Identification and analysis of social factors responsible for adoption of electric vehicles in India

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Environmental crisis and energy security concerns have forced researchers to look for a cleaner mode of transportation. Rigorous efforts are on to make electric vehicles (EVs) feasible for commercial use in terms of technological advancements and economic viability. Despite being among the top automobile manufacturing countries in the world, the adoption rate of EVs in India has been poor. There is a need to understand the social acceptability and sustainability of EVs. To bridge this gap, the present study identifies the social factors responsible for slow adoption of EVs in India. The results may help in orienting the manufacturers and decision makers towards faster adoption of EVs. This study will assist researchers to get a better understanding of the factors responsible for slow adoption of EVs in India. The Government of India could benefit in its goal to achieve its ambitious target projected in the FAME India scheme.

Keywords: Descriptive statistics, electric vehicles, hypothesis testing, social factors, structural equation model.

INDIA, the seventh largest commercial vehicle manufacturer in the world[1], has huge potential for a flourishing electric vehicles (EVs) market. The global EV industry is in its growth phase. It can provide employment to many people in the manufacturing sector, charging infrastructure sector, after-sales service sector and even scrap management sector. Adoption of EVs in major cities like New Delhi can bring down the harmful effects of pollution from extensive use of conventional fossil-fuel vehicles (CFFVs), and make significant improvement in the air quality of the region. Choosing EVs over CFFVs has its own social benefits as well. It helps improve the social lifestyle and outlook. Thus, focusing attention of the automotive industry on EVs can bring about economic, social and environmental benefits to the citizens.

Development of EVs in India

In India, the EV is still in its infancy stage. Understanding the importance of EVs, the Government of India (GoI) is implementing various policies and incentives. It has launched the faster adoption and manufacturing of (hybrid) and electric vehicles (FAME) India scheme under which both the customers as well as the manufacturers are provided with uniform demand incentives @ INR 10,000 per kWh for all EVs, except e-buses and @ INR 20,000 per kWh for all e-buses[2]. Currently, India has around 750,000 EVs deployed on the roads and the number is continuously increasing[3].

The manufacturer of EVs and the charging infrastructure should go hand-in-hand. One cannot grow without the other. Therefore, it is equally important to invest in EV charging infrastructure as well. In January 2020, the Department of Heavy Industries (DHI), Ministry of Heavy Industries, GoI approved 2636 EV charging stations in 62 cities across 24 states and Union Territories under the second phase of the FAME India scheme[4].

The potential of EVs to reduce dependency on non-renewable fossil fuels is what drives the nations across the world to switch to them. However, if electricity which is powering EVs is in turn generated by burning coal, the efforts to reduce pollution levels go in vain[5]. At present, 63% of India's total energy comes from coal and other fossil fuels, and the share of renewable sources is limited to 17% (ref. 6). Therefore, it is equally important to make sure that there is a fair share of renewable energy sources that back up the EV industry.

Study area

Air pollutants, including particulate matter (PM), sulphur dioxide (SO_2), nitrogen oxides (NO_x), carbon monoxide (CO) and ozone (O_3) often exceed the National Ambient Air Quality Standards (NAAQS) in Indian cities[7]. Delhi, the capital of India, has been selected as the study area. Delhi (area 1484 sq. km) has the worst air quality in the world with respect to presence of PM10 particular matter with an air quality index (AQI) of 292 micrograms particulate matter per cubic metre (according to Statista Infographic Newsletter), while the acceptable safe limit is 60. According to data from the Transportation Department, Government of Delhi, 109.86 lakh vehicles were registered in Delhi by 2018. Pollution-related death toll was more than 10,000 per year. These factors make Delhi a suitable site for this pilot study.

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Research questions

Countries like Norway, China, USA, Japan, etc. have been successful in adopting EVs, whereas India despite its continuous efforts is still struggling to deploy EVs on its roads. So, it is necessary to understand how the customers perceive EVs and the related social factors. Hence the present study examines the following questions:

- What are the social factors responsible for the widespread adoption of EVs?
- Are these social factors significantly affecting the public adoption of EVs?
- Which social factors have a positive effect and which ones have a negative effect on purchase intentions of people?

Literature review

Efforts have been made by researchers worldwide in identifying the barriers to the adoption of EVs in the automotive market. The factors could be technological, economic, political, environmental or even social. While the technological, economic and environmental aspects have been explored in the past, the social factors need to be studied in-depth to gain competitive advantage in the global market. Axsen *et al.*[8] have evaluated customer perception in the UK and discussed the impact of social influences on these perceptions. After identifying the social factors, they categorized them into translation, reflexivity and diffusion. Digalwar and Giridhar[9] have implemented interpretive structural modelling (ISM) approach for prioritizing factors which are barriers to deployment of EVs in India. They found that lack of awareness and passive government commitment are the greatest barriers and hence have to be tackled first. The other barriers such as industrial growth, supplier's availability, customer's management and battery technology have high dependencies and will automatically be eliminated if the other barriers are sorted out.

She *et al.*[10] performed a similar study in Tianjin, China and found that most of the people recognized the importance of EVs and encouraged their promotion, while a few people adopted 'wait and watch attitude' because of various concerns associated with EVs such as safety, reliability and range. The people of China opined that the policies needed to be extended and more subsidised given for an increase in the adoption rate. Westin *et al.*[11] studied the adoption of EVs in Sweden and found that people had a positive attitude towards them due to ecological motives. This attitude provides the customers with opportunities to show their concern towards the environment. Their results mention that social influence plays a crucial role on the adoption of EVs. Park *et al.*[12] have also analysed such social factors in Korea and found that people were satisfied with the driving experience of EVs. The purchase price and battery replacement cost, however, posed a big barrier to them. Moving a step ahead, Zheng *et al.*[13] established a trade-off between production decisions and government subsidies from the perspective of maximal social welfare in China. They concluded that government policies should be made keeping in mind both the customers and manufacturers.

Financial factors

The EVs market and the corresponding infrastructure market go hand-in-hand. Original equipment manufacturers will not take the initiative to build charging stations if there is no scope for EVs and vice versa. Due to this, the EVs market is still in its infancy in India. As a result, the production cost of EVs becomes high, which automatically results in a high purchase price for the EVs. As India does not have enough resources for the manufacture of lithium-ion batteries, these are imported from the North Asian countries, leading to high cost of the batteries due to transportation charges and import-related taxes. Thus, battery cost indirectly becomes a financial factor that influences the adoption of EVs in the automotive market[14]. Although purchase cost of an EV is comparatively higher than that of a CFFV, the lower fuel and maintenance costs of EVs make them better choice in the long run[15].

Vehicle performance factors

The biggest problem with EVs are their range. There is a trade-off between seating capacity and range. If seating capacity is increased, the range decreases. A typical four-wheeler EV with seating capacity of four persons has an average range of 130 km, which is enough for the daily driving of a customer. However, this may not be able to fulfil the requirement of long-distance tours as they need battery charging[16]. Also, it takes around 10 h to charge the battery with a normal 220 V AC power. In such cases battery swapping may be considered as a viable solution, as it takes a couple of minutes to swap exhausted batteries with charged ones[17]. Safety of EVs is also a sensitive factor as it has been seen that the battery explodes upon crash of an EV. The top speed and acceleration of EVs are also directly dependent on the battery. Due to this, an old or partially charged battery cannot be used for high-speed purposes. The end-of-life phase of the battery also poses a serious problem for its disposal. Few important factors to be considered in case of EVs are reliability, performance consistency and trustworthiness.

Infrastructure factors

For the successful deployment of EVs, charging infrastructure needs to be available throughout the country.

Table 1. Frequency analysis of various factors affecting the adoption of electric vehicles (EVs)

Reference	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14
10	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
9	✓	✓	✓	✓	✓	✓		✓	✓					
13	✓	✓	✓	✓	✓	✓				✓	✓	✓		✓
12	✓	✓	✓		✓	✓	✓	✓		✓	✓			✓
8	✓	✓			✓	✓	✓		✓	✓	✓	✓	✓	✓
21	✓	✓	✓	✓	✓	✓			✓	✓	✓	✓		
11	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			
22	✓	✓	✓		✓	✓	✓	✓	✓	✓		✓	✓	
14	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓				
23	✓	✓	✓		✓	✓	✓		✓	✓	✓	✓	✓	✓
15	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓		
24	✓	✓	✓		✓	✓	✓	✓	✓		✓	✓	✓	✓
25	✓		✓	✓		✓	✓		✓	✓	✓			
26	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓	
27	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓
28	✓	✓	✓	✓	✓	✓	✓	✓	✓					
29	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓		
16	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
17					✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
30	✓	✓		✓	✓	✓	✓	✓	✓	✓				
31	✓	✓		✓		✓		✓	✓	✓	✓	✓	✓	
32	✓	✓	✓	✓	✓	✓	✓	✓						
33	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓				
34	✓	✓	✓	✓			✓	✓	✓	✓	✓	✓	✓	✓
35	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
36	✓	✓	✓	✓	✓	✓	✓	✓						
37	✓				✓		✓	✓			✓			✓
38	✓	✓	✓			✓		✓	✓	✓		✓	✓	✓
39	✓	✓			✓	✓	✓	✓			✓	✓	✓	
40	✓	✓	✓	✓				✓	✓	✓				
41	✓		✓	✓		✓	✓	✓				✓	✓	
42	✓	✓	✓	✓	✓	✓	✓			✓	✓			
43	✓		✓	✓				✓			✓	✓		
44											✓	✓	✓	✓
45	✓	✓	✓	✓	✓		✓	✓		✓				✓
46					✓	✓	✓	✓	✓	✓	✓	✓		
47	✓		✓	✓			✓	✓				✓	✓	✓
48	✓			✓	✓				✓	✓	✓	✓		
49	✓				✓				✓	✓				✓

The charging stations are of two types – fast charging grid system and slow speed charging system. The fast-charging stations need to be located at highways and the city roads. The slow chargers can be installed at homes or workplaces because there is not much constraint regarding the charging time. In order to resolve consumer concerns about charging, the construction of charging infrastructure should be the top priority in India[18].

Policy incentives

Several innovative policies have been adopted by various countries for attracting customers and increasing the adoption rate of EVs. Some of them are purchase subsidy, vehicle tax benefits and dedicated lanes for EVs. In India, to begin with, the cap on incentives for buses is kept at 40% of the cost of vehicles and for all other categories it is fixed at 20% (ref. 19). The other policies, under government consideration are discounted toll tariff, subsidized charging fee, etc. The government is continuously allocating funds to establish charging infrastructure and decrease the purchase price of EVs through the FAME India scheme. The study done in this article implies that the central government incentives affect the consumer willingness to buy EVs; however, strategic support from the states and placement of charging points are crucial elements to the widespread adoption of EVs[20].

From an exhaustive literature survey, frequency analysis of the factors (Table 1)[21–49] was done.

Table 2 provides a clear understanding of the public perception and these would be tested by the following hypotheses:

H1 – Financial factors have a significantly negative impact on EV adoption.

H2 – Vehicle performance factors have a significantly negative impact on EV adoption.

H3 – Infrastructural factors play a significantly negative impact on EV adoption.

Table 2. Factor type, grouping and explanation

Factor type	Alias	Factor	Explanation
Financial	F1	Purchase cost	Purchase price of EV without subsidy
	F2	Battery cost	Cost of a new battery once its life ends
	F3	Lack of awareness about maintenance	Routine servicing cost of the vehicle
	F4	Lack of awareness about fuel cost	Electricity cost for charging the batteries
Vehicle performance factors	F5	Driving range	Longest distance covered per full charge
	F6	Refuelling time	Time to charge battery from zero to full
	F7	Safety	Safety of passengers during the lifetime of an EV
	F8	Reliability	Trustworthiness and performance consistency
	F9	Life of battery	Time from purchase to disposal of battery
	F10	Vehicle power	Top speed, acceleration of EV
Infrastructural	F11	Public charging infrastructure	Service radius of charging station
	F12	Charging infrastructure at home	Charging facility at home
	F13	Charging infrastructure at work	Charging facility at work
	F14	Charging infrastructure on highways	Service range and fast charging station on highways

It has also been examined whether personal characteristics and policy incentives impact public perceptions regarding EV adoption.

Methodology

Questionnaire survey

A questionnaire survey was done in Delhi to determine the customer perception regarding EV adoption and the relevant social factors associated with it. The questionnaire consisted of four parts.

Part-1 contained demographic information of the respondents, such as their age, sex, education, income, car ownership, etc.

Part-2 was about the customer's attitude towards various factors and had to be answered on a five-point 'Likert scale'. The significance of the scale was: 1 (least important) to 5 (most important), and was included in the survey for a clear understanding of the respondents.

Part-3 was regarding government incentives and policies regarding EVs. This aimed to understand the customer's attitude regarding the driving power of government incentives and policies. Here also the responses were recorded on a five-point 'Likert scale' with significance: 1 (least inspiring) to 5 (most inspiring).

Part-4 was on the customer's willingness to buy an EV. Three questions were asked: whether the customers were ready to buy an EV, ready to recommend an EV to others and ready to have more EVs in the market. The responses were collected on the same five-point Likert scale having significance: 1 (not at all willing) to 5 (most willing).

The survey was administrated in November 2019 through an open Google survey form. The collection of responses continued till 90 days and a total of 632 responses were collected. These were then filtered using the following criteria: (i) The respondent must be an adult, i.e. than 18 years of age. (ii) He/she must have lived in Delhi for more than two years.

In the next step, contradictory responses for similar questions placed under different sections of the survey were filtered out and 543 responses were finally accepted assuming that all the respondents had a valid driving licence. The criterion of vehicle ownership was relaxed as many people may be using vehicles which are owned by their family members.

Structural equation model

The structural equation model (SEM) is a causal modelling tool, commonly used for finding the output of various social analyses. It assesses the latent variable from the observed variables and the output model is developed using the independent regression equations. It provides a quantitative study on the interacting relations among the variables. The factor analysis and path analysis were done in SEM, and the relationships between various factors and customer willingness were judged.

Results and discussion

As the survey was conducted at one phase, there was no need to test the variation in the responses received from the respondents. Descriptive statistics was implemented on the data, and mean and standard deviation were calculated for each factor to rank them. The Statistical Package for the Social Sciences (SPSS) was used to get the model. Later, the hypothesis tests were performed on the results.

Descriptive statistics

Table 3 describes the data about mean and standard deviation of all the factors from the responses accepted. The results show that battery cost (F2) is the most critical factor amongst all the social factors followed by purchase cost (F1) and public charging infrastructure (F11), which implies that the main reasons for the unwillingness to buy EVs are the associated costs and underdeveloped

Table 3. Descriptive statistics of possible factors affecting the adoption of EVs

Factor (alias)	Minimum	Maximum	Mean	Standard deviation	Rank
Battery cost (F2)	1	5	4.92	0.74	1
Purchase cost (F1)	1	5	4.88	0.59	2
Public charging infrastructure (F11)	1	5	4.77	0.81	3
Driving range (F5)	1	5	4.69	0.65	4
Vehicle power (F10)	1	5	4.61	0.74	5
Reliability (F8)	1	5	4.55	0.68	6
Safety (F7)	1	5	4.46	0.77	7
Charging infrastructure on highways (F14)	1	5	4.41	0.79	8
Life of battery (F9)	1	5	4.32	0.76	9
Refuelling time (F6)	1	5	4.26	0.7	10
Lack of awareness about maintenance cost (F3)	1	5	4.19	0.84	11
Lack of awareness about fuel cost (F4)	1	5	4.02	0.67	12
Charging infrastructure at work (F13)	1	5	3.76	0.74	13
Charging infrastructure at home (F12)	1	5	3.51	0.82	14

Table 4. Descriptive statistics of public adoption of EVs

Survey questionnaire	1 (strongly unwilling, %)	2 (unwilling, %)	3 (confused, %)	4 (willing, %)	5 (strongly willing, %)
Willing to purchase EVs	5.68	28.39	11.61	51.22	3.10
Willing to recommend EVs	1.22	5.21	28.47	49.94	15.16
Ready to have more EVs in the market	0.15	3.18	16.87	62.17	17.63

charging infrastructure. It can be inferred that the adoption rate cannot be improved until more subsidies and incentives are provided to the customers on purchase of EVs. The most significant factor for vehicle performance is the driving range, which can only be improved by intense research on battery technology.

Table 4 presents the results of the analysis of responses for part 4 of the questionnaire. It indicates that more than 50% of the people are willing to purchase EVs. This could be due to the adverse environmental conditions due to the use of CFFVs. The fraction of population willing to purchase EVs is much more than the current share of EVs in Delhi, suggesting a huge potential for the growth of the EVs market in the region. Furthermore, 65.10% of the population is willing to recommend EVs to others; 79.80% of the population is of the opinion that there must be more EVs on Delhi's roads.

Structural equation model

The path diagram shown in Figure 1 was made using a software 'draw.io' from the results of the regression fit analysis (RFA) done with IBM SPSS Statistics 11.0 software. The results display a good model fit because the values of the standard errors lie within the accepted range (i.e. between 0.05 and 0.15) for the model fit. The Cronbach's alpha values and values of composite reliability (CR) for each factor were also computed to check the reliability of the factors (Table 5). The estimated parameters of structural equation model (SEM) are also shown in Table 5.

H1 – The financial factors have a significant negative impact on the adoption of EVs.

The path coefficients shown in the path diagram ($\beta = 0.37$, $P = 0.021$) do not support the hypothesis, and hence we reject the null hypothesis (Table 6). The positive effect suggests that the customers for whom financial factors are more significant, show greater adoption to EVs. This can be understood from two aspects. First, the purchase cost is exclusive of the purchase subsidy, which shows a positive effect on public adoption. Under the FAME India scheme, a subsidy of 20% of the ex-factory price subjected to a maximum of Rs 150,000 for electric four-wheelers has proved to be an effective solution. The public adoption of EVs will certainly improve with increase in subsidies and incentives. Also, the overall cost of ownership of a vehicle may decrease by around 50% if a customer switches from CFFVs to EVs. The regression coefficient of battery cost (0.77) is highest amongst all other financial factors (Table 6), which verifies the results of descriptive statistics. Hence battery cost is the most significant financial factor for EVs, and the only solution is to increase R&D budgets on batteries.

H2 – The vehicle performance factors have a significantly negative impact on the adoption of EVs.

The path coefficient ($\beta = -0.25$, $P = 0.014$) confirms that there is a negative correlation between vehicle performance factors and public adoption, and thus the null hypothesis is accepted. This means the customers who feel that vehicle performance is a significant factor for EVs, have a passive attitude towards EV adoption due to the low performance specifications. Regression coefficients for all the vehicle performance factors were positive (Table 6), which shows that all these factors are potential barriers for EVs in the Indian market.

H3 – The infrastructural factors play a significantly negative impact on the adoption of EVs.

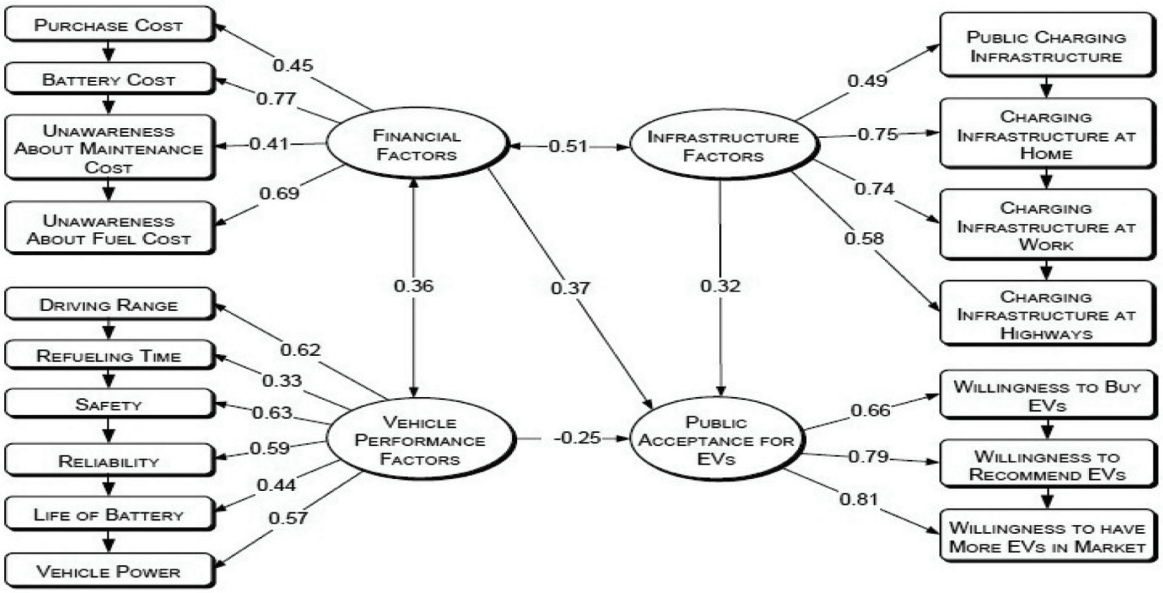

Figure 1. Structural equation model path diagram.

Table 5. Reliability of structural equation model constructed variables

Factor type	Factors	Cronbach's alpha (α)	Composite reliability
Financial	F1, F2, F3, F4	0.63	0.77
Vehicle performance	F5, F6, F7, F8, F9, F10	0.69	0.68
Infrastructure	F11, F12, F13, F14	0.74	0.72
Public adoption	Willingness to buy Willingness to recommend Willingness to have more EVs	0.72	0.75

Table 6. Estimated parameters of the structural equation model

Grouping of factors	β	P	SE
Financial factors			
Purchase cost	0.45	<0.001	0.054
Battery cost	0.77	<0.001	0.074
Lack of awareness about maintenance cost	0.41	<0.001	0.066
Lack of awareness about fuel cost	0.69	<0.001	0.059
Vehicle performance factors			
Driving range	0.62	<0.001	0.112
Refuelling time	0.33	<0.001	0.135
Safety	0.63	<0.001	0.134
Reliability	0.59	<0.001	0.094
Life of battery	0.44	<0.001	0.083
Vehicle power	0.57	<0.001	0.105
Infrastructure factors			
Public charging infrastructure	0.49	<0.001	0.096
Charging infrastructure at home	0.75	<0.001	0.069
Charging infrastructure at work	0.74	<0.001	0.087
Charging infrastructure on highways	0.58	<0.001	0.089

The path coefficients from the path diagram ($\beta = 0.32$, $P = 0.011$) do not support the hypothesis that there is a negative effect between the infrastructural factors and public adoption, and thus we reject the null hypothesis. The customers for whom infrastructural factors are significant, are willing to purchase EVs. This may be because the government has allocated an outlay of Rs 10,000 crores to the FAME India scheme in 2019 and an ambitious target of selling 6–7 million hybrid vehicles and EVs by the year 2020 has been fixed by the government[50]. To achieve such an ambitious target, the need for sufficient vehicle charging infrastructure is also being addressed by the government in Phase-II of the FAME India scheme.

Conclusion

The present study is based on responses received from 543 respondents collected through a survey conducted in Delhi. The results show that despite having a positive attitude towards the growth of the EV market, people are reluctant to switch to EVs because of various barriers associated with them. SEM suggests that the respondents for whom vehicle performance is the most significant factor, are most reluctant to buy EVs. Current government policies include subsidies only for purchase cost and

infrastructure building, while there is lack of polices on the grounds of safety and reliability which can be improved by providing incentives like insurance subsidy, salvage value subsidy, etc. Besides the steps being taken by the government, the manufacturers must also work on improving vehicle performance by allocating more funds on research and development activities.

Battery cost and purchase cost are the top two concerns of the respondents. This clearly suggests that more efforts are needed to bring down the cost of EVs. However, the hypothesis shows a positive relation between financial factors and public adoption. This could be attributed to the fact that a large amount of funds is being allocated by the government to the FAME India scheme. Meanwhile, there are customers with a 'wait-and-watch' attitude, who are willing to wait until the purchase cost for EVs is at par with that of CFFVs, and switching to EVs would be affordable. Providing subsidy on the modification of a CFFV to EV might be a promising idea. Awareness about low maintenance cost and ultra-low running cost must also be promoted. Using such measures, the customers should be convinced that the total cost of ownership of EVs would be reduced to 50% even after a higher purchase price.

The public charging infrastructure is ranked third among the social factors. A dense network of charging stations is needed for successful deployment of EVs. The SEM results suggest that there is a positive relation between infrastructure and public adoption, which again is the result of large funding allocated for the setting up of charging infrastructure. The charging stations located on highways must be equipped with a smart on-grid system to provide fast charging. Operational connectivity should also be installed among the stations; so that the driver is notified about the nearest charging station, in case his vehicle needs urgent charging. Innovative business models such as inviting private players to install and run charging stations must be adopted to ensure faster deployment of EVs in the Indian market.

The present study, has some limitations. As a few respondents were actual EV users and most of them were in possession of CFFVs, thus the responses may be from a prejudiced mindset. Extensive research must be done in the future by introducing a few more questions in the survey and by circulating the survey questionnaire so as to gather more responses, which will enable the researchers to conduct a more in-depth analysis.

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