Project Dissertation Report on

Sustainability of Electric Vehicles in India

Submitted by

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2K20/DMBA/39

Under guidance of

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Declaration

I, Deepak Prakash, roll no. 2K20/DMBA/39 declare that the project report named “Sustainability of Electrical Vehicles in India” is a true work done by me. The matter typified in this task work has not been submitted before for the honor of any degree or certificate apparently and conviction.

Acknowledgement

I am very appreciative and pay my appreciation to my mentor Dr. Sonal Thukral (Assistant Professor) for her important directions and backing for consummation of this project. I am thankful to domain experts for their guidance with respect to technical aspects of the project.

I stretch out my appreciation to Delhi School of Management, Delhi Technological University for giving me this chance.

I accept this open door as a major achievement in my vocation improvement. I will be utilizing acquired abilities and information in the most ideal manner and will keep on enhancing these skills.

Thanking You

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This is to certify that **Deepak Prakash (2K20/DMBA/39)** has submitted the project report titled **"Sustainability of Electric Vehicles in India"** in partial fulfillment of the requirements for the award of the degree of Master of Business Administration (MBA) from Delhi School of Management, Delhi Technological University, New Delhi during the academic year 2021-2022

Mentor

Dr. Sonal Thukral

Assistant Professor

Executive Summary

It has been observed that AQI of different regions in India is increasing, which is further degrading the environment. Internal combustion engines are major contributors in these phenomena. Electric Vehicles could be one of the solutions to limit this problem. This project is about sustainability of Electric Vehicles in India.

In this project, I have tried to cover different perspectives for sustainability of Electric Vehicles in India. Those perspectives covered are environmental sustainability, economic sustainability, and social sustainability and consumer preferences for EV adoption in India.

Along with literature review, domain expert interviews have been conducted to understand the challenges and solutions with respect to environmental, economical and social sustainability. A Google form was generated to understand consumer preferences, which have been analyzed through SPSS and PowerBI dashboard. The sampling techniques being used are simple random sampling and snowball sampling for over 112 participants. All the responses have been taken on 7 pointer likert scale, covering both positive and negative view points. Statistical techniques being incorporated are descriptive analysis, mean comparison and factor analysis. On the dashboard, different gauges have been used to understand strength of different factors with respect to different segments.

It has been observed that there is high sustainability of electric vehicles in India, if following challenges can be minimized:

- High cost of Electric vehicles
- Cell voltage balancing of EV batteries
- Lack of charging infrastructure
- High electricity demand
- Lack of awareness
- Mismatch between customer demands and EV offering with respect to different segments of Indian consumers.

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1 Introduction

Since decades, we have been dependent on conventional vehicles running on fossil fuels. With the emerging shift in the technology, people are shifting to more environment friendly options like electric vehicles. These electric vehicles not only environment friendly but also have low operating cost. Even the number of moving parts in these electric vehicles is less in comparison to conventional vehicles, which makes their service requirements very low. With reference to(Virta Global, 2022), it can be observed that these has been a tremendous growth in the EV segment all over the world. From 2020 to 2021, there has been a growth of 98% in EV sector all over the world and Europe is the market leader in terms of number of sales of electric vehicles. It can be observed from (evreporters, 2022) that in India, the growth rate of EV sector was 168% in 2021. Uttar Pradesh is leading the market with 3 wheelers in terms of total sales. Uttar Pradesh is followed by Karnataka, Tamil Nadu, Maharashtra and Delhi leading in 2 wheelers segment.

There have been many states in India, which are struggling with high Air Quality Index (AQI). Many of them lies in the unhealthy, very unhealthy and hazardous segments with AQI ranging from 150 to 302(The World Air Quality Index, 2022). There is a need to control these air quality index parameters; Emission from fossil fuel operated vehicles is one of the causes of high AQI. Thus, an environment friendly alternative to conventional vehicles is required and electric vehicles can be opted for the same.

If more and more people can be persuade to shift from conventional fossil fuel vehicles to environment friendly electric vehicles, it can be very beneficial for accelerating renewable and clean energy use by 40% by 2030. It will also help India to attain zero carbon emission goal by 2070(Goel, 2021). For the following research, I have applied different research methodologies which are as follows:

1. Literature review from research papers.
2. Expert panel interviews (3 Experts)
   Focusing upon Environmental, Economical and Social Sustainability
3. Analysis of consumer preferences through SPSS and PowerBI, with reference to (Digalwar et al., 2021)

Thus this research has covered multi dimensional perspectives from different stake holders like government, consumers, Technical Staff and research experts working on real time problem for developing sustainable Electric vehicles. It will be very beneficial for those who want to research more about the sustainability and adaptability of Electric Vehicles in India.

For the sustainability of electric vehicles in the Indian market, all three perspective i.e. environmental, economical and social sustainability are required to be focused upon. There are technically challenges like lack of charging infrastructure, lack of R&D in term of batteries. The cost, size and weight of energy storage systems are very high. 40% of the cost of the electric vehicle is due to the cost of battery. In terms of economic stability, the operating cost of EV is very low. Even the maintenance cost of EV is also very low due to low number of mobile parts but the purchase cost is high. For the social sustainability, it is important to focus on the needs of customers belonging to different segments. There is a need to aware people about facts so that all the myths can be reduced and adoptability of electrical vehicles increases in the near future.

2 Rationale of the study

With the increase in Air Quality Index, there is a need to look for alternative to fossil fuel operated vehicles. Electric vehicles can act as that alternative to fossil fuel operated vehicles. Thus it becomes very important to do the research in this domain. This research work consists of multi dimensional perspectives

- How the government is observing the situation and what are the steps taken by government to persuade more and more people to shift to Electric Vehicles. It also reflects the objectives set by government with a calculated timeline.
- The challenges faced by technical staff and research experts with respect to
    - Charging Infrastructure
    - EV Batteries
    - Cost
    - EV Adoption
- The expectations of consumers from different segments with respect to
    - Types of Vehicles
    - Range
    - Power
    - Speed
    - Safety
    - Comfort
    - Price
    - Appearance
    - Charging
    - Battery
    - Reliability
    - Auto Pilot

3 Objectives of the Study

- **To analyze the environmental, economical and social sustainability of EVs in India**

  (Assessing Sustainability of Electric Vehicles in India)

  Through – Literature review, Interview of 3 domain experts from EV department, DTU

- **To understand consumer preferences towards EVs in India**

  (With respect to different segments of consumers)

  Through Questionnaire survey - 112 people

4 Literature Review

4.1 Technological Specifications

4.1.1 Types of Electric Vehicles

In the Indian market, there are variety of electric vehicles available to people. Some of the types of Electric Vehicles have been mentioned as follows:

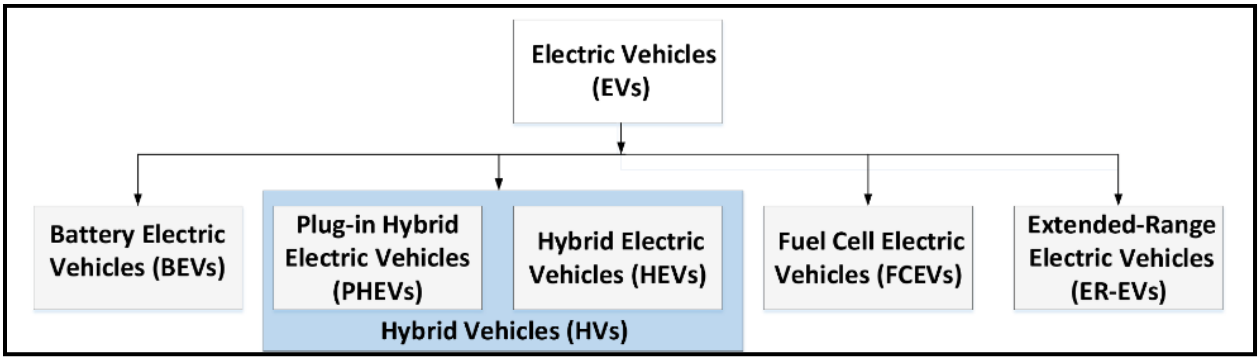

Figure:1, Source: (Abo-Khalil et al., 2022)

4.1.1.1 Battery Electric Vehicles (BEV)

BEV are 100% electric vehicles, instead of the IC engine, there is a battery connected to the electric motor. This complete dependency on the electric battery reduces the range of the vehicle(Abo-Khalil et al., 2022). Even the size of the battery present in BEV is large in comparison to other types of electric vehicles. There are zero emission rates in case of BEV. BEV can utilize the concept of regenerative braking, where electric motor can absorb the energy and can charge the battery in case of braking.

4.1.1.2 Plug in Hybrid Electric Vehicles (PHEV)

PHEV are built in with both the technologies, Internal combustion engine (ICE) and electric motor. PHEV can be connected to the power grid, where electric motor is being used and in case of increased speed, the PHEV switch itself to the ICE for enhanced performance. PHEV also uses the regenerative technology, where the kinetic energy is used to charge the battery in case of braking. Due to enhanced technological characteristics, it has low barrier for entry into the market(Abo-Khalil et al., 2022).

4.1.1.3 Hybrid Electric Vehicle (HEV)

HEV are similar to plug in HEV, the only difference is that HEV cannot be connected to the power grid directly. Both ICE and battery works in parallel and battery get charged when vehicle is running on ICE. The emission rate of HEV is low, 0.062 Kg CO2/Km (Abo-Khalil et al., 2022).

4.1.1.4 Fuel Cell Electric Vehicle (FCEV)

FCEV makes use of hydrogen cell due to its high oxidation capacity. While oxygen passes through the cathode, hydrogen passes through the anode, and its molecules are separated into protons and electrons due to reaction electrochemistry (Abo-Khalil et al., 2022). FCEV also has zero emission and can operate from medium to high range in terms of distance travelled. It is 100% electric vehicle where the electric motor and fuel cell are connected in series.

4.1.1.5 Extended Range Electric Vehicle (ER - EV)

ER-EV consists of both IC and batteries. There is extra mechanism to charge the batteries present in vehicle. This extra mechanism acting as the generator for batteries extends the range of the vehicle. The main source of energy is battery only, with extra mechanism connected in series to charge the batteries. The emission rate of ER-EV is 0.060 Kg CO2/Km, similar to that of HEV and Plug in HEV.

4.1.2 Types of Batteries

Currently in the Indian market, there are 4 types of batteries available for EV, Lead Acid, Lithium ion, Nickel Cadmium and Nickel metal hydride (Abo-Khalil et al., 2022). These batteries are analyzed on the basis of energy density, Voltage/cell and number of life cycles. Out of all these kind of batteries, Lithium ion battery performs best, in terms of energy density. The lead acid battery performs least with respect to others in terms of environment safety.

Characteristic/Battery type	Lead-Acid	Ni-Cd	Ni-MH	Li ion
Cost	Low	Medium	High	Very High
Specific Energy (Wh. kg^{-1})	30–50	50–80	40–100	100–275
Voltage per cell	2	1.25	1.25	3.6
Charge current	Low	Very Low	Moderate	High
Cycle number (charge/ discharge)	200–500	1000	1000	up to 3000
Autodischarge per month (10% of total)	Low (5%)	Moderate-high (20%)	High (30%)	Low (10%)
Minimum time for charge (h)	8–16	1–1.5	2–4	2–4
Activity requirement	180 days	30 days	90 days	-
Environmental warning	High	High	Low	High

Figure 2, Source: (Abo-Khalil et al., 2022)

4.1.3 Types of Charging Infrastructure

- Existing individual electricity supply charging infrastructure

  The energy consumption is from the main meter of the house with power supply of 3.3 KW, Current of 16 Amp and voltage of 220V (Abo-Khalil et al., 2022).

- New individual electricity supply charging infrastructure

  A new meter is being connected for the electricity supply to the charging point present in individual's house.

- Existing collective electricity supply infrastructure

  A main meter for electricity supply to parking space and then separate secondary meter for each charging point for load sharing.

- New collective electricity supply infrastructure

  New separate meters for each charging point present in the parking.

4.2 Stakeholder Engagement System for Sustainable development of EV Industry

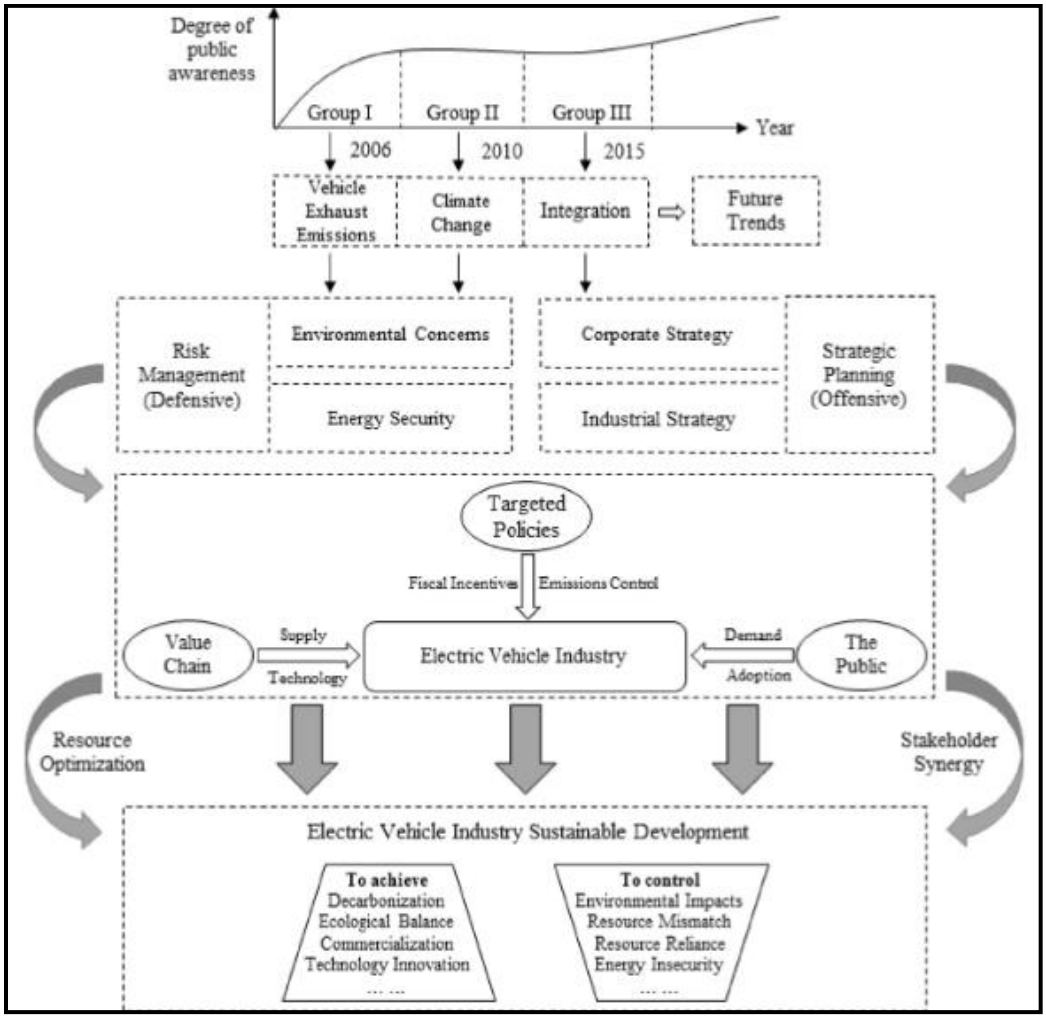

Figure 3, Source: (Cao et al., 2021)

For the risk management; environmental concerns, integration strategies and future trends of the EV industry are taken into consideration. In the environmental concerns, there are factors like vehicle exhaust emissions and climate changes have been taken into consideration. In integration strategies, value chain analysis has been taken into consideration. According to (Cao et al., 2021), there are 4 phases in the integration strategies focusing on different parameters which are as follows:

- Upstream: Batteries, Raw material and labor
- Midstream: Electric Motors and Controllers

- Downstream: Charging, Battery swap and resale
- Bottom stream: Battery recycling

At the end of 2020, even under the pressure of COVID-19 the EVs market skyrocket with a 43% upsurge of global sales from 2.1 millionin 2019 to 3.1 millionin 2020, and more than 10 million EVs are currently operating on the ground. By fore casting, the cumulative sales of EVs will exceed125 million before 2030 (Cao et al., 2021).

On supply side, suppliers on the value chain should consistently implement R&D investment and innovation infusion for eco-friendly technology growth and carbon-based business phase-out (Cao et al., 2021).

4.3 Factors for Sustainable manufacturing of EV

Technological	Power, Speed, Range, Charging Infrastructure, Charging Time, Appearance, Battery life, Fuel economy, Comfort, Reliability, Research and Development
Social	Resistance to change, Awareness, Average daily driving distance, After sales service, Career, Social appreciation
Cultural	Age, Education, Occupation, Region of residence, Family Income
Economic	Fuel price, Electricity price, Purchase cost, Operating cost, Maintenance cost, Battery cost, Replacement cost, GDP/Capita, Resale value, Competitors
Geographical	Raw material availability, Renewable electricity and Fossil fuel availability
Political	Government subsidy, Tax exemption, Electricity cost subsidy, Free public charging, Fossil fuel taxes, Climate policy and Reserved parking spots
Environmental	Battery recycling, Noise, Global warming and Air quality

Table 1, Source: (Digalwar et al., 2021)

4.4 Charging Infrastructure guidance by Government of India

- Electric vehicles can be charged through existing electricity connections present at home or at offices.
- If all the standards are taken care of, then public charging stations can be set up by any individual.
- Requirements for public charging stations
    - Public charging stations must consist of exclusive transformer with set standards.
    - Electrical work safety and cables of set standards.
    - Ample space for movement and charging of vehicles.
    - Fire protection safety measures.
    - For online booking of charging, there should be at least one partnership with online network service provider.
    - Share charging station data with the appropriate State Nodal Agency (SNA) and adhere to protocols as prescribed by Central Nodal Agency (CNA) i.e., Bureau of Energy Efficiency (BEE) for this purpose. The CNA and SNA shall have access to this database. (Ministry of Power, 2022)
- In case of long range EVs and for heavy duty EVs
    - Liquid cooled cables for high speed charging.
    - Minimum 2 charging ports (100Kw, 200-750 V or higher) with different specifications.(Ministry of Power, 2022)
- Within cross section cross section area of 3Km*3Km, there should be minimum one charging station.
- At every 25 Km, there should be charging stations on both the sides of the road.
- Bureau of Energy Efficiency (BEE) shall create and maintain a national online database of all the Public Charging Stations in consultation with State Nodal Agencies (SNAs) (Ministry of Power, 2022)
- Till 31st march, 2025, tariff should not exceed the average cost of supply and there should be single part tariff (Ministry of Power, 2022).
- For public charging stations, there has been a provision for land at promotional rates.

5 Research Methodology

5.1 Method A: Exploratory Research

Interview of domain experts

Relevance	Primary Question	Follow up Question
	What are your views on the sustainability of Electric Vehicles?	What are the enablers for acceptance of Electric Vehicles?
Environmental sustainability	While establishing public charging infrastructure, what could be the challenges?	How can these challenges be minimized?
	What could be the technological challenges with respect to EV batteries?	Are these batteries going to impact the environment in the long run?
	What could be the sources of uncertainty in the supply chain of EVs?	
Economic Sustainability	What could be the factors highly impacting manufacturing of EV and EV batteries?	
	How purchase cost, operating cost and maintenance cost affect the sustainability of EVs?	In the long term, is it going to drastically increase the cost of electricity, leading to high operating costs?
	How are EVs going to impact the power and energy industry?	
Social sustainability	Why are EVs not getting very high attention from the Indian market?	What are the factors that influence adoption of EV?

Table 2, Source: Primary research based on literature review

Expert 1: Dr Mayank Kumar (Assistant Professor- Electrical department (EV), DTU)

Expert 2: Mr Deep Chand (Technical Staff- Electrical department (EV), DTU)

Expert 3: Mr Danish (Technical Staff- Electrical department (EV), DTU)

5.1.1 Transcript for Expert 1 (Dr Mayank Kumar) interview

Q.1 What are your views on the sustainability of Electric Vehicles?

Ans.1 In the coming future, we will definitely use EV but there are some problems like

- Cost of energy storage system (ESS)
- Size of ESS
- Weight of ESS

Since the calorific value of ESS is very low with respect to fusil fuels, In future the research is concerned on to increase the energy density.

Q.2 What are the enablers for acceptance of Electric Vehicles?

Ans.2 Some of the enablers for acceptance of EV are

- Charging Infrastructure
- Cost of Li ion battery / Battery to be used in future
- The problem related with cell voltage balancing

Q.3 While establishing public charging infrastructure, what could be the challenges?

Ans.3 The challenges could be Space – time ratio.

Space will be same but time will change, this challenge is very relevant for public charging infrastructure.

Q.4 How can these challenges be minimized?

Ans.4 All these challenges can be resolved with the help if fast charging

Q.5 What could be the technological challenges with respect to EV batteries?

Ans. 5 Currently we are working with the help of Li ion batteries and some of the difficulties we are facing are in terms of

- Cell voltage balancing
- Battery capacity in term of energy, since the calorific value of fossil fuels is very high and it is dificult to achieve same calorific value through electric batteries.

Q.6 Are these batteries going to impact the environment in the long run?

Ans. 6 yes, there are certain batteries like lead acid battery which can affect the environment but very less in comparison to internal combustion engines.

Q.7 What could be the sources of uncertainty in the supply chain of EVs?

Ans.7 Two of the sources of uncertainty in supply chain of electric vehicles are price of electric vehicles and the charging infrastructure.

Q.10 How purchase cost, operating cost and maintenance cost affect the sustainability of EVs?

Ans.10 The purchase cost of EV in India is really very high. 40% of the cost of vehicle is from the cost of battery. Thus the cost of the EV battery is very high. If we talk about the operating cost of EV, It is definitely going to be less than that of ICE after optimization.

Q.11 In the long term, is it going to drastically increase the cost of electricity, leading to high operating costs?

Ans.11 It is definitely going to increase in long run but will be less than that from fossil fuels , Energy demand will increase exponentially after enhanced adoption into the Indian market.

Q.12 How are EVs going to impact the power and energy industry?

Ans.12 With respect to power and energy industry, energy demand will definitely increase due to 2 reasons:

- With the Increased adoption of EV in the India market, the power requirements are going to increase.
- Energy storage devices like batteries and ultra capacitors are required for the high energy density requirements of Electric Vehicles. Due to which the power and energy industry of India is going to get affected.

Q.13 Why are EVs not getting very high attention from the Indian market?

Ans.13 Two of the major reasons are high price of EV and the charging infrastructure.

5.1.2 Transcript for Expert 2 and 3 (Mr Deep Chand and Mr Danish) interviews

Q.1 What are your views on the sustainability of Electric Vehicles?

Ans.1 For the zero emission target, it is really very imp to adopt EV.

Q.2 What are the enablers for acceptance of Electric Vehicles?

Ans.2 Some of the enablers are awareness, myth, EV anxiety, less charging time and comfort which can be enhanced by the advance charging infrastructure.

Q.3 While establishing public charging infrastructure, what could be the challenges?

Ans.3 In terms of charging infrastructure, there could be challenges like charging standards, battery standards. There is no standardization which leads to change in the battery life with respect to range, mileage. For different batteries, there are different voltage systems (48 volts, 60 volts) and different charging/discharging current.

Q.4 How can these challenges be minimized?

Ans.4 These challenges can be reduced with help of government initiatives on public charging infrastructure. Making standard for public charging infrastructure, similar or same charging port for all the vehicles

Q.5 What could be the technological challenges with respect to EV batteries?

Ans.5 The life span of the EV batteries is very less and it consists of large proportion of EV vehicle cost. Some of the technical challenges are safety, size, capacity, life spam, cost, recycling, reusing, cell manufacturing. Work also needed to be done on the battery reuse.

Q.6 Are these batteries going to impact the environment in the long run?

Ans.6 Environmental pollution caused by ICE will decrease in long run. Renewable power source are required in background for enhanced sustainability of EV in India.

Q.7 What could be the sources of uncertainty in the supply chain of EVs?

Ans.7 There could be many sources of uncertainty in the supply chain of EV in India. Some of them are

- Batteries- the raw material for batteries is facing shortage due to COVID situation, the import and export has been affected drastically.
- Controller
- Wiring harnesses
- Motor- these EV motors makes use of rare earth metals, more copper in comparison to ICE. Thus efficient management of these resources becomes very essential.

Q.9 What could be the factors highly impacting manufacturing of EV and EV batteries?

Ans.9 Factors impacting manufacturing of EV and EV batteries are high investment in technical infrastructure and technical staff.

Q.10 How purchase cost, operating cost and maintenance cost affect the sustainability of EVs?

Ans.10 At present, in comparison to ICE, the purchase cost of EV is high in Indian market. This is required to be reduced. The operating cost of EV is very low in comparison to ICE. In terms of maintenance cost, it is also low which is very impactful to the customers in a positive way.

Q.11 In the long term, is it going to drastically increase the cost of electricity, leading to high operating costs?

Ans.11 It totally depends on the government initiatives. Since India produces majority of its electricity by its own, therefore it is not necessary that there will be increase in the price of electricity.

Q.12 How are EVs going to impact the power and energy industry?

Ans. In short term, there is no problem and in long term, it can be managed by India through various renewable sources of energy.

Q.13 Why are EVs not getting very high attention from the Indian market?

Ans.13 Due to factors like lack of awareness, Myth and less comfort due to poor charging infrastructure.

Q.14 What are the factors that influence adoption of EV?

Ans.14 Awareness, affordability, low maintenance cost and low operating cost.

5.2 Method B - Consumer preferences survey

For the following research work, a Google form was floated consisting of series of questions regarding the demographic variables and the preferences of the consumers.

Google form link:

https://docs.google.com/forms/d/e/1FAIpQLSfbTaBrI8Ww5AjV8m-EzIzmxgz9MV381Xj_LgE5_NqNd3_3kA/viewform?usp=sf_link

This questionnaire has been formulated with reference to (Digalwar et al., 2021).

Number of responses: 112 people

Sampling techniques: Simple random sampling and snowball sampling

Attributes:

Nominal Scale	Interval Scale	Ratio Scale
Gender	Speed	Age
Owns EV	Appearance	Distance traveled
Type of EV	Auto pilot	Price preference
Type of vehicle	Battery life	
Annual Family Income	Battery swapping infrastructure	
	Charging time	
	Comfort	
	Fast charging infrastructure	
	Fuel economy	
	Power	
	Range	
	Reliability	
	Safety	
	Sitting and boot space	

Table 3, Source: Primary research based on literature review

	Name	Type	Width	Decimals	Label	Values	Missing	Columns	Align	Measure	Role
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5	Own_EV	String	3	0		None	None	3	Left	Nominal	Input
6	Govt_sche...	String	3	0		None	None	3	Left	Nominal	Input
7	EV_type	String	31	0		None	None	13	Left	Nominal	Input
8	Vehicle_type	String	13	0		None	None	8	Left	Nominal	Input
9	Price	Numeric	12	0		None	None	6	Right	Scale	Input
10	Range	Numeric	12	0		None	None	5	Right	Scale	Input
11	Power	Numeric	12	0		None	None	2	Right	Scale	Input
12	Appearance	Numeric	12	0		None	None	4	Right	Scale	Input
13	Speed	Numeric	12	0		None	None	4	Right	Scale	Input
14	Sitting_boot...	Numeric	12	0		None	None	4	Right	Scale	Input
15	Fuel_econo...	Numeric	12	0		None	None	3	Right	Scale	Input
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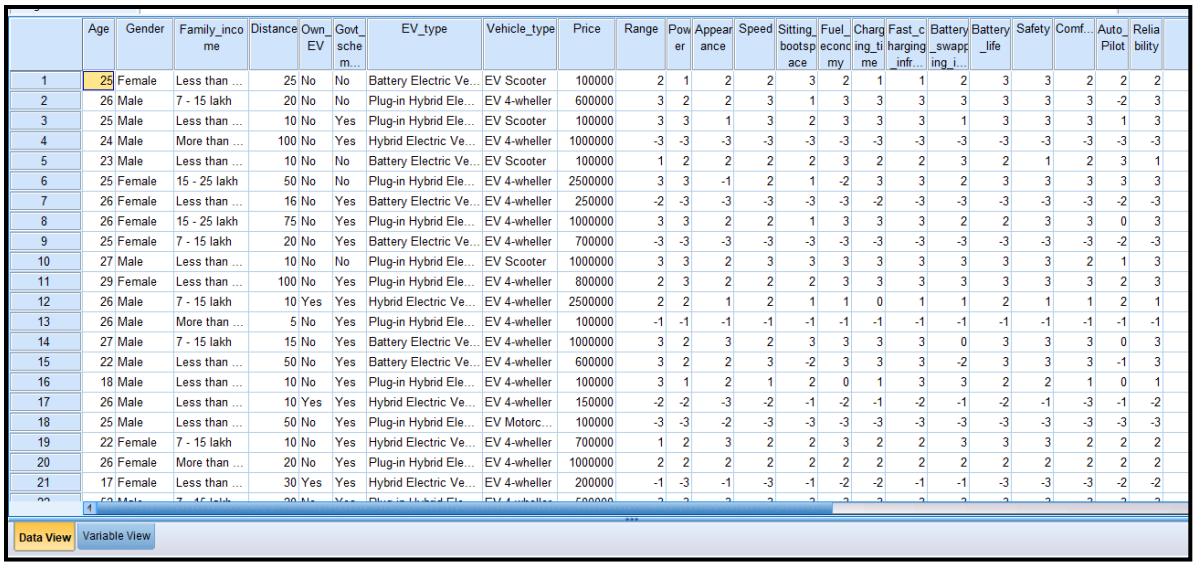
20	Safety	Numeric	12	0		None	None	4	Right	Scale	Input
21	Comfort	Numeric	12	0		None	None	4	Right	Scale	Input
22	Auto_Pilot	Numeric	12	0		None	None	3	Right	Scale	Input
23	Reliability	Numeric	12	0		None	None	3	Right	Scale	Input
24											

Data View | Variable View

Figure 4, Source: (SPSS) – Primary data



	Age	Gender	Family_income	Distance	Own_EV	Govt_scheme...	EV_type	Vehicle_type	Price	Range	Power	Appearance	Speed	Sitting_bootspace	Fuel_economy	Charging_time	Fast_charging_infr...	Battery_swapping_i...	Battery_life	Safety	Comf...	Auto_Pilot	Reliability
1	25	Female	Less than ...	25	No	No	Battery Electric Ve...	EV Scooter	100000	2	1	2	2	3	2	1	1	2	3	3	2	2	2
2	26	Male	7 - 15 lakh	20	No	No	Plug-in Hybrid Ele...	EV 4-wheller	600000	3	2	2	3	1	3	3	3	3	3	3	3	-2	3
3	25	Male	Less than ...	10	No	Yes	Plug-in Hybrid Ele...	EV Scooter	100000	3	3	1	3	2	3	3	3	1	3	3	3	1	3
4	24	Male	More than ...	100	No	Yes	Hybrid Electric Ve...	EV 4-wheller	1000000	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3
5	23	Male	Less than ...	10	No	No	Battery Electric Ve...	EV Scooter	100000	1	2	2	2	2	3	2	2	3	2	1	2	3	1
6	25	Female	15 - 25 lakh	50	No	No	Plug-in Hybrid Ele...	EV 4-wheller	2500000	3	3	-1	2	1	-2	3	3	2	3	3	3	3	3
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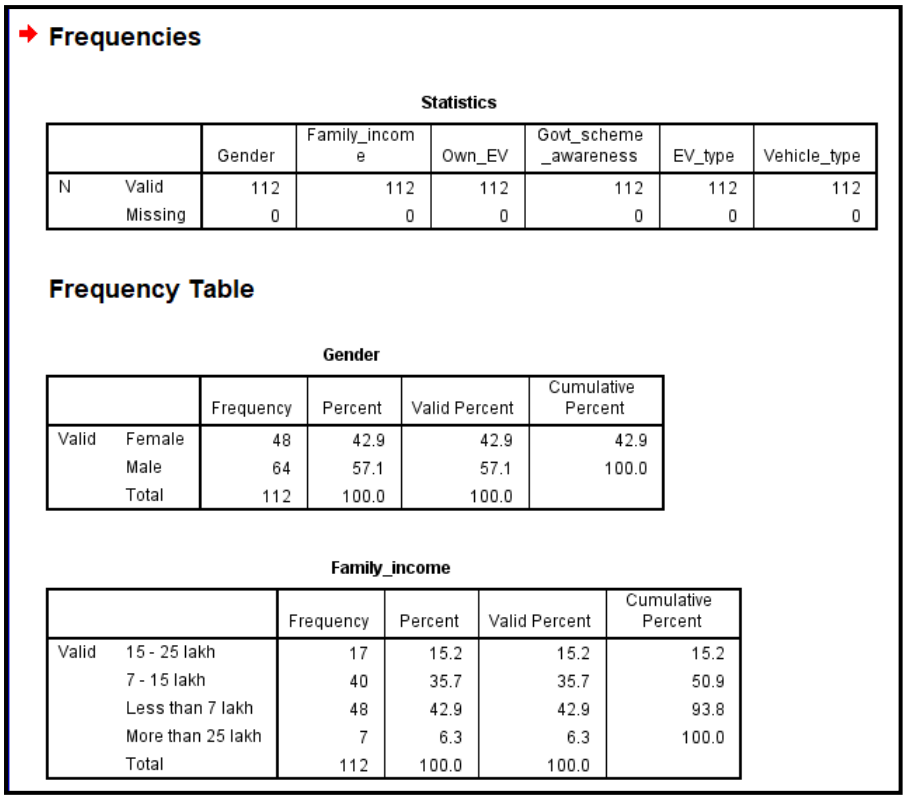
9	25	Female	7 - 15 lakh	20	No	Yes	Battery Electric Ve...	EV 4-wheller	700000	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-2	-3
10	27	Male	Less than ...	10	No	No	Plug-in Hybrid Ele...	EV Scooter	1000000	3	3	2	3	3	3	3	3	3	3	3	2	1	3
11	29	Female	Less than ...	100	No	Yes	Plug-in Hybrid Ele...	EV 4-wheller	800000	2	3	2	2	2	3	3	3	3	3	3	3	2	3
12	26	Male	7 - 15 lakh	10	Yes	Yes	Hybrid Electric Ve...	EV 4-wheller	2500000	2	2	1	2	1	1	0	1	1	2	1	1	2	1
13	26	Male	More than ...	5	No	Yes	Plug-in Hybrid Ele...	EV 4-wheller	100000	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
14	27	Male	7 - 15 lakh	15	No	Yes	Battery Electric Ve...	EV 4-wheller	1000000	3	2	3	2	3	3	3	3	0	3	3	3	0	3
15	22	Male	Less than ...	50	No	Yes	Battery Electric Ve...	EV 4-wheller	600000	3	2	2	3	-2	3	3	3	-2	3	3	3	-1	3
16	18	Male	Less than ...	10	No	Yes	Plug-in Hybrid Ele...	EV 4-wheller	100000	3	1	2	1	2	0	1	3	3	2	2	1	0	1
17	26	Male	Less than ...	10	Yes	Yes	Hybrid Electric Ve...	EV 4-wheller	150000	-2	-2	-3	-2	-1	-2	-1	-2	-1	-2	-1	-3	-1	-2
18	25	Male	Less than ...	50	No	Yes	Plug-in Hybrid Ele...	EV Motorc...	100000	-3	-3	-2	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3
19	22	Female	7 - 15 lakh	10	No	Yes	Hybrid Electric Ve...	EV 4-wheller	700000	1	2	3	2	2	3	2	2	3	3	3	2	2	2
20	26	Female	More than ...	20	No	Yes	Plug-in Hybrid Ele...	EV 4-wheller	1000000	2	2	2	2	2	2	2	2	2	2	2	2	2	2
21	17	Female	Less than ...	30	Yes	Yes	Hybrid Electric Ve...	EV 4-wheller	200000	-1	-3	-1	-3	-1	-2	-2	-1	-1	-3	-3	-3	-2	-2

Data View | Variable View

Figure 5, Source: (SPSS) – Primary data

5.2.1 Frequency Analysis



Frequencies

Statistics

		Gender	Family_income	Own_EV	Govt_scheme_awareness	EV_type	Vehicle_type
N	Valid	112	112	112	112	112	112
	Missing	0	0	0	0	0	0

Frequency Table

Gender

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Female	48	42.9	42.9	42.9
	Male	64	57.1	57.1	100.0
	Total	112	100.0	100.0	

Family_income

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	15 - 25 lakh	17	15.2	15.2	15.2
	7 - 15 lakh	40	35.7	35.7	50.9
	Less than 7 lakh	48	42.9	42.9	93.8
	More than 25 lakh	7	6.3	6.3	100.0
	Total	112	100.0	100.0	

Figure 6, Source: (SPSS) – Primary data

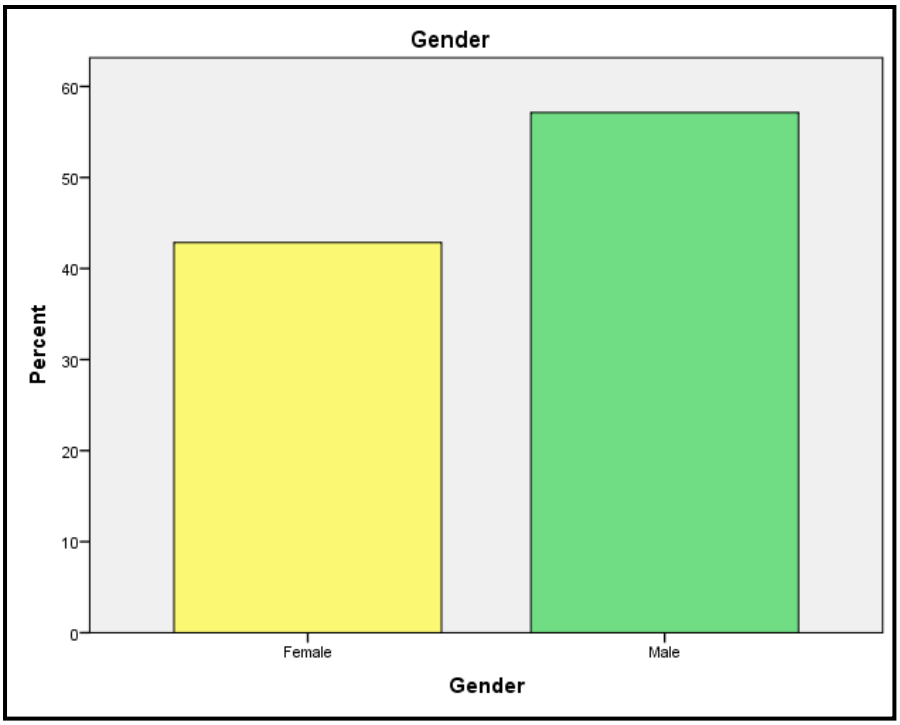


Figure 7, Source: (SPSS) – Primary data

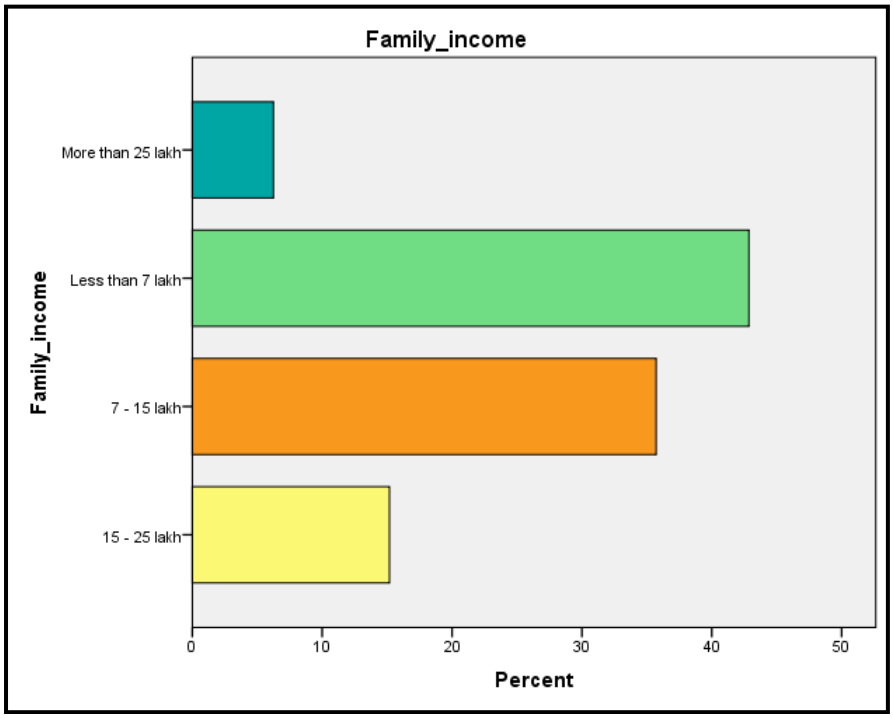


Figure 8, Source: (SPSS) – Primary data

Own_EV

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	99	88.4	88.4	88.4
	Yes	13	11.6	11.6	100.0
	Total	112	100.0	100.0	

Govt_scheme_awareness

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	54	48.2	48.2	48.2
	Yes	58	51.8	51.8	100.0
	Total	112	100.0	100.0	

EV_type

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Battery Electric Vehicle	34	30.4	30.4	30.4
	Hybrid Electric Vehicle	31	27.7	27.7	58.0
	None	1	.9	.9	58.9
	Plug-in Hybrid Electric Vehicle	46	41.1	41.1	100.0
	Total	112	100.0	100.0	

Figure 9, Source: (SPSS) – Primary data

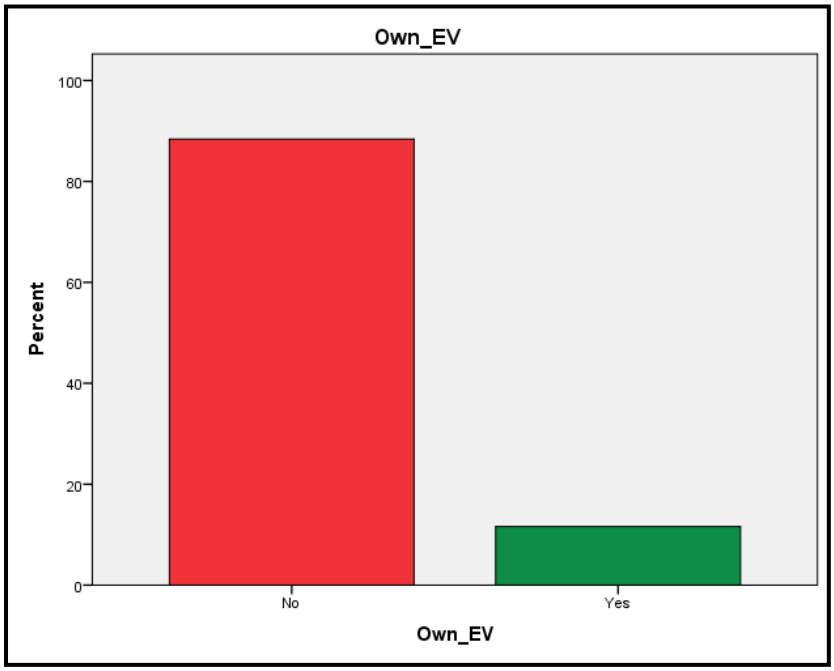


Figure 10, Source: (SPSS) – Primary data

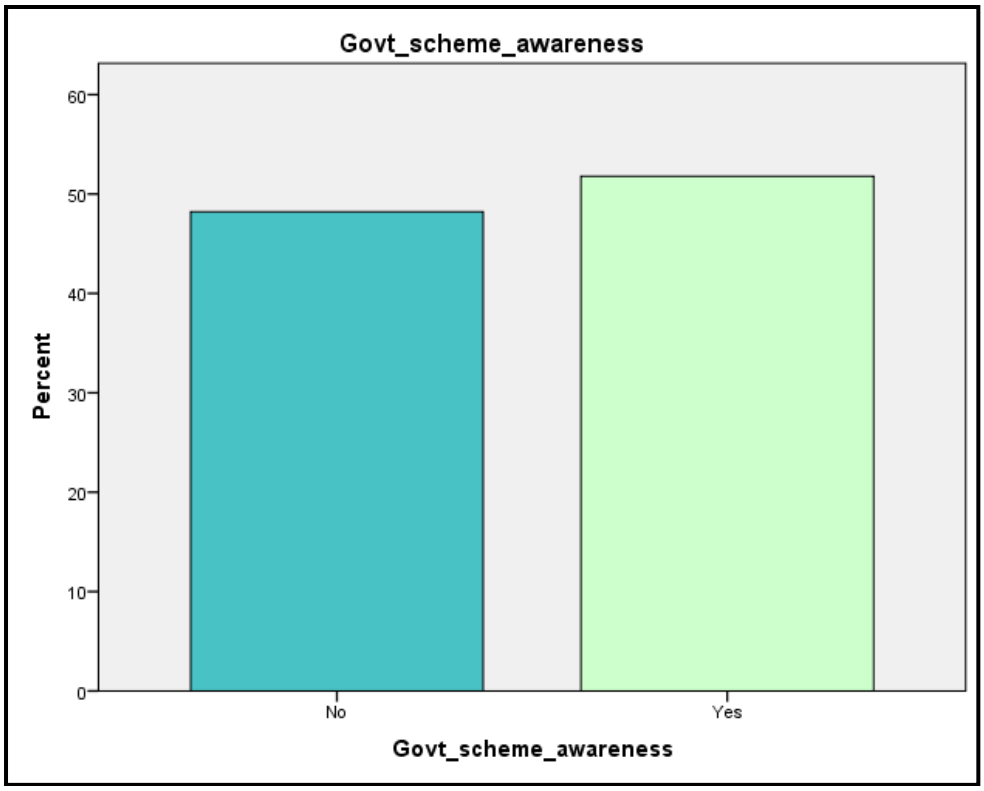


Figure 11, Source: (SPSS) – Primary data

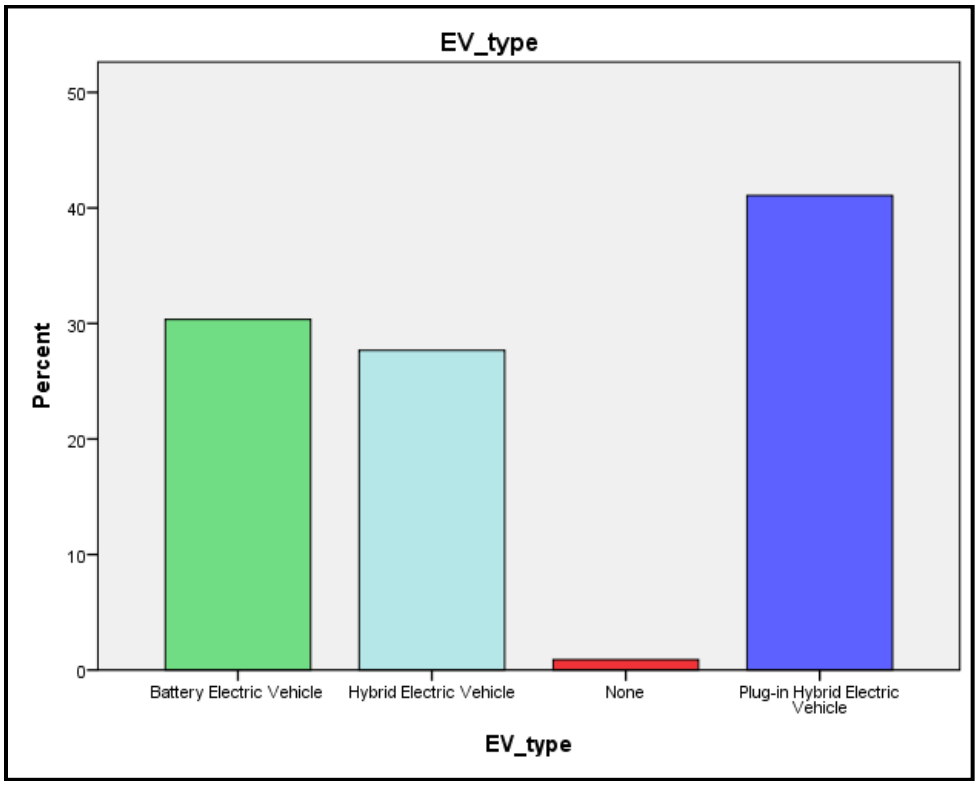


Figure 12, Source: (SPSS) – Primary data

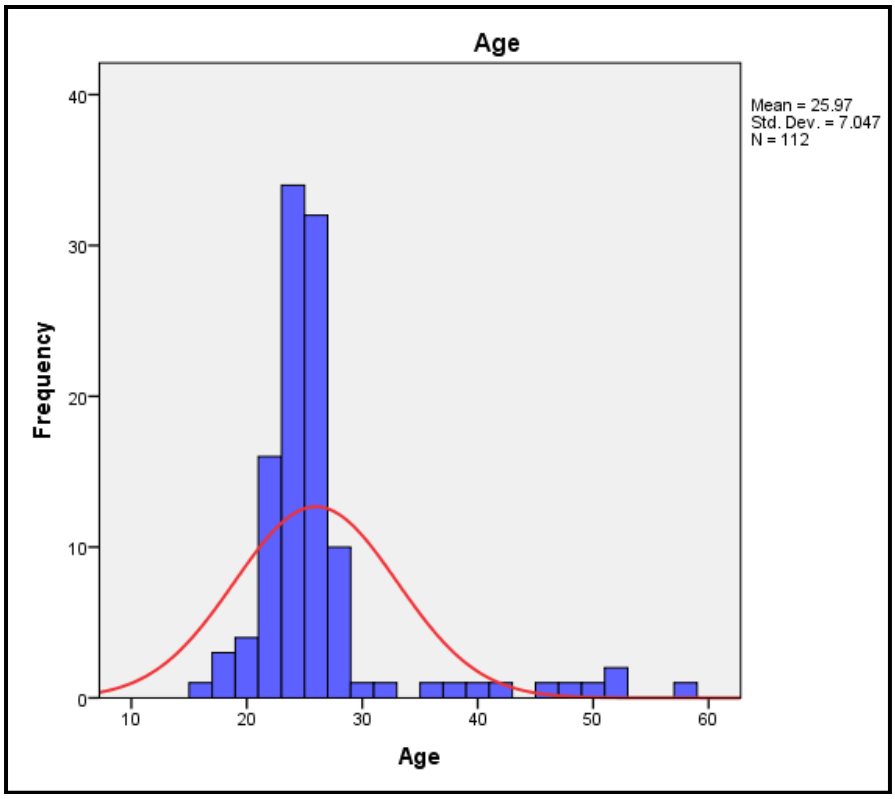


Figure 13, Source: (SPSS) – Primary data

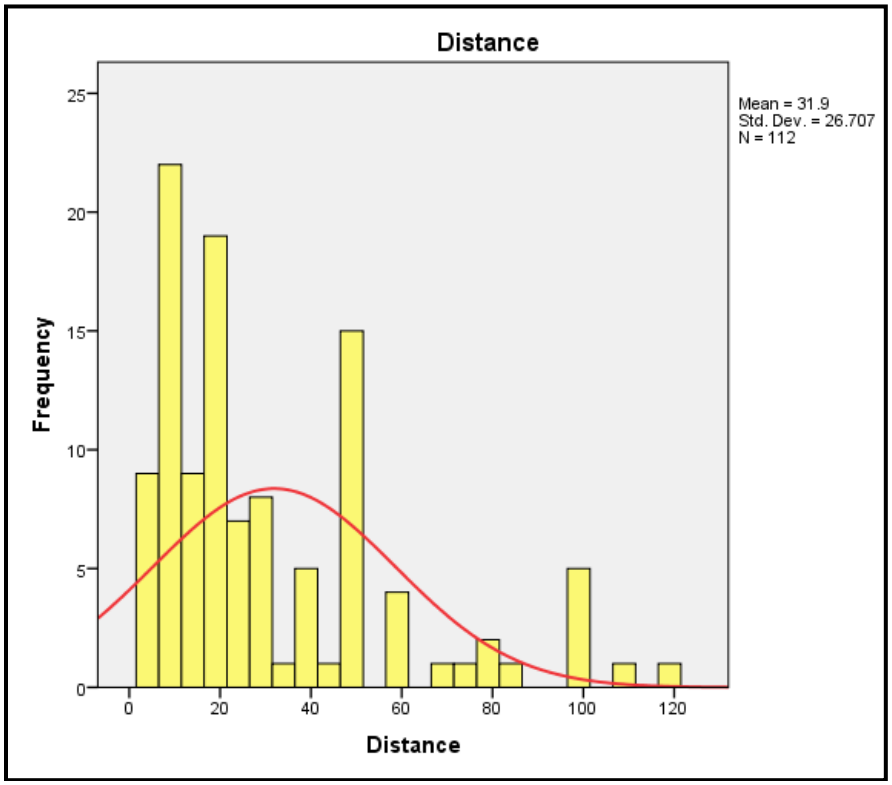


Figure 14, Source: (SPSS) – Primary data

5.2.2 Factor Analysis

Descriptive Statistics

	Mean	Std. Deviation	Analysis N
Range	1.25	2.200	112
Power	1.26	2.339	112
Appearance	1.17	2.122	112
Speed	1.21	2.352	112
Sitting_bootspace	1.27	2.234	112
Fuel_economy	1.22	2.320	112
Charging_time	1.27	2.329	112
Fast_charging_infrastructure	1.39	2.326	112
Battery_swapping_infrastructure	1.25	2.264	112
Battery_life	1.52	2.360	112
Safety	1.41	2.384	112
Comfort	1.34	2.358	112
Auto_Pilot	.83	1.977	112
Reliability	1.35	2.300	112

Figure 15, Source: (SPSS) – Primary data

Component Matrix[a]

	Component
	1
Range	.963
Power	.980
Appearance	.940
Speed	.982
Sitting_bootspace	.963
Fuel_economy	.955
Charging_time	.974
Fast_charging_infrastructure	.983
Battery_swapping_infrastructure	.949
Battery_life	.980
Safety	.984
Comfort	.984
Auto_Pilot	.861
Reliability	.986

Extraction Method: Principal Component Analysis.

Figure 16, Source: (SPSS) – Primary data

5.2.3 Mean comparison of parameters with respect to ownership of EV

Own_EV		Range	Power	Appearance	Speed	Sitting_bootspace	Fuel_economy
No	Mean	1.37	1.36	1.25	1.29	1.33	1.33
	N	98	99	99	99	99	99
	Std. Deviation	2.146	2.306	2.067	2.327	2.231	2.295
Yes	Mean	.69	.46	.54	.54	.77	.38
	N	13	13	13	13	13	13
	Std. Deviation	2.359	2.537	2.504	2.537	2.279	2.434
Total	Mean	1.29	1.26	1.17	1.21	1.27	1.22
	N	111	112	112	112	112	112
	Std. Deviation	2.172	2.339	2.122	2.352	2.234	2.320

Figure 17, Source: (SPSS) – Primary data

Own_EV		Charging_time	Fast_charging_infrastructure	Battery_swapping_infrastructure	Battery_life	Safety
No	Mean	1.40	1.51	1.34	1.64	1.52
	N	99	99	99	99	99
	Std. Deviation	2.312	2.318	2.255	2.279	2.362
Yes	Mean	.23	.54	.54	.62	.62
	N	13	13	13	13	13
	Std. Deviation	2.279	2.295	2.295	2.844	2.501
Total	Mean	1.27	1.39	1.25	1.52	1.41
	N	112	112	112	112	112
	Std. Deviation	2.329	2.326	2.264	2.360	2.384

Figure 18, Source: (SPSS) – Primary data

Own_EV		Comfort	Auto_Pilot	Reliability
No	Mean	1.46	.85	1.44
	N	99	99	99
	Std. Deviation	2.292	1.981	2.278
Yes	Mean	.38	.69	.62
	N	13	13	13
	Std. Deviation	2.725	2.016	2.434
Total	Mean	1.34	.83	1.35
	N	112	112	112
	Std. Deviation	2.358	1.977	2.300

Figure 19, Source: (SPSS) – Primary data

5.2.4 Dashboard for visualizing preferences of different segments

A) Overall mean preferences for the sample

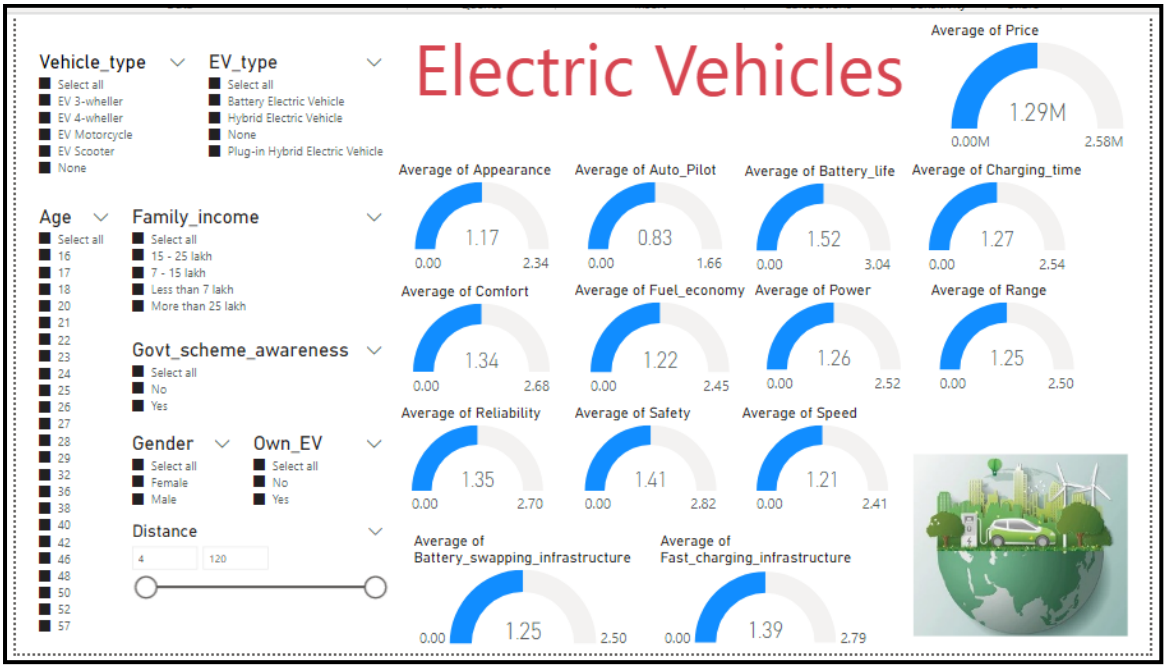


Figure 20, Source: (PowerBI) – Primary data

B) Preferences of people showing interest in 4 wheelers EV

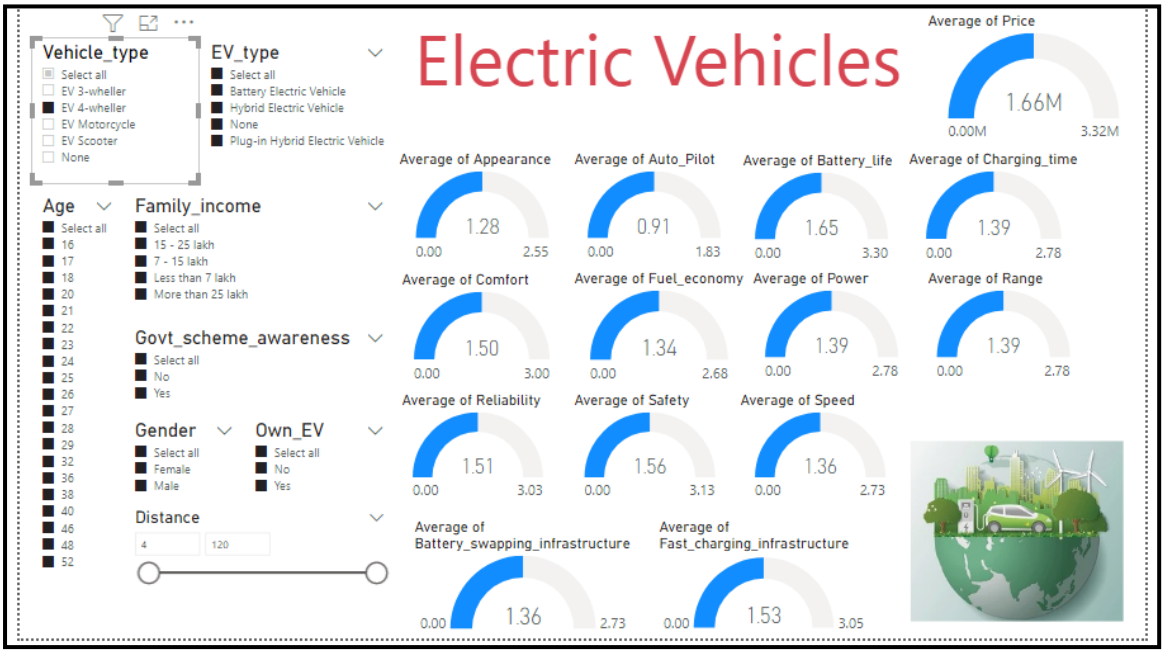


Figure 21, Source: (PowerBI) – Primary data

C) Preferences of people showing interest in EV scooter

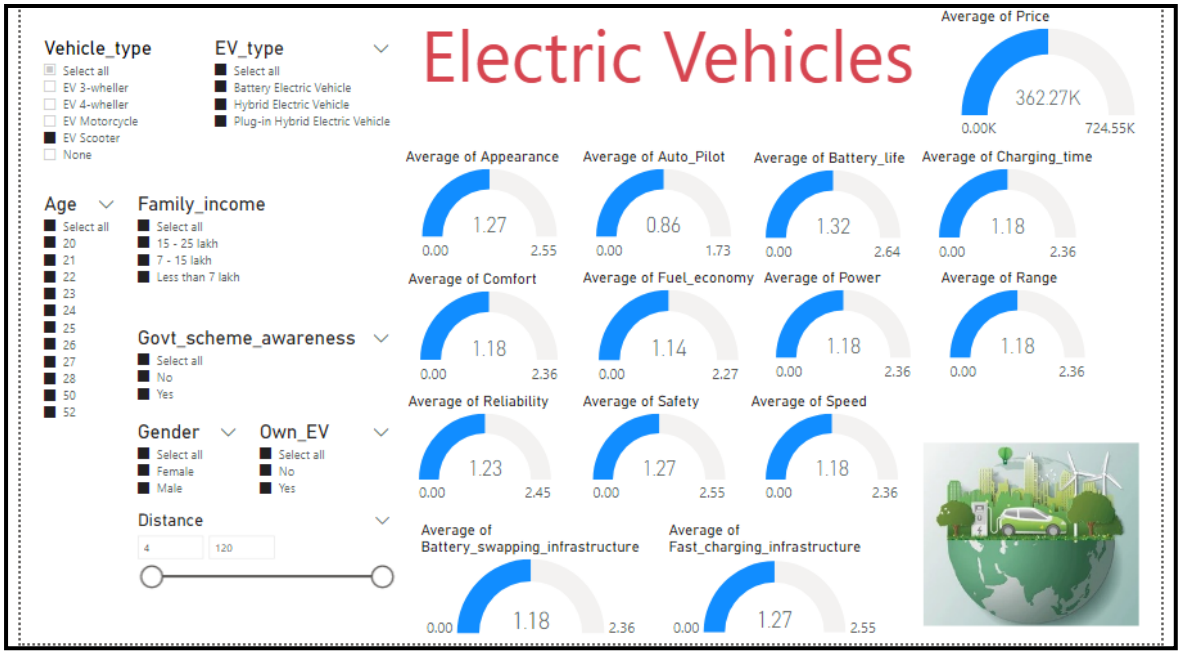


Figure 22, Source: (PowerBI) – Primary data

D) Preferences of people showing interest in BEV

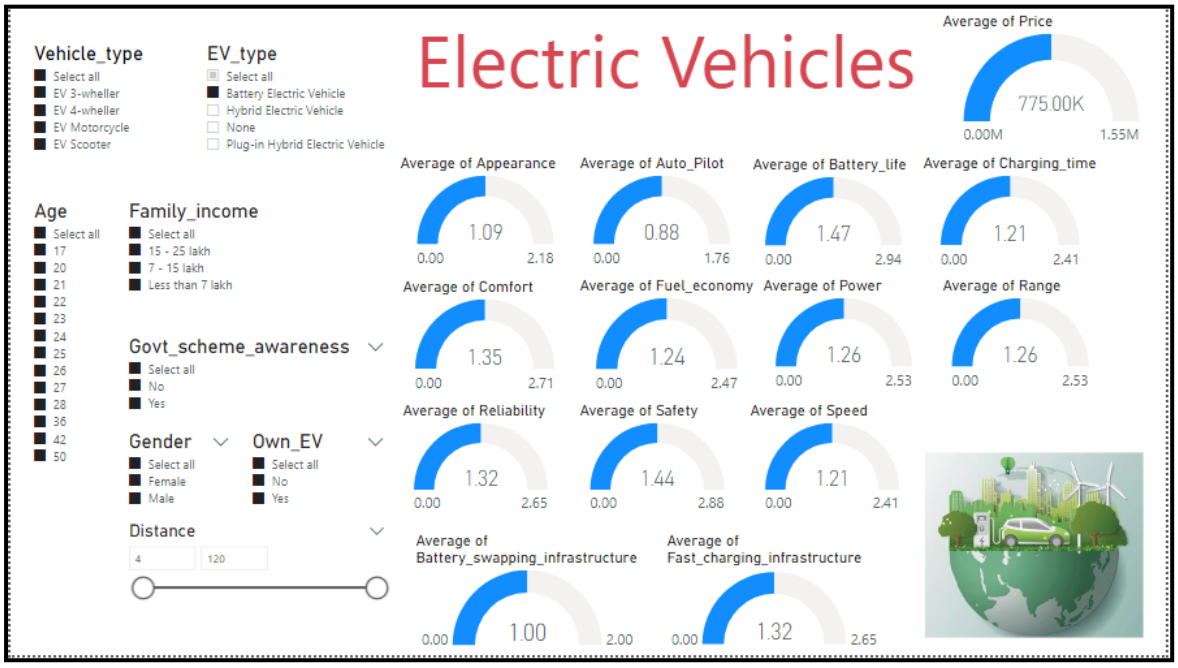


Figure 23, Source: (PowerBI) – Primary data

E) Preferences of people showing interest in HEV

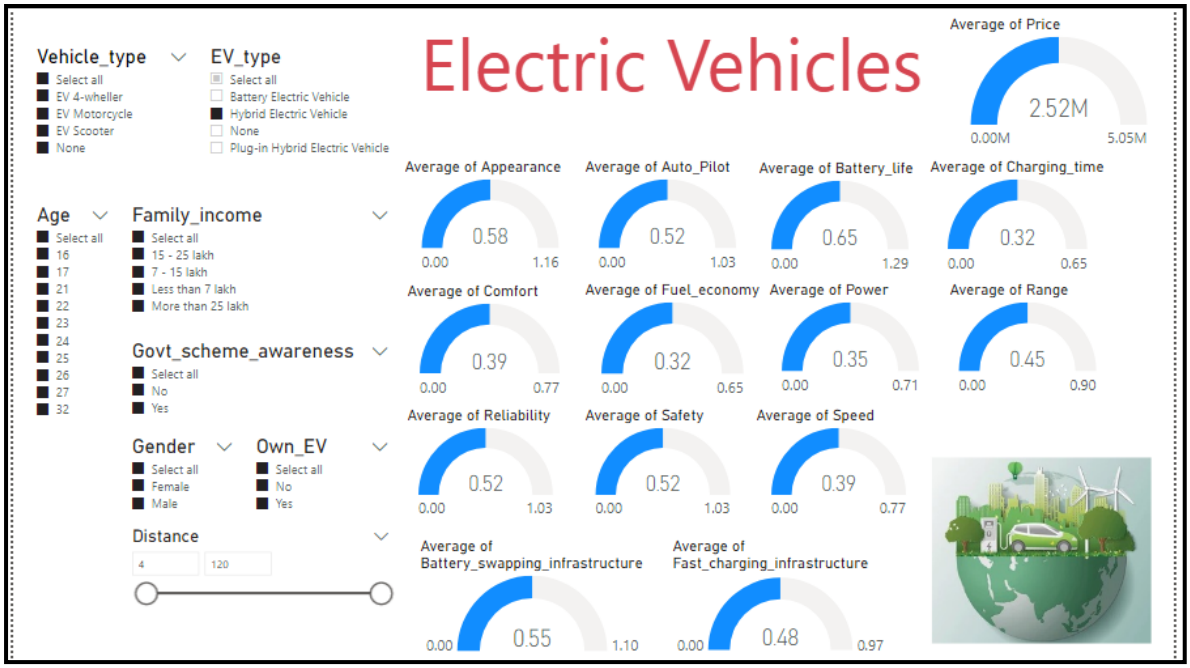


Figure 24, Source: (PowerBI) – Primary data

F) Preferences of people showing interest in EV and have annual family income between 7 lakh and 15 lakh

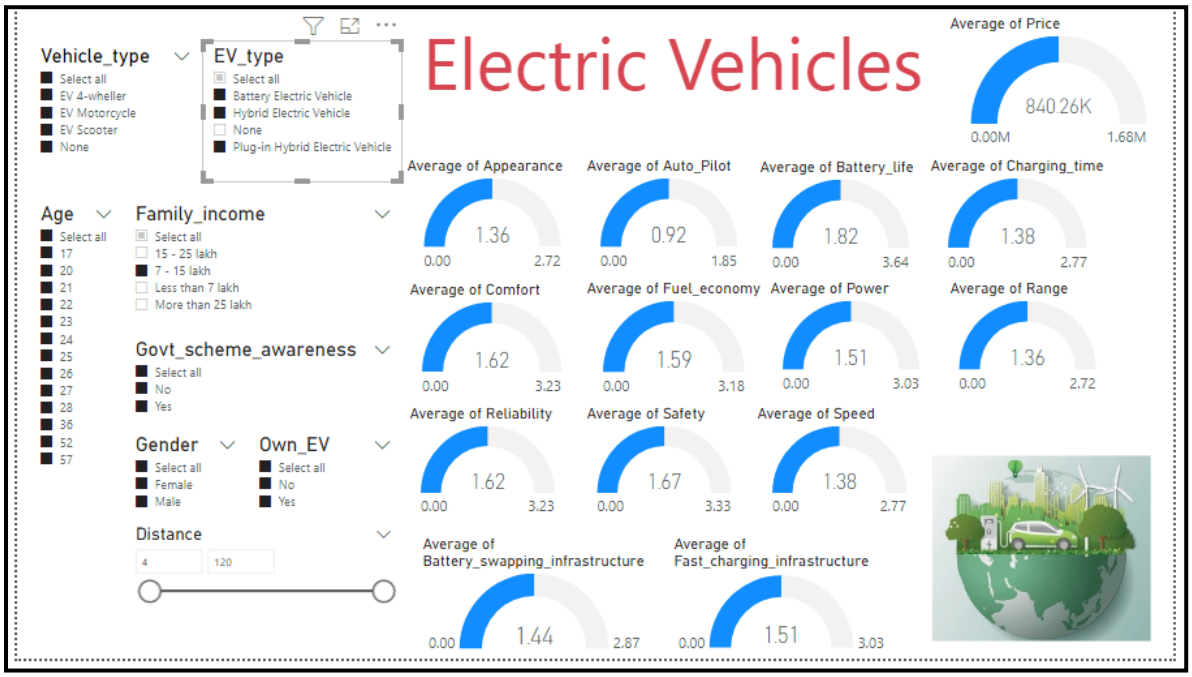


Figure 25, Source: (PowerBI) – Primary data

G) Preferences of people showing interest in EV and have annual family income between 15 lakh and 25 lakh

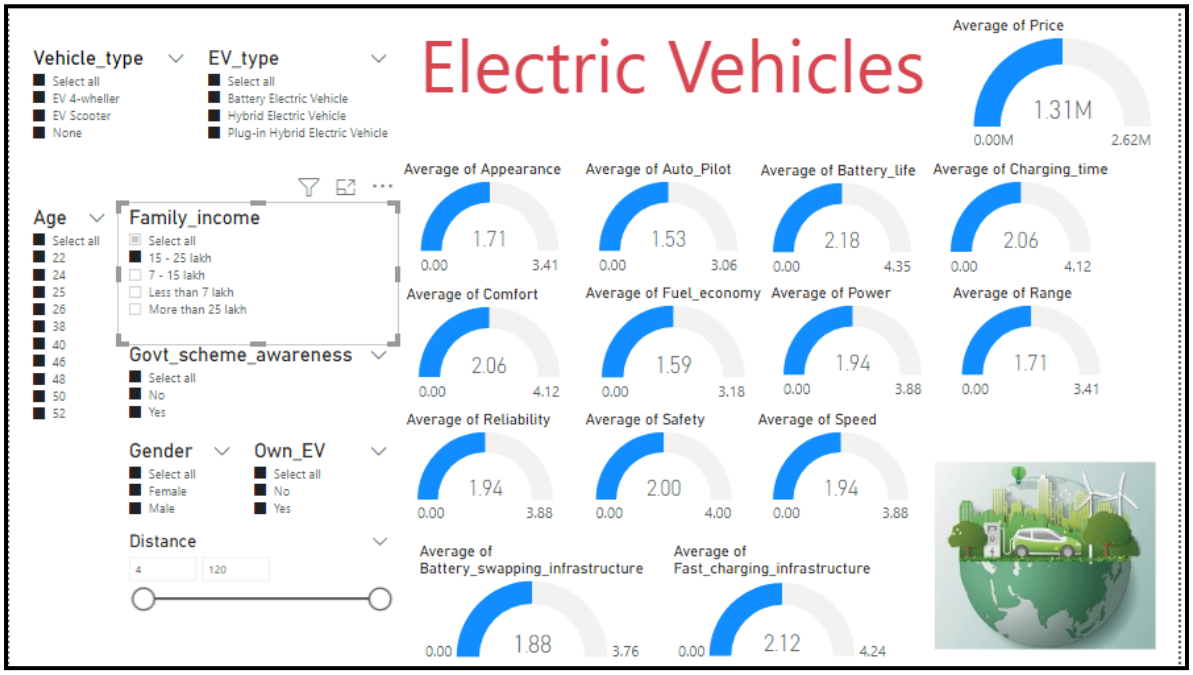


Figure 26, Source: (PowerBI) – Primary data

H) Preferences of males showing interest in EV

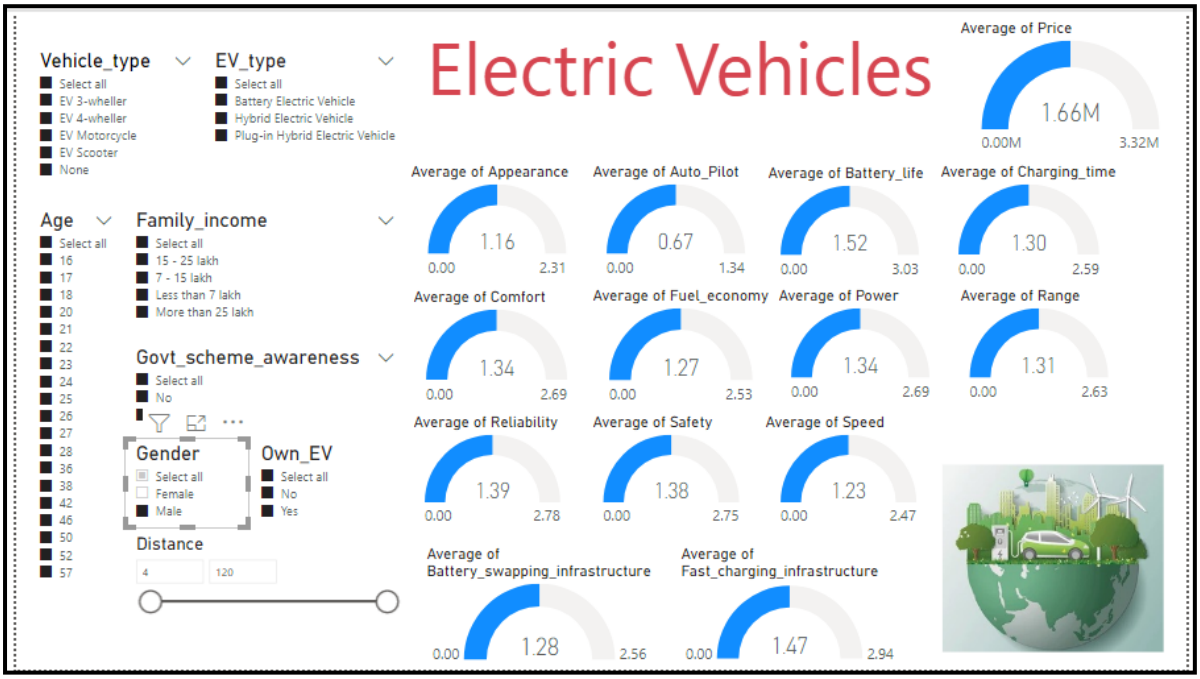


Figure 27, Source: (PowerBI) – Primary data

I) Preferences of females showing interest in EV

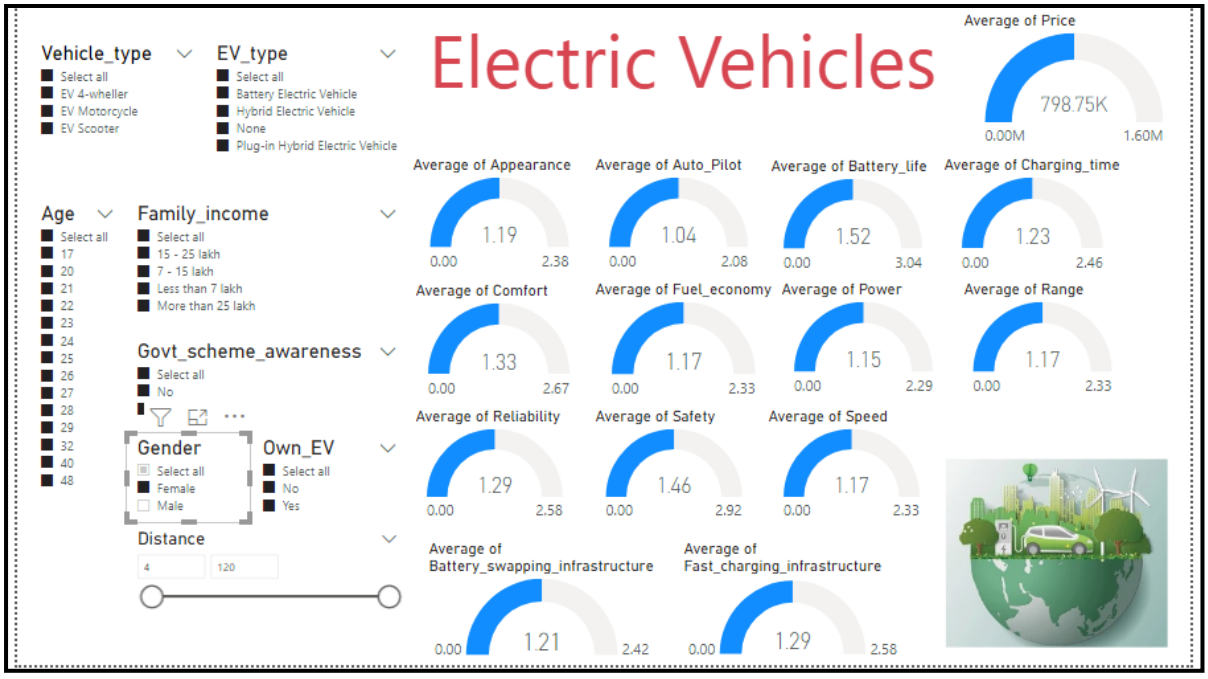


Figure 28, Source: (PowerBI) – Primary data

J) Preferences of people interested in EV and younger than 30 years

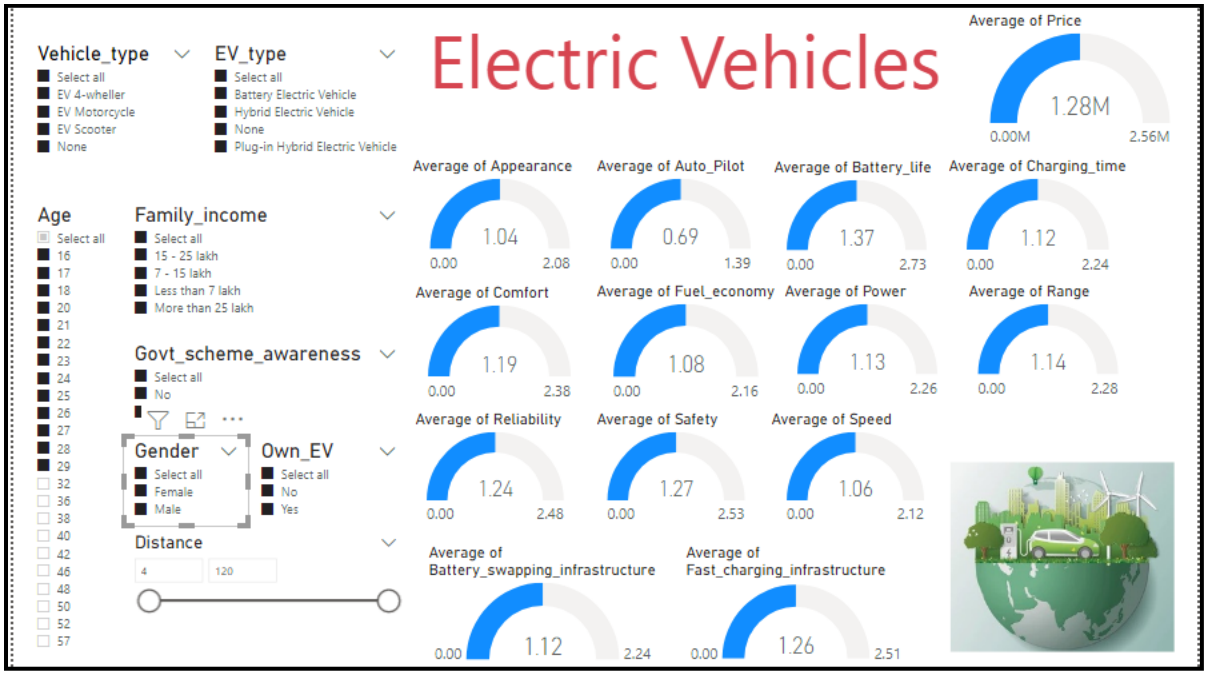


Figure 29, Source: (PowerBI) – Primary data

K) Preferences of people interested in EV and older than 30 years old.

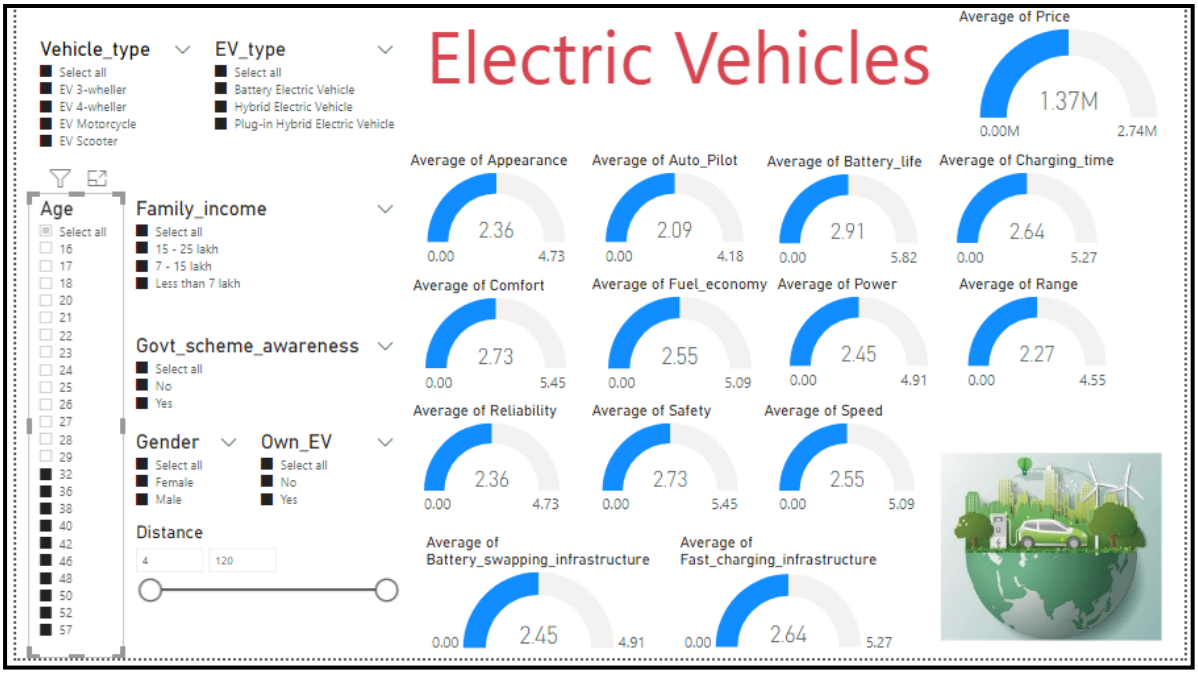


Figure 30, Source: (PowerBI) – Primary data

L) Preferences of people interested in EV and travel at max 30 km a day

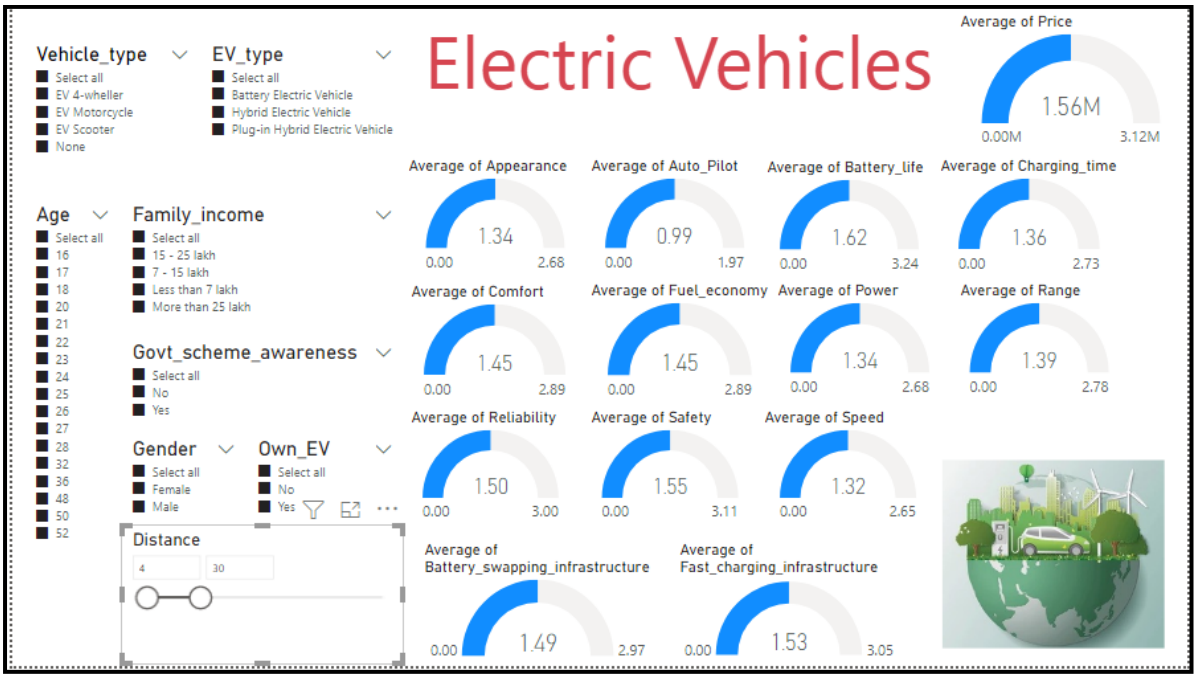


Figure 31, Source: (PowerBI) – Primary data

M) Preferences of people showing interest in EV and travel more than 30 km/day

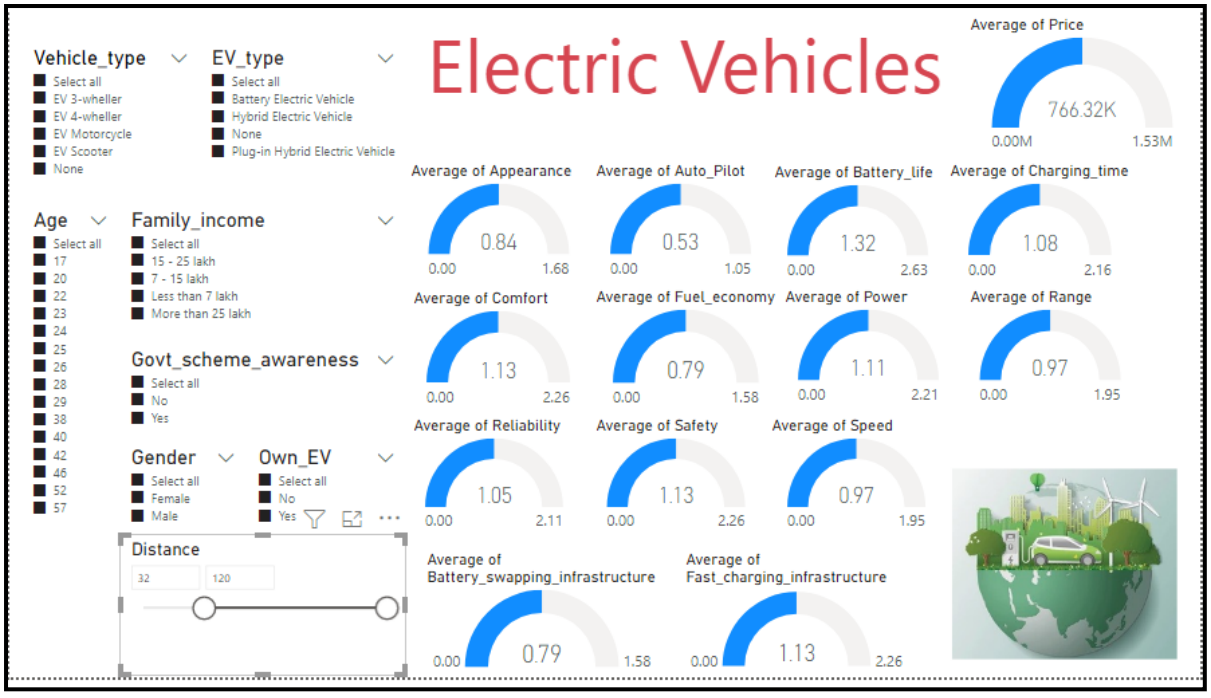


Figure 32, Source: (PowerBI) – Primary data

N) Preferences of people showing interest in 4 wheelers EV and have annual family income between 15 lakh and 25 lakh

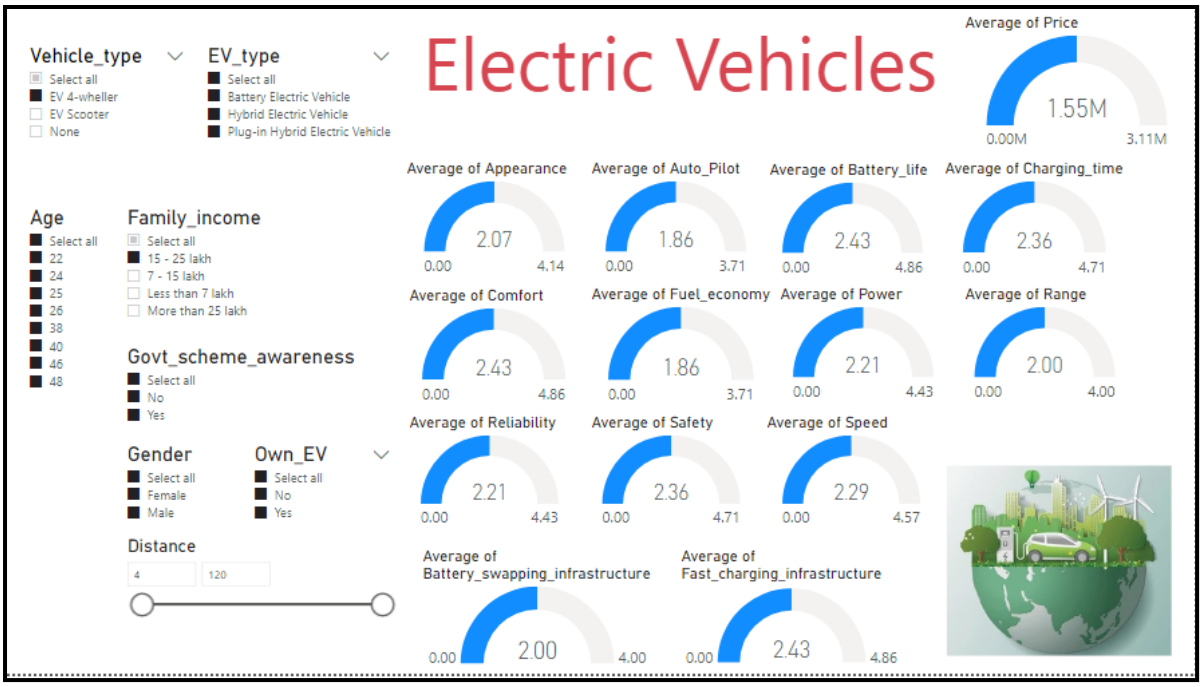


Figure 33, Source: (PowerBI) – Primary data

O) Preferences of people showing interest in EV scooter and have annual family income less than 7 lakh

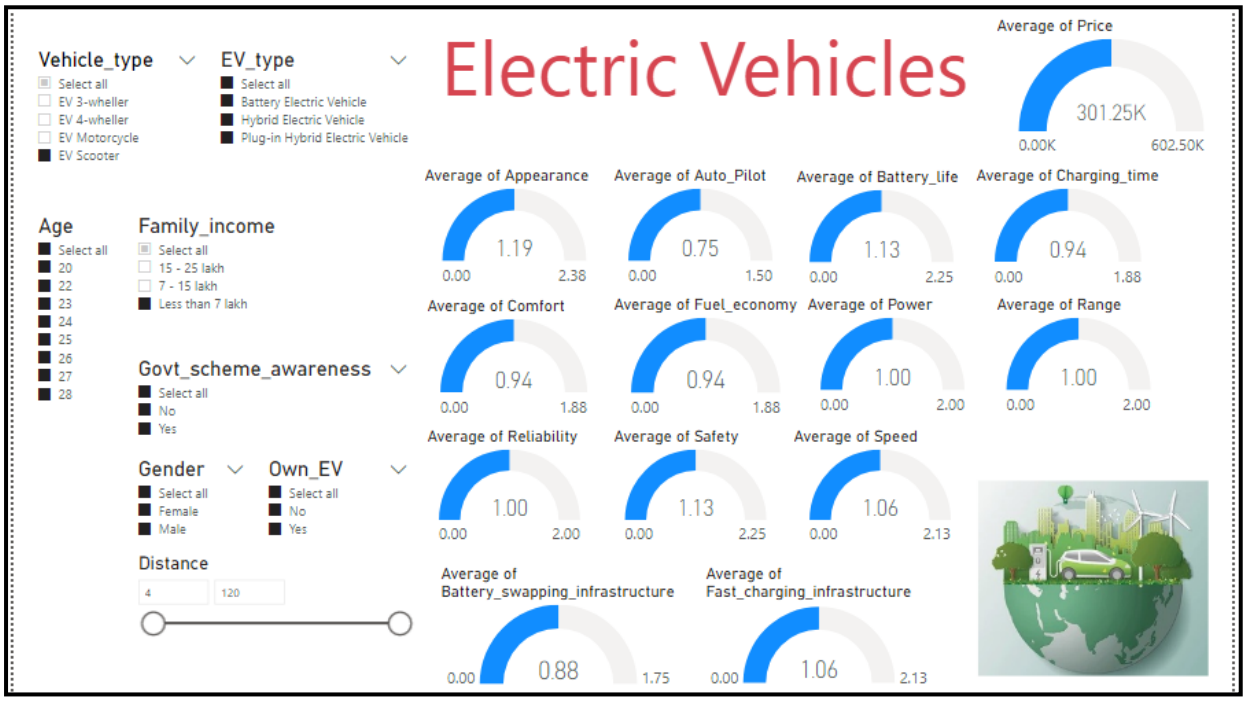


Figure 34, Source: (PowerBI) – Primary data

6 Results

Environmental Sustainability

There is a huge challenge with respect to the charging infrastructure in India. Problems like space-time ratio, undefined integrated charging guidelines from government are there. There is a need to have defined guidelines for similar port of charging and cell voltage balancing of EV batteries. So that batteries can be operated at a specific voltage level with specific discharge current for enhanced life spam of the EV. Also, there is a need to invest more on research and development of controllers and motors to reduce the uncertainty in EV supply chain.

Economical Sustainability

Around 40% of the cost of the EV is of battery, there is a need to optimize the price of EV batteries, so that the overall price of the EV could be reduced. The operating cost of electric vehicles is comparatively low with respect to ICE but this is going to increase the demand of electricity exponentially. Thus, India is required to have more power plants operating on renewable sources of energy.

Social Sustainability

Two major reasons for low adaptability of EV in Indian market are high price and lack of charging infrastructure. These challenges can be minimized by enhancing environmental sustainability. There is also lack of awareness among people regarding government guidelines which is required to be solved by various campaigns, so that more and more people can be persuaded to adopt electric vehicle in near future.

Consumer Preferences

It has been observed that top 5 factors which are affecting decisions of people while buying EV are (With reference to 5.2.4.A):

- Reliability
- Safety
- Comfort
- Fast charging infrastructure
- Speed

These factors are followed by

- Power
- Battery life
- Charging time

People are willing to pay 12.9 lakh rupees on an average for an Electric vehicle. Those who already owns electric vehicle, are emphasizing more on sitting and boot space, auto pilot. Thus it could be implied (With reference to 5.2.3) that EV manufacturers are required to do more research and development in upper segment models in terms of auto pilot mode, since those people will be switching to upper model in near future.

With reference to 5.2.4.H and 5.2.4.I, male customers willing to pay 16.6 lakh rupees with focus upon battery life, fast charging infrastructure, safety and power. While female are willing to pay up to 8 lakh rupees with focus upon battery life, safety and comfort. Thus it can be implied that if the EV manufacturing is applying operational strategies like mass customization, then they can launch different variants with high power and color combination keeping in mind preferences of males. Whereas, another variant can be with comparatively lower price, focusing on interiors, color combinations for enhanced safety and comfort, keeping in mind preferences of females.

A. 4 wheelers EV (With reference to 5.2.4.B)

It has been observed that people are willing to spend 16.6 lakh rupees on an average for an EV. There major focus is on Battery life, safety, fast charging infrastructure and least focus on auto pilot.

For BEV, people are willing to pay 7.75 lakh rupees on an average with focus upon Battery life, comfort and fast charging infrastructure. In case of HEV, people are willing to pay up to 25 lakh rupees with focus upon battery life, appearance and fast charging infrastructure. (With reference to 5.2.4.D and 5.2.4.E)

Thus, it can be implied that for premium customers, EV manufacturers are required to focus upon HEV, considering factors like appearance as well with battery life. For customers with comparatively lower budget, the focus should be upon BEV considering factors like battery life, comfort and charging infrastructure for sure.

B. EV scooters (With reference to 5.2.4.C)

While choosing EV scooters, people prefer battery life the most, followed by safety and fast charging infrastructure. Thus it can be implied that EV manufactured could use replaceable batteries, in case of battery related issues, so that the safety of EV scooters can be enhanced to certain level. With reference to 5.2.4.O, people interested in buying EV scooter, have major focus on appearance, battery life and safety.

Scooter are generally used for travelling lesser distance, and a similar result has been obtained with reference to 5.2.4.L, that EV manufactures are required to invest on research and development regarding battery life, safety and charging infrastructure.

C. Annual family income

With reference to 5.2.4.F, people from 7-15 lakh categories are willing to pay up to 8.4 lakhs with major focus on battery life, safety and reliability. With reference to 5.2.4.G, for those who are from 15-25 lakh category, the expected price is 13.1 lakh rupees with majority focus on battery life, charging time and comfort.

Thus inference can be developed for incorporating cost cutting in specific segment, to meet the customer requirements in desired market price of the product. Similarly, for premium customers, price can be set according to requirements of those customers, focusing upon comfort from that segment. With reference to 5.2.4.N, for buying 4 wheelers EV, people from 15-25 lakh categories are focusing upon comfort, battery life and fast charging infrastructure.

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Positive Coherence between domain expert's perspective and demands of consumers

Perspective	**Interviews**	**Questionnaire Survey**
Environmental	Charging Infrastructure Similar charging ports guidelines Battery capacity in term of energy Lifetime of EV batteries Raw material for batteries, controllers and motors	Charging Infrastructure Battery Life Reliability Speed
Economical	High cost of EV (due to batteries) Exponential rise in electricity demand	Optimized Price
Social	High Price Less comfort-Charging Infrastructure Awareness	Safety Comfort

Table 4, Source: Based on the research

7 Conclusion

For assessing the sustainability of electric vehicles in India, there can be multi dimensional approach consisting of aspects like environmental sustainability, economic sustainability and social sustainability. In the present scenario, there has been a significant increase in the Air quality index, which is further degrading the environmental conditions. Experts say that it is very crucial to pursue more and more people to adopt electric vehicles. There has been so many options available to people, they can choose between BEV, HEV, FCEV and EREV depending upon their needs.

For the sustainability of electric vehicles in the Indian market, all three perspectives i.e. environmental, economical and social sustainability need to be focused upon. There are certain challenges in each of the perspective but they can be limited to certain extent. There are technically challenges like lack of charging infrastructure, lack of R&D in term of batteries. The cost, size and weight of energy storage systems is very high. 40% of the cost of the electric vehicle is due to the cost of battery. Not only the cost is the challenge but also the voltage cell balancing is major issue. The calorific value of these batteries is low in comparison to that of conversation internal combustion engines. Another major issue regarding the sustainability of electric vehicles in India is the charging infrastructure. There are no battery standards and standardized guidelines for charging infrastructure. This particular problem can be solved by government initiatives to standardize the processes, which government is already trying to focus upon.

There are certain sources of uncertainty in the supply chain of electric vehicles in India. These sources can be defined as battery, controller, wiring harness and motor. Large amount of rare earth metals are being used along with copper. Majority of the raw material is being procured from outside, thus makes the supply chain uncertain. In case of any crises like COVID -19, it becomes extremely difficult to arrange parts for electric vehicles which further delays the process and customer tend to switch to the substitute products. Another problem is that these electric vehicles are demanding energy storage devices and ultra capacitors in large quantity, which is going to affect the power and energy industry of India. Thus power and energy industry will also have to forecast the demand properly and take proactive measures.

In terms of economic stability, the operating cost of EV is very low. Even the maintenance cost of EV is also very low due to low number of mobile parts but the purchase cost is high. Majority of the people are not aware about the government subsidies being provided to general public. This high purchase cost is because of the high cost of battery, more research and development is required to be conducted so that the problems with the energy storage devices can be resolved as soon as possible. There is a

need to invest high amount in developing the technical infrastructure for manufacturing of EV at low cost.

For the social sustainability, it is important to focus on the needs of customers belonging to different segments. Different operational strategies like cost differentiation, product differentiation, postponement strategies are required to be applied for catering customer needs. Government is also providing various subsidies but people are not aware of them. There is a need to aware people about facts so that all the myths can be reduced and adoptability of electrical vehicles increases in the near future.

Implications

Shareholder	Implications
Marketer	• Market segmentation • Demand prediction for consumer segments • Increased sales
Consumers/ Buyers/ Potential Buyers	• Optimized price with respect to demand • Desired features with respect to the consumer segments
Government	• Investment in research and development of batteries and charging infrastructure • Standardized guidelines for EVs • Need for awareness • Collaborative testing
Manufacturers	• Mass customization - JIT • Enhanced charging infrastructure • Initial price setting • Reduced uncertainty in supply chain
Society/ Environment	• Reduced emission rates • Reduced oil import

Table 5, Source: Based on the research

8 Bibliography

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