Impact Analysis of Security and Charging Infrastructure on the Adoption of Electric Vehicles

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Abstract. In the Global innovation index report, 2019, India ranked 52 among the 129 nations, thus strengthening its standing in terms of technological adoption. Developed countries for long have adopted electric vehicles, and India too has initiated this. EVs have proven to be better than fossil-based traditional vehicles in terms of convenience, efficiency in operations, price, and performance. This research paper focuses on understanding the consumer perception regarding the adoption of EVs across factors like price, performance, ease of availability, security issues, efficiency, charging Infrastructure, and user experience. This paper focuses on two factors, namely security issues and charging Infrastructure, and draws an inference of how important these factors were in the respondents’ eyes. The results showed these two factors contributed to about 68% of the concerns of the Indian consumers.

Keywords: Security issues and Charging Infrastructure, Global Innovative index, Electric vehicles

1. Introduction
In the event of rapid globalization and liberalization, almost all Indian cities have seen increased air pollution, specifically carbon emissions from fuel-based vehicles; to add to it, air pollution due to transportation makes up more than 10 percent of India’s total carbon emissions. Management of air pollution has been a major challenge [3]. According to the Air Quality database of 2016 released by The World Health Organization, there are 14 Indian cities among the world’s top 20 most polluted cities. The switch from fuel-based vehicles to battery-based vehicles (EVs) has become an accepted norm across countries [2]. Governments all over the world have made it their business to get EVs on their country roads. Various adoption policies in the form of incentives and environmental campaigns have been coming up. In India specifically, to create a sustainable alternative to curb air pollution, the government has created creative policies that would incentivize consumers to switch to electric vehicles [3]. However, the key concerns that need to be attended to fulfill this dream are many. Of these, this paper presents two factors, namely security concerns and charging Infrastructure. The idea is to do both primary and secondary research and collect data from different age groups about the factors mentioned above [4]. This paper’s outcome is an analysis as to how much relatable our factors would be to the consumers’ perception [5-6].

2. The objective of the study
This paper aims to understand the perception and prior mindset of the Indian consumers towards Electric Vehicles and what concerns they perceive would be impediments towards the adoption of the same [7]. By analyzing our respondents’ responses, we calculated how much concern is stressed on Security and Charging infrastructure factors, as a percentage of the 14 factors considered in the research.

3. Literature Review

The IPCC [1], from their research, drew out that the emission of harmful gases into the atmosphere would significantly reduce the human lifespan and cause the extinction of up to 30% of the habitats and other species. Of all the gases released into the atmosphere, a major chunk is from the transport sector (approx. 22%). The [1] duly noted emission of highly harmful greenhouse gases would not only affect the normal human lifespan. Still, it might also drive around 20-30% of the habitats and other species to prevent extinction. An enormous source of the contribution of these greenhouse gases like carbon dioxide and nitrous oxide is the burning of fossil fuels in an uncontrolled environment with the stats in 2010, indicating around 22% of carbon dioxide released, was contributed to the transport sector [2]. Bringing statistics specific to India, the transportation sector has been quite a contributor with around 10-12% in the carbon emission standards. This has now raised a huge concern for us since 14 out of 20 cities in the world’s most polluted cities index are a part of the Indian subcontinent [3].

The adoption of electric vehicles can be one of the paths to tackle this. However, some factors like an increase in fuel prices, financial incentives, and emission regulations can be some of the most crucial stimulants for this practice [4]. Of these factors, the financial aspects influence human adoption to the most extent [5]. The figures for EV adoption haven’t seen a rise because of inadequate knowledge standards about the EV’s benefits which has in turn brought about a market failure for this industry. There hasn’t been much of a push to the firms and going for more production of these vehicles. Furthermore, neo-classical economics states that the government should participate in resolving such an issue with different measures [6]. Out of all the measures, steps about the financial aspects are always considered to side with the human mind and thus are considered most important [5]. But there have been early studies showing that these financial subsidies might not be everything at last.

Considering the cost, there has been much evidence that shows a direct-proportion relation between higher fuel prices and the consumption of HEVs (hybrid electric vehicles) [16]. With the advancements in technology, some of the radical and rapid innovations have pushed the perceptions of consumers in a direction that is unfavourable to the adoption [17] of EVs since it differs from the normal knowledge of HEVs and other electric models and brings them back to the traditional vehicular [18] models that have already mounted over the trust of the conventional audience [9]. This further enhances the levels of uncertainty and brings in ambiguity in their minds, which can even bring an EV adoption-ready mind skeptical [10]. This, in turn, defeats the firm’s future possibility of earning revenue, reduces government’s involvements and at last, the willingness of a customer to pay for such a service (as perceived in a consumer's mind) the more different is the innovation, the less minded the people are in favour of it[11]. Besides all these choices, financial subsidies may come to a standstill because of a lack of faith in the consumer's mind as well as the low fleet of EV’s numbers that additionally doesn’t much instill confidence in them [22]. However, it is easier said than done; there are a lot of other factors that need to be looked into for the actual conversion to happen and to bring about the change in consumer’s perception.

To tackle the problem of pollution, many governments are working, considering different steps via electrical, share, autonomous driving, and certain other measures like low battery cost, raising motor’s performance efficiency, infrastructure support [14]. A 2017 McKinsey report states that the credibility of all plug-in vehicles might be supportive shortly, and this includes different electric vehicles like Battery Electric vehicles and Plug-in Hybrid Electric Vehicles [15].

We have now stepped into the era where there is a high usage of internal combustion engine (ICE) vehicles, but it is expected to decrease starting from the mid-2020s gradually. According to a
Bloomberg report, the European and Chinese markets might see a rise in their figures up to 44% and 41% respectively in these sales, followed by the US with 34% and Japan with 17% [16]. Unfortunately, there haven’t been many talks for India about such developments. As per the NITI Aayog report, the energy demand for mobility can be brought down to save around 67% and reduce the carbon emissions by 34% by the year 2030 using these electric vehicle concepts. There have been some plans like the National Electric Mobility Mission Plan (MEMMP), which is working towards a complete shift to electric vehicles by 2030 due to the current ill climatic scenario.

Considering an aspect of performance, the longest distance it can travel in both charge time for full recharging and safety can act as crucial parts [8]. Past research has shown the impact of greater financial incentives on consumers’ decision to invest in green vehicles more and thus reducing the operational cost of fuelled vehicles and enhancing the figures of fuel efficiency. Tested is stated through his research about the increasing fuel prices as a crucial concern for investment in travelling.

It is a very important point to be taken care of, even considering different financial incentives being provided like direct financial benefits, lower fuel, and operating costs. Many more, it should be considered that the consumers use these vehicles for a shorter distance [13]. Also, since quite a proportion of the Indian population is concerned about the future gains, a significant edge that EVs can give is on their resale value. Its market is still not completely tapped and can gain high excitement for the next audience or buyer. Research has also shown that people who consider themselves environment-friendly and passionate about the nature envelope around them are more likely to adopt the new technology of environmental-friendly EVs[12]. A very practical example of this was a study in Tokyo that said the environment-concerned people were not just adopting these new means but were also promoting them to the audience that wasn't.

Peer pressure can be one of the most driving factors in investing in this technology. It guides the vehicular industry towards a "green" zone and leads to having a positive perspective on one's society. Research in Canada confirmed the "neighbour effect" pattern to influence the consumers' decision towards the purchase of EVs[21]. Increased adoption of electric vehicles will lead to increased load on the electricity grid systems. A genetic algorithm toolbox solved a mathematical model of data of 1000 battery EVs and created distribution curves on drivers' driving and charging habits. These curves helped optimize the load at the grid site. Hence, reducing load fluctuation from 22.7% to 22%, which greatly increases the security and economy of the grid? EVs would communicate with one another through the internet, creating the Internet of EVs (EV). This is a complex system of vehicles, sensors, charging points, and security [22]. Communication among these entities through various protocols like Zigbee, WIFI, Cellular networks, etc., makes the system vulnerable to cyber-attacks like Denial of service and the likes. Countermeasures to prevent and/or recover from these attacks are very crucial. The concept of the Electric Vehicle Cloud and Edge (EVCE) can be related to IoEV; a network paradigm where EVs become potential resources for information and data. This huge network of EV communication becomes crucial for security reasons, over the cloud and edge infrastructure [23]. The data transmitted by the EVs over the internet could get misused and hence blockchain-inspired network has been proposed to create transparency on a distributed consensus.

The investment comes with some future expenses as well. Buying in EV comes with the thought of keeping the infrastructure support available around you. Past research has shown that many people wanted to charge stations near their workplace, their homes, and some frequently visited zones like highways. Also, for successful market penetration, charging Infrastructure is not just a necessity but a crucial part [24].

An efficiently equipped infrastructure setup is required to promote the trend of EVs in the consumer’s minds by providing an electric refuelling station layout for any area in which it is trying to gain a market. Lack of infrastructure support may not only hinder the confidence of a consumer but also lead to a loss of faith in the EV technology itself [25].

Having done an extensive literature review, we have found that there are so many aspects that are researched upon, for example, pricing, performance, efficiency, and their impacts on the EVs adoption. However, there is little research done on finding out how much the security and charging
Infrastructure is crucial in the buying intentions of the Indian consumer. Traditional drivers look for the convenience factor viz. charging Infrastructure, safety, and fuel efficiency [26].

4. Research Methodology

Data Collection: In our study, we have done data collection through an online sample survey from 250 respondents across India. We took specific factors, which we perceived would be crucial for the purchase of Electric vehicles, all from the shoes of the Indian consumers. Our online survey was done in the form of a 25-question questionnaire. These questions were finalized from a list of 100 odd questions, considering all those factors that were highlighted in the literature review and were found to be relevant to the concerns of Indian consumers. The responses were initially analyzed using factor analysis through the use of SPSS software; the sole reason being to drop all redundant questions, thus making the questionnaire crisp and to the point. This would let consumers take the survey with ease and with minimum time consumption.

Further, since this quantitative research is specifically carried out to analyze the weightage given by consumers to factors such as Security and Charging Infrastructure, we have done a hypothesis on the questions related to these factors.

Respondent Segregation: It was essential for us to find out as to which group/bracket every consumer belonged to, be it age, gender, or income. This way, when the data is sent for analysis, we would be able to exactly contemplate as to which group has weighted a particular factor as per perception.

Note:
- We have considered respondents that are over 20 years of age. The reason being, these respondents are likely to be generating an income and/or able to make a buying decision.
- The age and income are taken in the form of brackets so that the customer is comfortable with sharing personal information.
- The option present in the questionnaire is given in the form of a scale ranging from strongly agree to strongly disagree.
- Gender is taken to understand the mindset of both genders.

5. Research Questions

5.1. Security: (Factor 1)

Research Questions:

a) Are EVs perceived to be more dangerous than fuel-powered cars in the event of an accident?

b) Would the EV leak my location-related information?

c) Would it be easier to hack into the EV as it is connected to the internet?

d) Since the safety of your family is important, will you make sure that electric vehicles are safe before buying them?

e) Do you fear that the battery in an EV might explode anytime?

5.2. Charging Infrastructure: (Factor 2)

Research Questions:

a) Should the government plan on building charging Infrastructure as soon as possible to push the demand for EVs?

b) Would you like to have to charge Infrastructure in your workplace?

c) Will the unavailability of charging stations be a stumbling block to adopt EVs?

d) Do you think ease and speed is the most important aspect when it comes to determining the charging time and station?

e) Do you think the limited availability of charging infrastructure can be a major impediment to the adoption of EVs?
6. Data Analysis and findings
Our main objective in surveying by floating a questionnaire is to understand different factors (i.e., Charging and Security Infrastructure) and the sub-factors (these were discovered via our analysis) that influence the mind of the Indian consumer. To get wider insights from the responses, we did the most reliable and approved technique of analysis: A factor analysis. The results obtained from the data analysis would show how the mind of the consumer works and what factors, according to the consumer, would bear the potential to adopt EVs. Lastly, this analysis would help us define each question under a certain variable.

We ran Factor Analysis on the responses and got the most essential result defining the factors: PATTERN MATRIX, which is discussed in Table 1.

Table 1: Pattern Matrix

| Component Description | Pattern matrix | Component 1 | Component 2 | Component 3 |
|-----------------------|----------------|-------------|-------------|-------------|
| Suits shorter travel in full charge | .249 | .345 | -.624 |
| Leakage of location information | -.137 | .890 | .130 |
| Possibility hacking through the Internet | .034 | .796 | .096 |
| Safety of family as a priority | .661 | .012 | .063 |
| Battery explosion anytime | -.025 | .666 | -.204 |
| Build charging infra ASAP | .733 | -.028 | .154 |
| Vouch for charging infra at the workplace | .689 | -.024 | .307 |
| Unavailability for charging infra reason to stay away from EVs | .694 | -.044 | -.158 |
| charging infra available in a few years from now | .242 | .225 | .625 |
| limited availability of charging infra impediment for adopting EVs | .703 | -.007 | -.253 |

Extraction Method: Principal Component Analysis.
Rotation Method: Obliging with Kaiser Normalization.
a. Rotation converged in 6 iterations.

Analysis on the responses and got the most essential result defining the factors: PATTERN MATRIX, which is discussed in below Table 2.

Table 2: Component Correlation Matrix

| Component | 1 | 2 | 3 |
|-----------|---|---|---|
| Component |   |   |   |
7. Discussion on the Results
To arrive at our findings and results, we have done Factor Analysis to understand the relevance and weight-age given to each of the ten questions. In this quest, we have created three matrices- Pattern matrix, Structure matrix, and Component relation matrix.

Each question is split into three components (evident in Component Correlation Matrix). The Factor Analysis algorithm uses complex mathematical models. With repeated iterations, each component of the question is rated (0 being lowest and 1 being highest). Then a correlation is obtained to find out which of two components when combined would make more sense. The Pattern Matrix is generated when the rotation method is used (in our case Oblimin with Kaiser Normalization) and when the factors are allowed to correlate. In most cases, component one is sufficient to convey the relevance. The highlighted questions in the above table are taken for examples. These questions show the highest and the lowest relevance to the perception of the consumers in the adoption of EVs.

For **Question 2-Leakage of location information** as evident from the above table, component 1 is found to be the lowest in value (-.137) when compared to that of the other questions in the table. Now for the interpretation of factor analysis, the results are based on the values obtained for each component of the questions. That being said, we can conclude that based on the results from the table, question 2 has been shown the least concern.

Similarly, question **6-Build charging Infra ASAP** shows results that project towards the other extreme i.e. the component 1 of question 6 displays the highest value (.733). Since this question shows the highest values and as per the interpretation done for factor analysis, we can conclude that question 6 tops the ladder in showing concerns of the consumer.

We wanted to find out the concerns of the consumer regarding Security and Charging Infrastructure as a percentage of the 14 factors we considered in the questionnaire. By calculating the number of positive responses towards these two factors against the total number of responses in the questionnaire, we have concluded that these two factors contribute to 68.015% of the consumers' concerns in the adoption of the EVs.

8. Managerial Implications of the Study
To understand the role of these factors on the managerial level, it is essential to deep dive into what these factors imply and how the same could be used to determine its practical purpose.

8.1. Security issues
Security issues are very delicate and crucial for a product, given its chances to achieve massive success in the market. The EVs we have conceived in this paper are those that have the facility to connect to the internet through the Internet of Everything concept. In this case, the risk of the EVs being hacked by an attack is present. Other risks such as the explosion of batteries, leakage of personal vehicle information, lower coverage of distance by EVs, etc are also considered.

8.2. Charging Infrastructure
This is a challenge that many users may not be able to perceive. But this challenge in itself can impede the adoption of EVs. Handy availability of charging infrastructure is the key to adoption. Further, the time taken for charging could be a deciding factor too.

The question of the location of these stations near workplaces and/or residential areas is also recorded in the responses. Table 3 shows the factor mapping with various questionnaires.

**Table 3: Factor mapping with a questionnaire**

| Factors                | Questions as mentioned in the questionnaire |
|------------------------|---------------------------------------------|
| Security               | **Ques 15.** Would the EV leak my location-related information?  
                        | **Ques 16.** Would it be easier to hack into the EV as it is connected to the internet?  
                        | **Ques 18.** Since the safety of your family is important, will you make sure that electric vehicles are safe before buying them?  
                        | **Ques 19.** Do you fear that the battery in an EV might explode anytime?  
                        | **Ques 20.** Are EVs perceived to be more dangerous than fuel-powered cars during an accident? |
| Charging Infrastructure| **Ques 21.** Should the government plan on building charging Infrastructure as soon as possible to push the demand for EVs?  
                        | **Ques 22.** Would you like to have to charge Infrastructure in your workplace?  
                        | **Ques 23.** Do you think ease and speed is the most important aspect when it comes to determining the charging time and station?  
                        | **Ques 24.** Will the unavailability of charging stations be a stumbling block to adopt EVs?  
                        | **Ques 25.** Do you think the limited availability of charging infrastructure can be a major impediment to the adoption of EVs? |

9. **Conclusion and Future Research Areas**

As of 2019, India ranks 52 in the global innovation index, which is a huge jump from the previous 57th position in the preceding year. Also, in these unprecedented times of the COVID-19, it has become furthermore important to understand what the new normal would be and create the demand for EVs. The main objective of this paper was to analyze what significance of the two factors (security and charging Infrastructure), out of the 14 factors that we considered, created in the minds of the Indian consumer.

Speaking in simpler terms, we have found out that the Indian population admits that security and charging infrastructure accounts for 68.015% of all the factors considered. This research proves that it's not just the monetary incentives that push for EV adoption but also the factors like the performance of EVs; fuel efficiency, distance covered in a single charge, and charging time. Security issues like hacking of the EV Software system, leakage of sensitive vehicle information, the explosion of car batteries, and handily available charging infrastructure. The endpoint and the real effort here is to...
understand the buying behavior of the consumers and accordingly build strategies to hammer it into their minds. With the technique of categorizing the respondents age-wise, income-wise and gender-wise, we can further streamline the buying behavior.

It is also understandable that this paper works on the above-mentioned two factors only and that it is not exhaustive research. However, our effort would be to try and bring about a change relating to these factors. The scope of this study could also extend to environmental sustainability, shifting to sustainable fuel from the conventional and rare energy resources, re-defined customer experience, and the like.

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