle can be charged at a time. It has been working for one year. The station receives hardly one or two vehicles for charging in four to five days. It takes 1.5 to 2 hours to charge a vehicle for up to 80%. The money charged is around US$ 0.10 (₹8.28 ~ US$ 0.10)per unit (refer to Figure 15). The payment was being accepted in cash only and there was no separate app for this. Since the

Figure 13 *Electric car charging point, Worli, Mumbai*

Figure 14 *Bharat DC-001 connector*

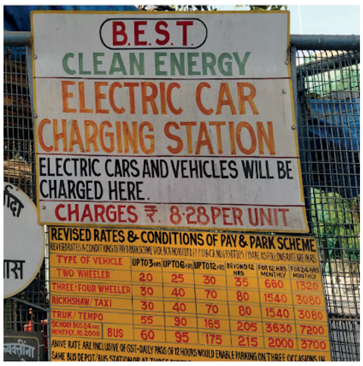


Figure 15 *EV charging fare*

frequency of vehicles coming for charging was very low, the charging station was left unattended.

4.5 Issues and challenges in the way of e-mobility in Indian cities

The Indian EV market requires a big change in its e-mobility eco-system, specifically in the case of manufacturing. Currently, most EV manufacturing companies rely on imports of major components like batteries and electric drivetrains from other countries (China, South Korea and Japan). In contradiction, if one looks at the ICE automobile industry, the major boost came through domestic manufacturing [16]. Even if the EV industry thinks about importing only raw materials from other resourceful countries and producing the components and battery packs in India, the shortage of talented workforce with experience in this field may be a roadblock [17].

From the e-mobility scenario of Indian cities it is observed that there is a wide gap between the claimed range by e-buses and the range accomplished. The assured range of buses was around 150-225 km, however, the range achieved was around 80-150 km only, equal to the range of e-rickshaws in the city. One of the reasons is heterogeneous traffic conditions in the city, which lead to congestion and the charge in the battery is exploited. Another reason could be the overloading of buses and frequent opening and closing of doors.

The EV owners sometimes come across a situation when there is a shortage of charge in the battery. Though charging points are installed at bus depots for e-buses and homes and workplaces for private vehicles, there is still a need for opportunity charging to use for a top-up charging. In Mumbai, there are some charging stations at a centralized location, however, the network is not dense enough to avoid the dead mileage. In addition, due to the very low frequency of consumers, the charging stations in Mumbai were often left unattended. Due to that, the EV users cannot get service even if a charging station is there.

Too many charging points were noticed, which might raise standardization issues for opportunity charging facilities in the future. In addition, the private charging points have developed their separate online platforms like a website and mobile navigation application, checking the availability of charging points, billing and payment. 80 % of the charging is done by fixed charging facilities at home and office. By using an opportunity charging facility once in a while, the EV users would not want to explore so many platforms, which might raise interoperability issues in the future.

5 Market diffusion strategy for electric vehicles and charging infrastructure

To tackle the chicken egg's dilemma in e-mobility, a co-diffusion strategy for EVs and charging infrastructure has been planned for Indian cities in this section. Firstly, the class-I cities have been classified based on the population into seven categories. Then, city-wise transport mode preference has been computed, which would help decide incentives for the type of vehicles in a city. The charging infrastructure

Table 4 City Categorisation [18]

City Category	Population
Category-1a	< 0.5 million with plain terrain
Category-1b	< 0.5 million with hilly terrain
Category-2	0.5-1 million
Category-3	1-2 million
Category-4	2-4 million
Category-5	4-8 million
Category-6	> 8 million

Table 5 Estimated mode share for selected cities for 2021

City Category	NMT	PT	2-W	Car	IPT	Avgerage trip length (km)
Category-1a	31	3	30	31	6	2.4
Category-1b	48	5	8	39	0	2.5
Category-2	43	6	31	16	4	3.5
Category-3	38	10	28	14	9	4.7
Category-4	41	8	31	13	7	5.7
Category-5	34	15	31	12	8	7.2
Category-6	29	31	14	15	11	10.4

NMT- Non-motorised transport,
PT- Public transport, buses
IPT- Intermediate public transport, auto-rickshaws

Table 6 Transport mode preference as per city size

City Category	Public transport (Buses, auto-rickshaws, cabs)		Personal transport (2-Ws, cars)	
	Share %	Preference	Share %	Preference
Category-1a	9	● (secondary)	60	● (primary)
Category-1b	5	● (secondary)	47	● (primary)
Category-2	10	● (secondary)	47	● (primary)
Category-3	19	● (primary)	43	● (secondary)
Category-4	15	● (primary)	44	● (secondary)
Category-5	23	● (primary)	43	● (secondary)
Category-6	42	● (primary)	29	● (secondary)

● Primary preference
● Secondary preference

requirement has been discussed, including the type of charging infrastructure and classification of the charging facility according to the land use. Then, the suitability of the charging facility according to different types of EVs and city categories has been presented by analyzing the turnover rate of different vehicles and time spent at several places.

5.1 City classification and their transport characteristics

The classification of cities with a population of 0.5 million to 8 million, as used in the "Final Report" by the Ministry of Urban Development, has been shown in Table 4.

Above is the classification of cities under the Class-I category, as per the Urban and Regional Development Plan Formulation and Implementation (URDPFI) Guidelines, 2015 [27]. The same classification has been used for the present study. Critical issues, like increasing GHG emission levels and deteriorating air quality, are associated with these cities only due to higher share of motorized transport. On the other hand, the smaller cities have higher share of non-motorized transport and, hence, have lesser issues of increasing emission levels and air pollution.

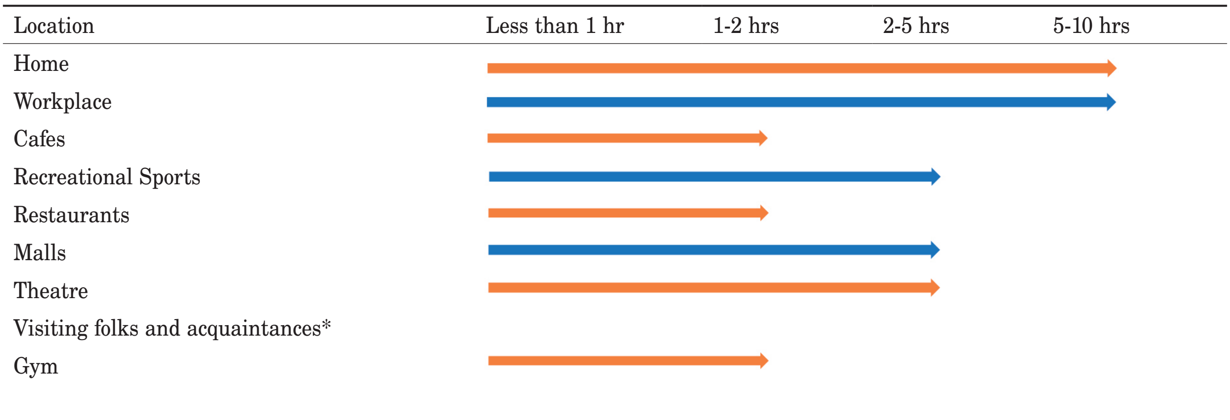
The passenger modal share data and average trip lengths for the above categories of cities for 2021 have also been retrieved from the report published by the Ministry of Urban Development. It is shown in Table 5.

By observing the share of motorized transport,

***Table 7** Time taken by different EVs to get charged, [20-23]*

Type of EV	Battery capacity (kWh) (approx.)	Time is taken by	
		Slow charger (in hrs)	Fast charger (in hrs)
2-W: Scooter	2.4	6-10	2.5-4
2-W: Motorcycle	3.24	4.5-6	0-80% in 36 mins. to 1.5 hrs.
3-W	4.5	6-7	1-2
4-W	12-40	6-10	0-80% in 1-2 hrs
Bus	320	7-8	2-3

***Table 8** Time spent at different locations*



*uncertain

it can be seen that 2-wheelers and cars dominate the choice of mode for commuting by people in cities under Category-1a, while in Category-6 cities the leading choice of mode is public transport. As the trip length of the city increases, the choice of commuting by public transport and para-transit mode is also increasing.

The share for public and personal transport modes is computed by combining IPT and PT under 'Public transport' and 2-W and cars under 'Personal transport.' The transport mode for a city with a preference above or equal to 50 percentiles is marked as "●" and with below 50 percentiles is marked as "●" as presented in Table 6.

The primary preference for personal transport, i.e., electric 2-W and cars, has been set for 1a, 1b and 2 categories of cities, which lies in the top 50% category of cities with 2-W and cars as the mode share. Primary preference for public transport, i.e., electric buses and para-transit modes, has been set for category-3, 4, 5 and 6 cities which lie in the top 50% category with public transport as modal share. This analysis of mode preferences will guide policy-making for the penetration of EVs in different types of cities.

5.2 Requirements for the charging infrastructure

An EV charger, also called Electric Vehicle Supply Equipment (EVSE), is an element in EV infrastructure that supplies electric energy for recharging electric vehicles. The EV batteries require the DC power to get charged and the power flowing in an electric distribution grid is AC type. Therefore, it is always necessary to have an AC/DC converter (or charger). If the converter is placed in the vehicle, it is called an "on-board charger," and if it is placed in the charging point, it is called an "off-board charger" [19]. In the case of an on-board charger costs of the charging station would be lower and for an off-board charger cost of the vehicle would be reduced.

5.2.1 Classification of charging point facility according to location

Every mode of EV requires its place for charging. In most situations, an EV user can set their vehicle in charging while eating, playing, working, or sleeping at places like home, offices, restaurants, malls and gyms. While in some situations, the EV has to be charged in areas where there is no option of stalling time, like roadside charging at a highway or a petrol pump. To find the suitable charging locations for each transport mode, it was firstly identified how much time is taken to charge these vehicles and then it was determined how much time is spent at different places. Then, the classification of the charging facilities based on their locations and the charging facility's requirement for each vehicle category, have been recommended.

Time taken by different electric vehicles to get charged by slow and fast chargers is shown in Table 7.

It is observed that slow charging takes about 5-10 hours and fast charging takes around 1-4 hours. The time depends on the battery capacity and electric vehicle supply equipment (EVSE), which controls the flow of charge between the charging station and the electric vehicle.

In Table 8 is demonstrated how much time is usually spent at different locations by people.

From the above places, people generally spend their time at home daily, at workplace 5-7 days a week, at gym 3-6 days a week, at rest of the places once a week or twice a month, it can be more or less dependent on the person.

During the case study, charging points were found at various places. Based on location, the charging point facilities for EVs have been classified as follows. Seeing the time required by an EV to get charged (as per Table 7) and time spent at different places (refer to Table 8), the type of EV charger suitable for that place has been suggested.

I. Domestic charging facility

It includes a charging point at the residence, where the vehicle is parked. It is for personal use only unless an acquaintance who owns an EV wants to use it. Generally, the time spent at home is between 5-10 hours a day. Therefore, slow chargers would be suitable for domestic use.

II. Workplace charging facility

It means charging points installed at work, such as those installed at Smart City Cell, Indore (shown in Figure 7); considering the usual office hour from 9 am to 5 pm, i.e. 8 hours. This time is sufficient to charge a vehicle with a slow charger. However, it might not be possible to provide individual charging points for every employee owing EV at the office. Therefore, slow or fast charging points would be preferable at the workplace.

III. Common charging facility

It denotes the charging stations at the parking zone of recreational spots like malls, cafes and restaurants, theatres, gyms, sports clubs and resorts. These places will be more suitable for personal EVs than e-cabs or e-rickshaws. For example, an owner of the cafe would want only his customers to charge their vehicles and not a line of e-rickshaws outside his cafe. Generally, the time spent at these places lies between 1 and 5 hours. For places where the time spent is 1-2 hours, a fast charger is suitable and where time spent is around 2-5 hours, both a fast charger and slow chargers are preferable.

IV. Public charging facility

Charging stations at administration properties like railway stations, forts, zoos and public civic centres comes under this category. Time spent at these places is generally 1-5 hours. So, both slow and fast charging points would be suitable here.

V. Depot charging facility

Charging points at a place where vehicles are kept overnight come under this facility. It includes mainly bus depots and spaces where multiple e-rickshaws or e-cabs are left. The vehicles are generally stationed idle at depots for 5-8 hours at night. In addition, it is required to charge a vehicle during the daytime at these places. A charger, which will take minimum time is suitable during the daytime. Therefore, installing fast chargers at these places is suitable, considering the day charging, like in bus depots at Lucknow, Indore and Navi Mumbai, although the slow chargers can also be installed, as in the case of one of the BEST depots in Mumbai, where during the day time both the plugs of a charger are inserted in the same bus for fast charging and during the night time, both plugs of one charger are used individually, to charge two buses at a time by slow charging.

VI. Commercial charging facility

This facility includes charging stations on-road sides, along highways and expressways and at petrol pumps, for opportunity charging. Fast chargers and battery swapping stations are suitable for such facilities as the EV owners will have to wait for charging only.

5.2.2 Suitability of charging facility for different EVs

The type of charging facilities suitable for different electric vehicles and the type of chargers preferable for that charging facility have been summarised in Table 9.

Table 9 demonstrates that personal vehicles, including 2-wheelers and cars, can be charged at home, workplace, common, public and commercial. For routine charging, home and workplace charging facilities are sufficient. Rest facilities are utilized during unusual trips. The 3-wheelers and cabs can be charged daily at

***Table 9** Suitability of charging facility for different EVs*

Charging facility	2-W	Private car	3-W	Cab	Bus	Charger type
Home	●	●	●	●	●	Slow
Workplace	●	●	●	●	●	Slow, fast
Common	●	●	○	○	●	Fast
Public	●	●	●	●	●	Fast
Depot	●	●	●	●	●	Slow, fast
Commercial	●	●	●	●	●	Fast, battery swapping

● Location is suitable ○ The location is partially suitable ● Location not suitable home or at the depot where the vehicle is kept overnight. For these vehicles, common places, like malls and restaurants, are partially suitable in emergency because extra money would be required to park the vehicle in the mall. Depending on the route, public and commercial charging facilities can be used. For buses, the routes are fixed; therefore, the buses are charged mainly at the depot only and depending on the trip length, a dedicated opportunity charging point can be there.

5.2.3 Prioritizing charging facilities by the city category

The city-wise preference for mode of transport has been discussed in Section 5.1. As deliberated in Section 5.2.1, the charging facility should supplement the vehicle preference of the city. Therefore, with help of the transport mode preference (refer to Table 6) and suitability of charging facility for different types of EVs (refer to Table 9), priority for charging facility in a city is set, as described below and shown in Table.

- **Home charging facility:** compulsory installation of a charging point in a new or renovated building for domestic charging (already considered by the Ministry of Housing and Urban Affairs) and mandatory charging points at the place of residence of an EV owner in all the city categories.
- **Workplace charging facility:** this facility is suitable for private EVs; therefore, it should be installed in the "primary preference" cities for personal transport, according to Table 6.
- **The common charging facility is mainly suitable** for private EVs; therefore, it should be installed in cities with the "primary preference" for personal transport.
- **Public charging facility:** it is suitable for personal vehicles and para-transit modes; therefore, this facility should be provided in all city categories.
- **Depot charging facility** is suitable for buses and para-transit modes like e-rickshaws and cabs; therefore, this facility should be provided in cities with the "primary preference" for the public transport.
- **Commercial charging facility:** it is suitable for every transport mode, though this facility should be provided primarily in cities with an average trip length greater than 5 km.

As discussed before, there is a dilemma that if charging facility is installed first, whether enough vehicles would be there to use it or not. Table 10 helps in addressing the chicken-egg dilemma and in deciding where to provide charging facility according to the size of a city.

6 Conclusion and way forward

The present study aims to address major barriers in implementing e-mobility in India. To achieve this goal, several works of literature were studied to understand the global barriers to EV adoption. It was found that there is a dilemma of what should be deployed first, EVs or charging infrastructure. Globally, this dilemma is termed the chicken-egg dilemma. This study has also discussed the e-mobility scenario in India and issues and challenges for the e-mobility adoption in Indian cities have been identified.

As per the literature review, the major barriers to acceptance of the EVs are infrastructure barriers due to shortage of charging infrastructure and lack of standardization of charging infrastructure and negative perception towards EVs due to their high initial cost, the short range of travel, longer charging period, lower top speed and uncertainty for a new technology. By studying the e-mobility scenario in Indian cities, it was revealed that there is a huge gap between the range experienced by EVs and the range claimed. Drivers sometimes face a shortage of charging, in the middle of a trip. Due to the very low frequency of consumers, the charging stations were often left unattended. In addition, standardization and interoperability issues were seen. Some recommendations for a way forward have been discussed in the next section to address these barriers.

A co-diffusion strategy for the EVs and charging

Table 10 *Priority of charging facility as per city category*

Type of charging facility	City category						
	1a	1b	2	3	4	5	6
Home	●	●	●	●	●	●	●
Workplace	●	●	●	○	○	○	•
Common	●	●	●	○	○	○	○
Public	●	●	●	●	●	●	●
Depot	○	○	○	●	●	●	●
Commercial	○	○	○	○	●	●	●

● Primary target
○ Secondary target

infrastructure as per the size of cities has been suggested in this study, which would resolve the dilemma for the decision-makers. The following section suggests some policies for the way forward that addresses the top barriers to the e-mobility adoption.

I. **City wise incentives on the upfront cost of vehicles:** Under the FAME-I scheme, from April 2015 to March 2019, a significant subsidy for private vehicles was provided and under the FAME-II scheme, which started in April 2019, the main focus is on the deployment of public vehicles. The study suggests providing incentives on the upfront cost of vehicles as per the city's primary preference of the transport mode. In cities with a higher preference for private vehicles (2-Ws, cars), subsidies should be given for private vehicles. In cities with higher share of public transport (buses, taxis, rickshaws, etc.), the incentives should be provided for public vehicles. For example, in Lucknow and Indore the modal share of private vehicles is higher than of the public vehicles. Therefore, incentives on upfront cost should be provided for 2-wheelers and cars in these cities. On the contrary, for Mumbai, subsidy for public vehicles should be provided.

II. **Manufacturing in India and developing expertise:** To bring down the upfront cost of vehicles, the primary step should be domestic manufacturing of batteries and EV components, which can get support under the "**Make in India**" initiative. By just importing the raw materials from mineral-rich regions for manufacturing batteries, India has an opportunity to save a significant amount [24]. Developing expertise in battery manufacturing and scaling domestic production capacity can build a strong economic advantage for the nation.

III. **Encouraging the battery swapping mechanism:** The battery is one of the most expensive components of EVs. It accounts for 30-40% of the cost of an EV. The battery swapping system allows users to buy/lease the vehicle without batteries from OEMs, thus reducing the upfront cost. It also facilitates the range anxiety issue and saves the time required to charge a battery. The MoP (Ministry of Power) has recognized battery swapping as another technology for charging batteries in an amendment notified on 8th June 2020 [25]. However, no subsidy is available under FAME-II for the battery swap technology. The Government should provide incentives for swap technology and reduce the Goods and Service Tax (GST) on swap services to 5%, which is currently 18%.

IV. **Expanding the scale of charging infrastructure:** It is strongly recommended by the MoP [26] to provide at least one charging station within a grid of 3km x 3km in a city. However, there is a dilemma regarding where to install charging points primarily. Therefore, the study defines criteria for providing a charging facility according to the mode of transportation for which the subsidy is recommended in I Point of this section.

V. **Giving advertisement rights at charging stations:** The charging rate for opportunity is as high as US$ 0.36 (Rs. 30) per unit. Putting a service kiosk for watching and warding chargers and bill payments can grab an opportunity to have the advertisement space. Providing the advertisement rights would help cater to the infrastructure and reduce the overhead expenses.

VI. **Promoting interoperable payment systems:** 80% of the time, charging is done at residences and offices. For occasional charging at centralized charging stations, interoperable payment systems should be encouraged, like automated payment on the spot and a single app for booking charging slots and payment. Synchronizing with already prevailing e-commerce payment systems like UPI and e-wallets can help to resolve interoperability issues.

VII. **Strict follow-up of standardization norms:** Technical standards for the EVs are issued by the Ministry of Road Transport and Highways and are governed by AIS (Automotive Industry Standards). Technical standards for charging stations and connectors exist under IEC (International Electrotechnical Commission) standards. These standards should be strictly followed.

VIII. **Reducing the dependency of charging stations on the grid:** The saving in emission levels by adopting e-mobility depends mainly on the source of power generation. Therefore, more and more renewable energy generation sources should be set up. The charging stations can be deployed at home, offices and parking, using the solar energy to reduce the dependency on the distribution grid. On 13th May 2020, Government of India started Aatmanirbhar Bharat Abhiyan (Self-reliant India Mission) towards making India Self-reliant. The concept of the net-zero energy building could be promoted considering the EV as an active component of the building's energy system which can get support under **"Atmanirbhar Bharat Abhiyan"** as infrastructure is one of the five pillars of this mission [28]. An EV owner with a green energy production system at their residence should be given a concession on electricity consumption tariff during the opportunity charging.

Vehicles with solar and/or wind energy systems could also reduce their reliance on the grid. Solar energy can be stored in a vehicle's battery while it is standing still and also when it is moving. The wind turbine system in vehicles allows for converting the kinetic energy from the wind into electric power, which can be used to charge a battery. Using the solar and wind energy can also improve the driving range of EVs.

IX. Taking India's "Swachh Bharat Abhiyan" (SBA) initiative to the next level [29]**:** There are visible benefits of using EVs regarding GHG emission level reduction compared to conventional ICE vehicles. However, a huge behavioural change is required by consumers to accept the EVs due to habits towards the conventional vehicles. Spreading awareness about environmental benefits could accelerate the penetration of EVs in India. It could be done in association with India's "Swachh Bharat Abhiyan" by taking the mission to the next level of cleanliness by including the 'air quality parameter'. **Government of India launched Swachh Bharat Abhiyan or Clean India Mission on 2nd October 2014. Under the mission a cleanliness survey is being conducted called as Swachh Survekshan. Based on the survey ranking of cities is done.** In Swachh Survekshan League-2020, a new category of cities with a 4 million-plus population has been added for the population-wise award [30]. In addition, in the Ministry of power's revised guidelines for the charging infrastructure, cities with a 4 million-plus population have been included in phase-I to provide charging infrastructure coverage. Therefore, primarily including a parameter for air quality improvement due to EVs in the SBA's focus area for these cities can inspire all the cities to adopt the EVs. Change in the air quality at most congested junctions can be monitored by identifying a drop in emission levels due to EV adoption. Since the SBA has successfully brought a behavioural change in every corner of the country and has a partnership with many famous influencers, celebrities and international agencies, thus this tie-up would be very beneficial for promoting the e-mobility.

X. Prohibiting ICE vehicles: Along with promoting the electric vehicles, some measures should be taken to slow down the ICE vehicles' penetration. Like, the Government should prohibit investment in the production plants of the new ICE vehicle and tighten the CO_2 emission regulations, which would force many automakers to produce the EVs. Excess tax on petrol and diesel can be imposed to develop charging infrastructure for EVs.

These ten policy measures have been proposed to address the top barriers in e-mobility implementation. Policy measures I, II and III focus mainly on reducing the high upfront cost of an EV. Policy measures II also encourages the training and preparation of human resources in India, increasing employment opportunities and improving the tech-savvy level of this emerging technology in India. Policy measure III for supporting battery swapping technology would also tackle the issues of shortage of charging infrastructure, range anxiety and long charging time for EV users. Policy measure IV concentrates on expanding the charging infrastructure for EVs in a city, reducing the range anxiety and charging point anxiety of EV owners. Policy measure V also diminishes the charging point anxiety by emphasizing the standardization of EVs and their chargers. Policy measure VI suggests providing advertisement rights at a charging point, catering to the infrastructure costs and reducing the bill for charging EVs, which was observed to be very high at private charging points during the site visits. The interoperable payment methods are recommended to be encouraged in policy measure VII to promote the use of centralized charging points. Policy measures VIII and IX focus on environmental concerns of e-mobility. Policy measure VIII is to promote the generation of electricity from renewable sources on-site, which would ultimately bring down the GHG emission level and reduce the dependency on the grid. Policy measure VII recommends spreading awareness among citizen about the environmental benefits of EVs to bring behavioural change in them to adopt EVs. The last policy measure, i.e., Policy measure X, asks to slow down the penetration of conventional ICE vehicles, without which the transition cannot take place. Thus, these ten policies complement each other so that the main obstacles can be removed and implementation of the e-mobility can be accelerated in developing countries like India.

To discuss the limitations of the present study, the strategies developed in the present study are specific to India, which are developed by studying issues and challenges in Indian cities. These strategies can be used for other developing countries with minor changes. If needed, similar strategies can be developed for other countries as well, using the methodology followed in the present study. In addition, the policy measures suggested are linked with schemes and initiatives in India, however, these can also be implemented in other parts of the world, especially developing countries.

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Conflicts of interest

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References

[1] JUYAL, S., SANJEEVI, H., SAXENA, A., SHARMA, S., SINGH, A., CHANDE, S., JHUNJHUNWALA, A. Zero emission vehicles (ZEVs): towards a policy framework. In: MOVE Global Mobility Summit: proceedings. 2018.

[2] Climate explained: the environmental footprint of electric versus fossil cars -The Conversation Media Group Ltd [online]. 2019. Available from: https://theconversation.com/climate-explained-the-environmental-footprint-of-electric-versus-fossil-cars-124762

[3] AMBROSE, H., KENDALL, A., LOZANO, M., WACHCHE, S. Trends in life cycle greenhouse gas emissions of future light duty electric vehicles. *Transportation Research Part D Transport and Environment*[online]. 2020, **81**(10), 102287. ISSN 1361-9209, eISSN1879-2340. Available from: https://doi.org/10.1016/j.trd.2020.102287

[4] BINIEK, K., HENDERSON, K., ROGERS, M., SANTONI, G. Driving CO2 emissions to zero (and beyond) with carbon capture, use and storage - McKinsey Quarterly[online]. 2020. Available from: https://www.mckinsey.com/capabilities/sustainability/our-insights/driving-co2-emissions-to-zero-and-beyond-with-carbon-capture-use-and-storage#/

[5] Blue skies, reduced emissions only temporary, won‘t benefit environment in long run: experts - The Economic Times [online]. 2020. Available from: https://economictimes.indiatimes.com/news/environment/pollution/blue-skies-reduced-emissions-only-temporary-wont-benefit-environment-in-long-run-experts/articleshow/75061943.cms

[6] GNANN, T., PLOTZ, P., WIETSCHEL, M. How to address the chicken-egg-problem of electric vehicles? Introducing an interaction market diffusion model for EVs and charging infrastructure. In: eceee Summer Study 2015: proceedings. 2015.

[7] BIRESSELIOGLU, M. E., KAPLAN, M. D., YILMAZ, B. K. Electric mobility in Europe: a comprehensive review of motivators and barriers in decision making processes. *Transportation Research Part A: Policy and Practice*[online]. 2018, **109**, p. 1-13. ISSN 0965-8564, eISSN1879-2375. Available from: https://doi.org/10.1016/j.tra.2018.01.017

[8] HARDMAN, S., JENN, A., TAL, G., AXSEN, J., BEARD, G., DAINA, N., FIGENBAUM, E., JAKOBSSON, N., JOCHEM, P., KINNEAR, N., PLOTZ, P., PONTES, J., REFA, N., SPREI, F., TURRENTINE, T., WITKAMP, B. A review of consumer preferences of and interactions with electric vehicle charging infrastructure. *Transportation Research Part D Transport and Environment*[online]. 2018, **62**, p. 508-523. ISSN 1361-9209, eISSN1879-2340. Available from: https://doi.org/10.1016/j.trd.2018.04.002

[9] FUNKE, S. A., SPREI, F., GNANN, T., PLOTZ, P. How much charging infrastructure do electric vehicles need? A review of the evidence and international comparison. *Transportation Research Part D Transport and Environment*[online]. 2019, **77**, p. 224-242. ISSN 1361-9209, eISSN1879-2340. Available from: https://doi.org/10.1016/j.trd.2019.10.024

[10] LEBEAU, K., MIERLO, J. V., LEBEAU, P., MAIRESSE, O., MACHARIS, C. Consumer attitudes towards battery electric vehicles: a large-scale survey. *International Journal of Electric and Hybrid Vehicles*[online]. 2013, **5**(1), p. 28-41. ISSN 1751-4088, eISSN1751-4096. Available from: https://doi.org/10.1504/IJEHV.2013.053466

[11] AZAROVA, V., COHEN, J. J., KOLLMANN, A., REICHL, J. The potential for community financed electric vehicle charging infrastructure. *Transportation Research Part D Transport and Environment*[online]. 2020, **88**,102541. ISSN 1361-9209, eISSN1879-2340. Available from: https://doi.org/10.1016/j.trd.2020.102541

[12] SACHAN, S., DEB, S., SINGH, S. N. Different charging infrastructures along with smart charging strategies for electric vehicles. *Sustainable Cities and Society*[online]. 2020, **60**,102238. ISSN 2210-6707, eISSN2210-6715. Available from: https://doi.org/10.1016/j.scs.2020.102238

[13] KESTER, J., DE RUBENS, G. Z., SOVACOOL, B. K. Public perceptions of electric vehicles and vehicle-to-grid (V2G): Insights from a Nordic focus group study. *Transportation Research Part D Transport and Environment* [online]. 2019, **74**, p. 277-293. ISSN 1361-9209, eISSN1879-2340. Available from: https://doi.org/10.1016/j.trd.2019.08.006

[14] JUNQUERA, B., MORENO, B., ALVAREZ, R. Analyzing consumer attitudes towards electric vehicle purchasing intentions in Spain: technological limitations and vehicle confidence. *Technological Forecasting and Social Change*[online]. 2016, **109**, p. 6-14. ISSN 0040-1625, eISSN1873-5509. Available from: https://doi.org/10.1016/j.techfore.2016.05.006

[15] Livemint [online]. 2020. Available from: https://www.livemint.com/companies/news/electric-vehicle-sales-in-india-up-20-in-2019-20-11587370389230.html

[16] NAIK, A. R. Inc42 [online]. 2020. Available from: https://inc42.com/features/will-covid-19-accelerate-growth-of-indias-electric-vehicle-ecosystem/

[17] VERMA, P. The economic times[online]. 2019. Available from: https://economictimes.indiatimes.com/jobs/modis-e-car-dream-has-a-problem-no-one-saw-coming/articleshow/70299606.cms

[18] Wilbur Smith Association. Study on traffic and transportation policies and strategies in urban areas in India. New Delhi: Ministry of Urban Development, 2008.[19] IRENA. Innovation outlook: smart charging for electric vehicles. Abu Dhabi: International Renewable Energy Agency, 2019.
[20] Best electric bike models - Greynium Information Technologies Pvt. Ltd. [online]. 2020. Available from: https://www.drivespark.com/best-electric-bikes/
[21] TVS king electric auto rickshaw specifications, review and price - Electricvehicles.in [online]. 2020. Available from: https://electricvehicles.in/tvs-king-electric-auto-rickshaw-specifications-review-and-price/
[22] Electric cars in India - carandbike[online]. 2020. Available from: https://www.carandbike.com/new-cars/electric-cars
[23] YADLAPALLI, B. Electric bus in India -goldstone ebus[online]. 2018. Available from: https://electricvehicles.in/electric-bus-in-india-goldstone-ebus/
[24] Enabling the transition to electric mobility in India. New Delhi: Rocky Mountain Institute, 2017.
[25] Amendment in the revised guidelines and standards for charging infrastructure for electric vehicles - reg. New Delhi: Ministry of Power, 2020.
[26] Charging infrastructure for electric vehicles (EV) - revised guidelines and standards reg. New Delhi: Ministry of Power, 2019.
[27] Urban and regional development plan formulation and implementation guidelines. Town and Country Planning Organisation, 2015.
[28] Innovative initiatives - G. o. I. Ministry Of Tribal Affairs [online]. Available from: https://tribal.nic.in/atmanirbhar-bharat.aspx
[29] Swachh Bharat mission - G. o. I. Ministry of Housing and Urban Affairs [online]. Available from : https://mohua.gov.in/cms/swachh-bharat-mission.php
[30] Swachh Survekshan. G. o. I. Ministry of Housing and Urban Affairs, 2020.